Time and the Writers: Models of Time in Literature, Science, and Busby Berkeley Films

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Aquém e Além do Cérebro

Behind and Beyond the Brain

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Bial

Instituição de utilidade pública

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The mystery of time

O livro "Aquém e Além do Cérebro" contém as atas do 13.º Simpósio da Fundação Bial, realizado na Casa do Médico, de 6 a 9 de abril de 2022, tendo como membros da Comissão Organizadora os Senhores Professores Axel Cleeremans, Etzel Cardeña, Miguel Castelo-Branco, Rui Costa, Rainer Goebel, Stefan Schmidt e Caroline Watt.
Os textos estão disponíveis em www.fundacaobial.com.

The book "Behind and Beyond the Brain" includes the texts of the Bial Foundation's 13th Symposium, held at Casa do Médico, from April 6th to 9th 2022, having as members of its Organizing Committee the following Professors: Axel Cleeremans, Etzel Cardeña, Miguel Castelo-Branco, Rui Costa, Rainer Goebel, Stefan Schmidt and Caroline Watt.
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SESSÃO DE ABERTURA E HOMENAGEM A
OPENING SESSION AND TRIBUTE TO
FERNANDO LOPES DA SILVA

DISCURSO DO PRESIDENTE DA FUNDAÇÃO BIAL

Luís Portela

Boa noite a todos. É com grande satisfação que vos recebemos pessoalmente hoje, depois de termos estado impedidos de o fazer durante cerca de dois anos. Bem-vindos ao XIII Simpósio Aquém e Além do Cérebro.

Agradeço a presença de todos, nomeadamente do Senhor Secretário de Estado do Ensino Superior, Prof. Pedro Teixeira, que também representa a Senhora Ministra da Ciência, Tecnologia e Ensino Superior – é para mim uma grande satisfação vê-lo aqui nas suas atuais responsabilidades governativas, um grande abraço –, do Senhor Presidente do Conselho de Reitores das Universidades Portuguesas, Prof. António Sousa Pereira, do Bastonário da Ordem dos Médicos, Dr. Miguel Guimarães, do Presidente da Comissão Organizadora do Simpósio, Prof. Axel Cleeremans, do Presidente da Secção Regional do Norte da Ordem dos Médicos, Prof. António Araújo e das demais autoridades presentes. Um cumprimento especial ao Prof. Manuel Heitor, ex-Ministro da Ciência, Tecnologia e Ensino Superior e amigo do Prof. Fernando Lopes da Silva, que aqui está também connosco, muito obrigado pela sua presença.

Deixem-me dizer-lhes que desde que aqui nos reunimos pela última vez, em abril de 2018, a Fundação BIAL incrementou e diversificou a sua atividade. Continuámos a realizar com sucesso o Prémio BIAL de Medicina Clínica, cujo júri, presidido pelo Prof. Manuel Sobrinho Simões, tem distinguido alguns dos mais notáveis investigadores portugueses na área da saúde. Em 2019, criámos um prémio internacional, mais abrangente, o *BIAL Award in Biomedicine*, cujo júri, presidido pelo Prof. Ralph Adolphs, distinguiu recentemente aquele que já foi chamado o mais importante cientista do século XXI, o Prof. Drew Weissman e a sua equipa, que criaram a tecnologia a partir da qual se desenvolveram várias vacinas, nomeadamente para COVID-19. Em 2021, associámo-nos à Ordem dos Médicos na criação do Prémio Maria de Sousa, que homenageia a nossa antiga administradora, com incentivos a jovens investigadores.

Também demos continuidade aos apoios à investigação científica, tipo bolsas. Nos últimos 28 anos, apoiámos 775 projetos de investigação, envolvendo 1.624 investigadores de 29 países. Desses projetos resultaram até agora 1.606 artigos em revistas indexadas, dos quais 1.361 em revistas com fator de impacto médio de 4.02. Até março passado foram contabilizadas 35.146 citações, como poderão ver num dos posters que estão expostos na galeria aqui ao lado.

É com muito gosto que lhes anuncio que estamos agora a abrir um novo concurso para apoio a projetos de investigação científica nas áreas da Psicofisiologia e da Parapsicologia, com características semelhantes aos anteriores, mas com o limite máximo de apoio aumentado de €50.000 para €60.000. O regulamento e a documentação para concurso estarão disponíveis a partir de amanhã no nosso site.

Organizámos desde 1996, de dois em dois anos, os nossos simpósios Aquém e Além do Cérebro, com o objetivo principal de os nossos bolseiros apresentarem publicamente os resultados do seu trabalho. Mas também sempre convidamos um conjunto de investigadores de primeiro plano a nível internacional para aqui discutirem um tema, este ano "o mistério do tempo". É nosso intuito fomentar um enriquecedor diálogo interdisciplinar e, também, a organização de projetos de investigação por equipas multidisciplinares.

Agradeço à Comissão Organizadora desta edição o excelente programa que nos proporcionaram e o facto de terem aceitado organizar também a XIV edição, em abril de 2024. Agradeço a todos os palestrantes a vossa renovada disponibilidade para aqui estarem hoje connosco, o que nos permitiu manter o programa idealizado para 2020. Infelizmente, por razões de saúde, quase todos COVID-19, quatro palestrantes não puderam vir. Uns vão intervir via internet e outros foram substituídos. Os meus votos de um excelente simpósio.

Nós na Fundação BIAL temos muito gosto no elevado nível científico que os nossos simpósios atingiram, o que se deve ao trabalho dedicado de muitas pessoas, nomeadamente os 174 palestrantes que por aqui passaram nas diferentes edições, ao trabalho de base da nossa pequena mas eficiente equipa e ao apoio que sempre recebemos do Conselho de Reitores das Universidades Portuguesas e da Ordem dos Médicos. Mas, tenho de realçar o papel das diferentes Comissões Organizadoras dos simpósios, que sempre se caracterizou por grande dedicação, elevada competência e enorme entusiasmo, que mais uma vez se verificou nesta edição, o que muito agradeço.

Mas, se o trabalho de todos os membros das comissões organizadoras foi importante para o sucesso dos nossos simpósios, permitam-me destacar o trabalho discreto, mas muito eficaz, sempre realizado com grande dedicação e entusiamo por aquele que foi o presidente da maioria dos nossos simpósios: o Prof. Fernando Lopes da Silva. Este é o primeiro simpósio que realizamos depois da sua passagem, em 2019. Por isso, entendemos prestar-lhe hoje uma homenagem simples, mas de profundo agradecimento. Teremos um pequeno vídeo a ele dedicado e as intervenções de duas das suas filhas – a Sofia, professora de biologia molecular na Stenden University of Applied Sciences em Leeuwarden, e a Suzana, arquiteta e professora de matemática, artes e tecnologias numa Escola Secundária em Haia –, bem como do presidente deste simpósio, Prof. Axel Cleeremans.

OBITUÁRIO - FERNANDO LOPES DA SILVA

Fernando Lopes da Silva licenciou-se em Medicina pela Universidade de Lisboa em 1959, com 19 valores. Colaborou alguns anos com o Departamento de Psiquiatria da sua Universidade, onde mostrou interesse pelo estudo da atividade cerebral. Em 1962 foi para Londres, onde teve formação em neurofisiologia no *Medical Research Institute* e fez uma pós-graduação em "Engenharia e Física para fisiologistas" no *Imperial College*.

Em 1965 foi viver para a Holanda, tendo completado o seu doutoramento em 1970 na Universidade de Utrecht. Fez a sua carreira como investigador e docente no *Brain Research Group* desta Universidade, na de *Twente* e na de Amesterdão, de que se tornou Professor Catedrático de Fisiologia em 1980. Foi Diretor do *Institute for Epilepsy of the Netherlands*, foi Diretor do *Institute of Neurobiology* da Universidade de Amesterdão, de que ficou Professor Emérito em 2000, e também Diretor Científico da *Foundation of Epilepsy Clinics of the Netherlands at* “Meer en Bosch”.

Ao longo da sua carreira, sempre colaborou com Universidades portuguesas. Apoiou a criação do Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto e da Escola de Medicina da Universidade do Minho. Colaborou com as Universidades do Algarve, da Beira Interior e de Aveiro. Ajudou à criação e coordenou o curso de Engenharia Biomédica do Instituto Superior Técnico. Participou nos Conselhos Gerais das Universidades de Lisboa e de Coimbra.

Desenvolveu na Junta Nacional de Investigação Científica e Tecnológica, com José Mariano Gago e Maria de Sousa, o trabalho de implementação em Portugal da avaliação científica independente. E, depois, foi colaborador incansável da Fundação para a Ciência e a Tecnologia.

Foi membro do Conselho Científico da Fundação BIAL desde 1997 até ao seu falecimento em 2019, tendo sido seu Presidente durante muitos anos. Participou em quase todos os Simpósios Aquém e Além do Cérebro, tendo sido seu presidente de 2009 a 2016. Em 2018 foi o primeiro presidente do Júri do *BIAL Award in Biomedicine*. O Prof. Fernando Lopes da Silva marcou o percurso e a história da Fundação BIAL, tendo tido um papel fundamental no reconhecimento e na afirmação da instituição.

Entre as muitas distinções e prémios obtidos ao longo da carreira, foi elevado a Cavaleiro da Ordem do “Nederlandse Leeuw” pela Rainha da Holanda e condecorado como Grande Oficial da Ordem de Santiago da Espada, de Portugal, em cerimónia que teve lugar durante o 3.º Simpósio da Fundação BIAL. Foi distinguido como Doutor Honoris Causa por quatro Universidades: Lisboa, Porto, Helsínquia e Rennes.

Nos seus tempos de estudante universitário, Fernando Lopes da Silva teve uma participação cívica intensa, na defesa dos princípios da democracia, tendo secretariado as Reuniões Interassociações de Estudantes da Universidade de Lisboa. Na Holanda, participou nos movimentos em prol da desnuclearização e da paz mundial. Depois, foi durante alguns anos vice-presidente da *International Physicians for the Prevention of Nuclear War*, associação de médicos e cientistas galardoada com o Prémio Nobel da Paz em 1985, a que sempre se manteve associado.

Era um homem de família, com uma fortíssima ligação à sua mulher, Carlota, enfermeira de profissão, com quem comungava ideias e ideais. Discreto, mas muito focado e eficiente, mantinha um enorme sentido de equilíbrio, uma permanente defesa dos valores universais e uma relação simples e serena com todos à sua volta. Amigo do seu amigo, foi uma grande referência na área das Neurociências e um ser humano fantástico.

Peço-vos que, durante 1 minuto, de pé e em silêncio total, homenageemos Fernando Lopes da Silva, com o nosso pensamento focado na paz, que ele apaixonadamente defendeu e que todos nós hoje profundamente desejamos, na Europa e no mundo. Peço-vos 1 minuto, de pé e em silêncio total, com o pensamento na paz.

Muito obrigado.

TRIBUTO A FERNANDO LOPES DA SILVA

Sofia Lopes da Silva

Boa noite,

Muito bonito. A Suzana e eu gostávamos de agradecer esta linda compilação de fotografias e de filmes. Ficamos muito comovidas por toda a atenção demonstrada para com a nossa família e o nosso pai. Muito obrigada.

Bem, eu tenho a certeza - também estava naquele filme - que o meu pai considerava a democracia a coisa mais importante na vida; poder avaliar as coisas objetivamente. Ele era um grande apoiante do Spinoza, e penso que os nossos pais, a mãe também, durante o tempo em que estivemos na Holanda, penso que por volta dos meados dos anos 70, começaram a ser ativos em várias organizações que se dedicavam à paz. A nossa mãe era vice-presidente de uma organização não-governamental das Nações Unidas, e ela até falou na Assembleia Geral, parece-me que em junho de 1988. Nessa mesma altura - sendo um interesse dos dois - o nosso pai também foi membro e teve várias funções de *in-board*. Ele esteve muito ativo na organização Médicos Internacionais para a Prevenção da Guerra Nuclear (IPPNW) e tinha muito orgulho nessa organização, a IPPNW, que obteve o Prémio Nobel da Paz em 1985. E agora gostava de dar o microfone à minha irmã.

Suzana Lopes da Silva

Obrigada. Isto vai ser um bocadinho diferente. Na Holanda, é costume haver uma cerimónia de despedida na altura do funeral. Eu gostaria de ler algumas partes do texto que li nessa cerimónia, para vos dar uma impressão do que o nosso pai significou para mim e para a minha irmã. É normal nestas cerimónias dirigir a homenagem diretamente à pessoa que faleceu, como ainda se ele estivesse lá. Aqui vamos.

Querido pai, querido Fernando, viveste todos os dias com uma intensidade enorme. A vida parecia interminável, mesmo já muito doente estavas ocupado com a ciência, a sociedade e a família. Essa energia sem limites, sempre curioso e interessado, sempre tentando desenvolver-se. Tu sempre disseste "Eu nunca vou para a cama no mesmo dia em que acordo". Tu sempre querias fazer coisas divertidas connosco. Lembro-me de muitas atividades que fazíamos juntos: jogávamos ténis, andávamos de canoa no mar, fazíamos passeios de bicicleta depois do jantar, aprendíamos a fazer surf - o que nessa altura era um desporto ainda muito desconhecido. Estavas sempre muito envolvido e querias aprender tudo. Também nos querias ensinar cultura, história e música. Muitas vezes tentaste-nos explicar a história de Israel, e ficavas um pouco dececionado porque eu não conseguia relembrar. Felizmente, a minha irmã Sofia e o meu irmão Zé recordavam-me. Rias e dizias "Não faz mal, cada um tem as suas qualidades". Eu adorava ouvir as tuas histórias, contavas sempre com muito entusiasmo e sabias muito de muitos assuntos.

Quando eu era criança, eu sabia que tinhas um trabalho importante e que muitas vezes estavas ocupado. No entanto, eu nunca senti isso como chato. Estavas sempre lá para nós, embora estivesses sempre atrasado para o jantar. Em certos momentos percebi que tu não eras só especial para nós, mas também para muitos outros. Um pequeno exemplo: uma vez, eu caminhava sozinha na Faculdade de Biologia, em Amesterdão, para ir almoçar contigo e estavas rodeado por estudantes. Nesse momento, ouvi os estudantes dizerem uns aos outros "Ah, sim, o Fernando Lopes da Silva, ele é que é um professor ótimo". De todos os prémios e medalhas que recebeste, o que te deu mais orgulho foi o prémio que recebeste em 1997, de melhor professor da Associação dos Biólogos.

Tanto eu como a minha irmã Sofia damos aulas; devemos ter herdado esse interesse. Eu estou muito grata pela educação que tu, e claro também a mãe, nos deram. Vocês optaram por uma educação especial, de acordo com a Maria Montessori, em que ensinar a ser uma pessoa responsável era central. Isso foi a vossa filosofia e mostrava-se na maneira como vocês nos criaram. Nunca ficavas realmente zangado, só te aparecia uma linha na tua testa. Quando eu via essa linha na testa, perguntava se tu estavas zangado e a resposta era sempre "Não, eu não estou zangado", mas eu sabia que tinha de refletir sobre as minhas próprias ações e assumir a responsabilidade pelo que eu não tinha feito bem. Eu tento passar esse sentido de assumir a responsabilidade aos nossos filhos e aos alunos.

Assim como o Pai Natal nunca morrerá, eu sempre pensei o mesmo de ti. Eu sei que ninguém é imortal, mas o pai, o Fernando que se foi, eu realmente não consigo imaginar.

DISCURSO DO PRESIDENTE DA COMISSÃO ORGANIZADORA

SPEECH OF THE PRESIDENT OF THE ORGANIZING COMMITTEE

Axel Cleeremans

I would like to say a few words about Fernando Lopes da Silva before I get into a brief overview of the symposium. I first met Fernando when I was invited to speak at the 8th BIAL symposium, which took place in 2010 and was dedicated to "Intuition and Decision-making". He immediately struck me as one of the kindest persons I ever met. Kindness is often considered to be a minor quality, sometimes, it is even used to demean someone, as when one means to suggest that the person is kind but perhaps also a little naive, a little unimpressive. But in Fernando, kindness was the keystone of his entire persona, the core quality that defined the manner in which he approached everyone and everything. Fernando's kindness was true benevolence, the intent to do good for the common good. It imbued every action he took and shaped every relationship he entertained. He respected everybody and always appeared to be in awe of everything around him. No wonder he was such a great scientist, because it is when you approach everyone and everything with an open, serene mind imbued by pure intentions that the best science gets done.

Fernando was an amazing scientist. Dr. Luís Portela already gave you an overview of his career, of the many responsibilities he assumed here and for many other institutions and of the many marks of recognition he was rewarded with. Now, I would like to say just a few words about his contributions to our understanding of how the brain works. In this respect, Fernando was a true pioneer. As Cristoph Michel and many of his colleagues wrote in a 2019 obituary, Fernando was "one of the most influential neurophysiologists of our time". This is reflected by several of his publications, two of which have been cited well over 5000 times each. Both concern the core principles of electroencephalography, a method through which the electrical activity of the brain is recorded and analyzed, so revealing the activation of neurons and the dynamics of their interactions. The latter aspect - the dynamics - is what Fernando was most interested in, particularly the so-called alpha oscillations. In a 1977 publication, he showed, and that was a truly pioneering study, using intracranial recordings in dogs, that such alpha rhythms find their origins in the visual cortex, so overturning decades of research and contributing to elucidate the functions of such oscillatory activity. His most influential publication, a 1999 article titled "Even-related EEG/MEG synchronization and desynchronization: basic principles" is about how one can use the variability inherent in the electrical signals produced by neuronal activity - synchronization and desynchronization - not only to understand neural information processing, but also to develop new clinical tools to detect epileptic seizures. Throughout his career, he endeavored to bridge the gap between fundamental research and clinical research, so unwittingly setting up what is now known as "translational research". His influence, beyond his 400 research articles, is well reflected in the major book he kept editing until his passing - *"Electroencephalography: Basic Principles, Clinical Applications and Related Fields"*. Characteristically, he renamed this book "Niedermeyer's Electroencephalography" in honor of his deceased collaborator. This book continues to be considered as the "EEG bible" today. Beyond these major achievements in neuroscience and neurophysiology, however, Fernando truly stands out for the discreet and selfless work he dedicated to helping others. The published obituaries all point out the central role he played in academic activities that often go unseen: Editing articles, refereeing submitted manuscripts, selecting grants, and mentoring.

In 2012, when I was asked to join the scientific organizing committee for the BIAL symposium, I had an opportunity to witness how skilled and respectful he was when managing sometimes challenging discussions, and how committed he was to make sure that everything was as perfect as could be. Determination was another quality of Fernando. On rare occasions, one could sense this determination manifesting itself as the slightest impatience during discussions.

To close, Fernando was a true humanist, a man who was interested in everybody and everything, driven by curiosity and by the pleasure of sharing his enjoyment with other people. Today, we really miss him badly.

So, now let´s move on to an overview of the symposium. I think Fernando would have really appreciated what we will do for the next three days, which is exploring "The mystery of time". I'll say a few more words about the content of our symposium in a few minutes, but I wanted to begin by expressing how relieved we all are that we can finally hold this event in person. It was initially planned for April 2020, already two years ago. At that time, Portugal was still comparatively unaffected by the pandemic, and it felt like we could actually hold the symposium then. Alas, the dynamics of exponential functions are such that it quickly became clear we would simply have to postpone our symposium, this symposium that we had already been planning for two years. We were optimistic about holding the event in 2021, but the uncertainties associated with the pandemic made that impossible as well, and the prospect of holding the event fully online was, to say the least, a bit depressing. So, it truly feels like a huge relief that we are finally able to be here together and share, in person, the excitement of thinking together about a question as big as "What is time?". We are all wearing masks, and as you will see some people couldn't make it because of the pandemic, so it is not that it is completely over, but at least, we can all be here in person today.

Now, let me say a few words about the people behind the organization of the symposium. We have all been working hard over the past four years to make this possible, and I very much hope you will enjoy the event as much as we enjoyed planning it. I am a cognitive scientist from the Université Libre de Bruxelles, and I have the honor of chairing the organizing committee, a responsibility that was handed to me by Dr. Luís Portela, who heads the BIAL Foundation that makes all of this possible. Thank you, dear Luís, for your constant support, for your curiosity, and for your generosity. I am also very lucky to be in the excellent company of the outstanding scientists who form the scientific committee: Prof. Etzel Cardeña, from Lund in Sweden, Prof. Miguel Castelo-Branco, from Coimbra, Prof. Rui Costa, from Lisbon and New York University, Prof. Rainer Goebel, from Maastricht University in the Netherlands, Prof. Stefan Schmidt, from Freiburg in Germany and Prof. Caroline Watt, from Edinburgh in Scotland. Unfortunately, the last two, Prof. Schmidt and Prof. Watt, couldn't make it today because of consequences of the pandemic. Thank you all for the excellent and challenging work you have undertaken to make this 13th symposium a success. You will meet all of them over the course of the symposium, but will also meet two other important actors: Prof. Mário Simões, from Lisbon, who will handle the oral poster presentations from BIAL Foundation grantees, and the well-known science journalist Ms. Teresa Firmino, who will oversee our latest experiment on Saturday afternoon - a conversation about time. But the most important actress in this entire organization is probably our dear Paula Guedes, who not only keeps time but also reminds all of us to speed up when we need to and to do things in due time. Thank you Paula for making sure we all have a good time doing all of that!

Let me now briefly overview the symposium itself. It's about time in a way, we talked about time, because time truly remains a big mystery. It is a mystery in the sense that the American philosopher Daniel Dennett described: It is a problem about which we do not know how to think about yet. On the one hand, we all know what it is: Time is what we begin missing as we get older, time reflects the effort it takes to get something done - time is money - time is what makes us impatient, time is what characterizes old memories and future ambitions. Time is also the fourth dimension in physics, but it is a dimension that appears strikingly different from the dimensions of space. Science-fiction writers, but also some physicists, have speculated about the possibility of time travel. It is a distinct characteristic of human cognition that we mentally travel through time all the time. We think of time as linear - it is an arrow that travels in only one direction. But what if that was not the case? What if future events could influence what we choose to do now?

As you can sense, those are all big questions, and I am truly excited that the next three days will give us a chance to at least address many of them - whether we can actually answer them is another question…

To approach these big questions, our symposium is organized in three main sessions, each taking place on a separate day. Tomorrow, in a session moderated by Prof. Etzel Cardeña, we will talk about the "arrow of time" - what do we know about the physics and metaphysics of time? We have an outstanding set of speakers who will address these issues, and the morning will close with a keynote lecture by Prof. Bernad Carr, a physicist from Queen Mary's University in London.

On Friday, we will explore the "biology of time". Here, we will move away from physics to delve into how biological organisms respond and adapt to the passage of time. Again, we will have a deeply multidisciplinary look at these issues, with different outstanding speakers addressing different facets of the biology of time. The session will be moderated by Prof. Miguel Castelo-Branco and will close with a keynote lecture by Prof. Wolf Singer.

Finally, our third session, on Saturday morning, is dedicated to the "experience of time", that is, to the psychology of time perception. From "remembering the future" to predicting it, from the neural underpinnings of the perception of time to how it feels for us to witness the passage of time, this will all be about how time is a fundamental dimension of our psychology. The session was supposed to be moderated by Prof. Caroline Watt, but it will be instead moderated by a different person and will close with a keynote lecture by Prof. Marc Wittmann.

I know I am running out of time, but I still have to tell you a little bit about the further happenings during those next three days.

First, I am very pleased to let you know that we will again have four parallel workshops on Friday afternoon, respectively dedicated to the "physics and metaphysics of time", to "precognition and anomalous experiences", to "the experience of time in altered states of consciousness", and to "the perception and memory of time". Some of the workshops will take the form of debates where we can go a bit deeper into the core issues; others will offer hands-on experiences made possible by the smaller size of the audience.

Second, as you know, the BIAL Foundation also supports the work of many scientists through its grants program. The BIAL fellows whose work benefits from such support form the core of the BIAL Foundation's activity, and we are very pleased to welcome many of them so they can let all of us know what they have been doing. Thus, tomorrow afternoon, we will not only have a poster session that showcases this work, but also a poster blitz session during which each grant holder has a chance to present his work in 2 minutes. This exciting session will be moderated by Prof. Mário Simões, who has becoming an expert at timing these presentations very precisely, and will take place here at 2:30 in the afternoon.

Finally, on Saturday, we will close the symposium with a conversation featuring speakers from each of the three sessions and expertly moderated by Teresa Firmino. We hope, with this closing event, to bring together different insights from the physics, biology, and psychology of time to engage in truly interdisciplinary dialogue fueled by your questions.

So, that's it for this overview - I am very excited to get going and very much hope that you will find the symposium challenging, stimulating, and timely.

Thank you.

DISCURSO DO BASTONÁRIO DA ORDEM DOS MÉDICOS

Miguel Guimarães

Boa noite a todos,

Senhor Prof. Pedro Teixeira, Senhor Secretário de Estado do Ensino Superior, muito obrigado por estar aqui presente nesta casa. Senhor Doutor Luís Portela, Presidente da Fundação BIAL, é sempre uma honra recebê-lo nesta casa que é a Casa dos Médicos, mas que hoje é a casa de todos estes cientistas, de todos estes investigadores, de todos estes pensadores. Senhor Presidente do Conselho de Reitores e Reitor da Universidade do Porto, Prof. António de Sousa Pereira, na sua pessoa cumprimento os Diretores das Escolas Médicas aqui presentes, da Faculdade de Medicina do Porto, do ICBAS, e também da Escola de Ciências da Saúde de Braga. Aproveito para cumprimentar também toda a comunidade científica presente nesta sala. Senhor Prof. Axel Cleeremans, Presidente da Comissão Organizadora deste 13º Simpósio.

Eu gostava de começar por dizer que é uma honra para a Ordem dos Médicos ter o privilégio de se poder associar a esta homenagem ao Prof. Fernando Lopes da Silva. O Prof. Fernando Lopes da Silva foi um investigador, foi um homem da Ciência, foi um cientista, foi também um professor notável, um humanista que deu muito a todos nós, que contribuiu através da Ciência para salvar muitas vidas. Esta é uma homenagem merecida, uma homenagem que não chega para realçar o brilhantismo que o Prof. Fernando Lopes da Silva teve durante todos estes anos.

Quero dar-vos as boas-vindas, a todos os investigadores, cientistas, que vão durante estes dias, como foi dito e muito bem pelo Senhor Presidente da Comissão Organizadora, honrar esta casa da Ciência. Mas quero também deixar aqui um cumprimento muito especial ao Senhor Presidente do Conselho Regional do Norte da Ordem dos Médicos, que nos está aqui a acompanhar e muito bem, o dono desta casa. Ao Senhor ex-Ministro da Ciência, Prof. Manuel Heitor, é uma honra tê-lo aqui. E também ao Dr. Artur Santos Silva, que muito honram esta casa e esta iniciativa.

Receber aqui este simpósio para nós é, de facto, um momento excecional. É um momento em que esta casa desperta para a Ciência. E este simpósio é um simpósio que tem um título notável; para além do título habitual. Ou seja, vai-se falar um pouco sobre aquilo que é o mistério do tempo. O tempo, de facto, é uma área que nós conhecemos mal, é uma área que interfere sempre em todas as dimensões da nossa vida, e é uma área que aqui tem uma relação especial com o espaço, que é este espaço que vai ser durante este tempo espaço da Ciência.

O debate que vai acontecer durante estes dias vai ser seguramente frutuoso, como sempre acontece nestes simpósios, em que se vai falar de várias matérias, todas elas centradas no tempo. Mas eu gostava de, nestes três minutos que me foram dados e que estão quase a acabar, deixar aqui duas citações que eu acho que são particularmente relevantes.

Uma do Luís Portela em 2018, quando disse que "é obrigação da Ciência investigar e esclarecer a humanidade". E é isto que o Luís Portela tem feito durante a sua vida e continua a fazer. É o grande responsável por muitas destas discussões fora da caixa que nós vamos tendo. É um homem que tem dado um contributo exemplar para o desenvolvimento da Ciência no nosso país e além-fronteiras e, portanto, eu quero aqui também dar-lhe esta palavra de agradecimento como Bastonário da Ordem dos Médicos. É médico. Luís Portela é médico também, investigador, gestor, e por aí fora.

A outra citação que eu gostava de vos deixar é do Prof. António Damásio. Em 2017, o Prof. António Damásio disse que "todas as memórias têm um contexto, um contexto de espaço, um contexto de tempo e de afeto. E é pela dimensão do afeto que não deve existir uma hiper-racionalização da Ciência".

Muito obrigado a todos e bom congresso.

DISCURSO DO SECRETÁRIO DE ESTADO DO ENSINO SUPERIOR, EM REPRESENTAÇÃO DA SENHORA MINISTRA DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Pedro Teixeira

Caro Presidente da Fundação BIAL, caro Doutor Luís Portela. Caro Presidente do Conselho de Reitores, Prof. António de Sousa Pereira. Caríssimo Bastonário da Ordem dos Médicos, Dr. Miguel Guimarães, de certa forma anfitrião, a quem muito agradeço por nos receber nesta casa. Caro Prof. Axel Cleeremans, e em si saúdo obviamente todos os membros da Comissão Organizadora do simpósio. Caras Sofia e Suzana Lopes da Silva. Caros Diretores das Escolas Médicas aqui presentes. Caros convidados. Num simpósio que se intitula "O mistério do tempo", para um economista, eu diria que ser parcimonioso se calhar era a melhor recomendação e, portanto, tentarei ser breve. Este momento, por uma coincidência feliz, é a minha primeira intervenção pública nestas novas funções. Permitam-me quatro breves notas que gostaria, de facto, de sublinhar.

Desde logo uma saudação da Senhora Ministra da Ciência, Tecnologia e Ensino Superior, que muito gostaria de estar presente nesta sessão, mas atendendo a que este é ainda um tempo muito intenso de assunção destas responsabilidades, viu-se impossibilitada de marcar presença, mas que me pede para vos saudar a todos e felicitar a Fundação BIAL por mais esta notável iniciativa. Esta era a primeira nota que gostaria de fazer.

Quem me conhece sabe que estas palavras poderão ser suscitadas pela amizade que me une ao Doutor Luís Portela, à admiração que lhe tenho e à colaboração de muitos anos, até recentemente, com a Fundação BIAL. Penso que é da mais inteira justiça, salientar o papel que tem tido e os serviços que o Doutor Luís Portela tem prestado ao país em muitas facetas, mas se me permitem, porventura, a Fundação BIAL é talvez a sua criação mais bonita e mais significativa. Por isso, muito obrigado por esta persistência, por este carácter visionário, por nos congregar para refletir e pôr a pensar. Para não me alongar, diria que uma das marcas do simpósio é de facto pensar temas diferentes, de uma forma diferente. Para muitos de nós que temos assistido a vários simpósios, é um desafio, do ponto de vista intelectual, mas é também um gosto pela forma como os organizadores do simpósio têm conseguido, não só encontrar temas diferentes, mas congregar investigadores nacionais e estrangeiros - colegas de áreas científicas diferentes, de formações diferentes - para o diálogo. Tem sido, de facto, fascinante. Estou certo de que o simpósio deste ano não será aquém, será certamente além, daquilo que eu pude dizer em breves palavras.

A terceira nota que gostaria de fazer, era para saudar o Prof. Manuel Heitor, que também é uma grata circunstância estar aqui presente, e para lhe dizer publicamente aquilo que ele sabe, porque já lho disse pessoalmente, de agradecimento pelo muito que fez ao longo destes anos pela Ciência e pelo Ensino Superior em Portugal. Há um legado de reflexão estratégica, de intervenção, de colocar a Ciência, a qualificação e o Ensino Superior como vetores fundamentais para a intervenção política em Portugal. É mais do que justificado esse agradecimento público. Portanto, Prof. Manuel Heitor, contamos com essa capacidade para continuar a ajudar-nos a pensar e a refletir os caminhos do Ensino Superior e da Ciência, agora mais liberto de algumas responsabilidades, mas certamente com o mesmo empenho e a mesma convicção de sempre.

A última nota é porventura a mais difícil, que é falar sobre o Prof. Fernando Lopes da Silva. É difícil porque, depois daquilo que muitos já disseram, muitos que o conheciam muito melhor do que eu, não é fácil acrescentar algo. Quando ouvia os testemunhos, quer do vídeo, quer da Sofia e da Suzana Lopes da Silva, mas também as palavras do Doutor Luís Portela, do Prof. Axel Cleeremans e do Dr. Miguel Guimarães, um dos aspetos que achei particularmente significativo é quão convergentes eram os nossos testemunhos. Porque quando nós pensamos no Prof. Fernando Lopes da Silva, o que nos vem à memória é alguém com uma capacidade de trabalho incansável, com um rigor científico e ético absolutamente assinaláveis, com uma originalidade, mas também com uma humildade e uma modéstia que muito nos impressionava. Tive o privilégio de privar com o Prof. Lopes da Silva nos anos mais recentes e pude beneficiar de tudo isso, como muitos de nós e, portanto, muito obrigado pela vossa presença.

E gostaria de acrescentar um pouco mais sobre o Prof. Lopes da Silva.

O Prof. Lopes da Silva serviu o país de muitas formas. Serviu através de uma carreira académica científica notável, como aqui foi salientado. Mas serviu também como um exemplo de cidadania exemplar: na forma como colaborou com muitas instituições de ensino superior e científicas portuguesas; na forma como ajudou a orientar os primeiros passos da carreira de colegas portugueses, seja em Portugal, seja fora; na forma como fez parte de uma geração que ajudou em grande medida a estruturar o sistema científico português - e a estruturá-lo assente em princípios de exigência, de avaliação, de integração com a comunidade científica internacional -, e esse é também um legado que o Prof. Lopes da Silva nos deixa. E em tudo isso há, de facto, a sua qualidade do ponto de vista científico, a sua qualidade do ponto de vista humano, mas também o seu exemplo de cidadania. É um legado pesado, é um legado que é difícil honrar, mas é também um encorajamento para todos nós. Muitas vezes na Ciência nós costumamos usar aquela expressão que uns atribuem a Einstein, outros atribuem a Newton, outros atribuem até a outros autores, que "nós vemos mais longe porque estamos nos ombros, assentes nos ombros, daqueles que nos precederam". Eu diria que do ponto de vista da nossa comunidade científica, e do ponto de vista da intervenção pública e política, também assim é em grande medida. Ou seja, nós conseguimos ir mais além pelo trabalho, pela dedicação, pelo compromisso científico, mas também cívico e ético, daqueles que nos precederam. Portanto, o legado do Prof. Fernando Lopes da Silva é uma responsabilidade, mas é também um encorajamento para todos nós, para poder fazer mais e para poder fazer melhor pela Ciência em Portugal.

De facto, nós só poderemos ter um futuro de desenvolvimento, certamente do ponto de vista económico, mas muito mais além do que isso, de desenvolvimento social, de desenvolvimento político e de desenvolvimento cultural, se a Ciência, o conhecimento e a qualificação forem absolutamente centrais, e se do ponto de vista político, nós formos capazes de reconhecer essa centralidade, dar-lhe a visibilidade, os recursos e a importância que estas têm que ter. E, portanto, aquilo que também gostaria de manifestar é esse compromisso que o legado do Prof. Lopes da Silva nos deixa a todos, para, enquanto sociedade, sermos capazes de estar à altura disso.

Muito obrigado e boa noite.

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THE PERCEPTION OF TIME IN HUMANS, BRAINS, AND MACHINES

Warrick Roseboom [1,2], Anil Seth [1,3], Maxine Sherman [1], Zafeirios Fountas [4]

Abstract

The experience of time passing is fundamental to human experience. Considerable experimental data has found that perceptual judgments of duration show systematic distortions away from physical 'clock' time. The majority of neurocognitive explanations of duration perception invoke some form of 'inner clock', or pacemaker. Systematic distortions can then be accounted for by alterations in this pacemaker mechanism. Here, we summarise our recent work exploring a different approach, according to which experiences of duration are based on activity within perceptual classification networks. Specifically, we propose that subjective time is constructed from accumulated salient changes within hierarchical perceptual networks and substantiate this proposal by (i) building an artificial neural network based model which is able to predict human subjective time judgements, including a number of its biases; (ii) using model-based neuroimaging to show that human subjective time can be predicted from activity in human perceptual cortex, as suggested by our neural network model, and (iii) locating the model within a larger 'predictive processing' framework which enables connections between time perception and episodic memory to be elaborated. Altogether, we provide a new mechanistic framework for understanding human time perception in terms of inference about information arising during perceptual processing.

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1. Introduction

"I have measured out my life with coffee spoons"
T. S. Eliot, The Love Song of J. Arthur Prufrock, 1915

The challenge of understanding the biological basis of time perception is made distinctive because, unlike for other perceptual modalities, there are no simple and easily found 'time sensors' in the human brain or body. More specifically, in the case of time perception there appears to be no straightforward correspondence between sensory stimulation and brain activity, as can be found for other forms of perception, such as in spatial vision (Paton & Buonomano, 2018). Dominant models of time perception have therefore presumed the existence of neural processes that continually track physical (objective) time - 'pacemakers' - similar to the system clock in a computer (see Allman et al., 2014 for a comprehensive review of this position). However, compelling neural evidence for the existence of simple pacemaker processes is lacking (Karmarkar & Buonomano, 2007; Paton & Buonomano, 2018).

Although pacemaker models are still popular, the approach stands in contrast with classical views in philosophy and behavioural science which emphasise that the experience of time passing is intimately tied to changes in the content of (non-temporal) perceptual experience. In accordance with this view, and as emphasised by early cognitive models (e.g. Ornstein, 1969), many studies have demonstrated the influence of stimulus characteristics, such as complexity (Ornstein, 1969; Poynter & Homa, 1983), and rate-of-change (Herbst et al., 2013), on subjective time perception.

Here, we build on this tradition to explore how human subjective time perception relates to aspects of perceptual processing. A key feature of our approach is that it is not the stimulus characteristics themselves that are considered important, but how the observer - or, more specifically, the perceptual mechanisms of the observer - respond to sensory stimulation. We summarise a series of three studies, through which we tested the proposal that human-like duration estimation can be generated by tracking changes in perceptual content, as measured in the dynamics of both artificial perceptual classification networks (Studies 1 and 3) and human neuroimaging data (Study 2).

In a first study (Roseboom et al., 2019), both human participants and an artificial neural network trained to classify images with their correct label (e.g. an image containing a cow should be classified as “cow”) were exposed to videos of natural scenes. Humans were asked to estimate the duration of the videos, while for the network, estimates of duration were extracted from the dynamics of its activity. We showed that the dynamics of network activity can produce human-like duration estimates, despite the network not being trained on human estimates. Notably, duration estimates from the model showed similar biases from physical time as human participants, in particular: (i) Vierordt’s law, in which short durations are perceived as being longer (and long durations perceived as being shorter) than they actually are, and (ii) a ‘content bias’ in which busy scenes are perceived as experienced as lasting longer than less-busy scenes (for the same physical time).

The second study (Sherman et al., 2022) concurrently collected behavioural and neuroimaging (fMRI) from human participants judging the durations of videos of everyday scenes. Using a model-based imaging approach to analysis, we showed that human duration estimates (and the corresponding biases) can be predicted by accumulated salient changes within sensory cortex. While the first study showed that information arising during perceptual processing provides a sufficient basis *in principle* for reconstructing human subjective time estimates, this second study showed that such information may also be sufficient *in practice*.

A final study returned to a combination of computational modelling and human behavioural data to set our proposal within the larger context of ‘predictive processing’ (Fountas et al., 2022). Predictive processing labels the general idea that perception depends on a process of neural inference on the causes of sensory signals - an idea which has gained prominence in the mind and brain sciences (Clark, 2013; Millidge et al., 2022). We developed a computational model connecting perceptual inference with episodic memory, and used this model to account for two further systematic influences on human duration estimation: (i) memory: time estimates depend on whether they are made prospectively (‘at the time’) or retrospectively (on the basis of memory), and (ii) attention: how much attention is paid to time also affects duration estimates, and does so differently for prospective compared to retrospective estimates. We replicated these biases in a large-scale behavioural experiment and showed that our model successfully accounts for them.

Altogether, by combining data from humans (behavioural data), brains (fMRI), and machines (computational modelling), we lay out a detailed mechanistic framework able to explain many aspects of human duration perception including many of its natural biases. Instead of relying on some internal clock-like mechanism for tracking physical time, our framework proposes that time perception depends on information arising from activity within perceptual networks. Specifically, we show that accumulated salient changes within hierarchical perceptual networks provide a sufficient basis for predicting human duration perception of natural scenes. The data we present demonstrate this on psychologically relevant time scales from a few seconds to up to a minute. Whether the approach extends to an entire lifespan, measured out in salient coffee spoons, remains to be discovered.

2. A computational model of human duration perception

The first study we review combined computational modelling with human subjective reports, to examine whether duration estimates could be predicted on the basis of information arising during perceptual processing. We offer a brief summary; full details are available in (Roseboom et al., 2019).

55 human participants viewed silent videos of natural scenes, such as walking through a city or the countryside, or sitting in an office or cafe (see Figure 1). The videos were split into clips with durations ranging from 1 sec (min) to 64 sec (max). Participants viewed video clips during sessions lasting 1 hour, which typically entailed ~80 separate trials. After viewing each clip, participants estimated its duration on a visual analogue scale. Eye tracking data was recorded throughout each session so that fixation paths could be recovered. The human reports, shown in Figure 3, confirm that people can perform the task: estimated durations correlate closely with actual (physical) durations. However, there are biases, which are expected on the basis of many previous studies. First, short durations are overestimated and long durations are underestimated. This is the well-

known 'regression to the mean' effect, known as Vierordt's law in the context of time perception (Lejeune & Wearden, 2009; Petzschner et al., 2015). Second, there is an influence of scene content. City scenes - which are busy, containing lots of change - are perceived as lasting longer, while office and cafe scenes - which are quiet, containing comparatively little change - are perceived as lasting for less time. These data provide the targets for computational modelling.

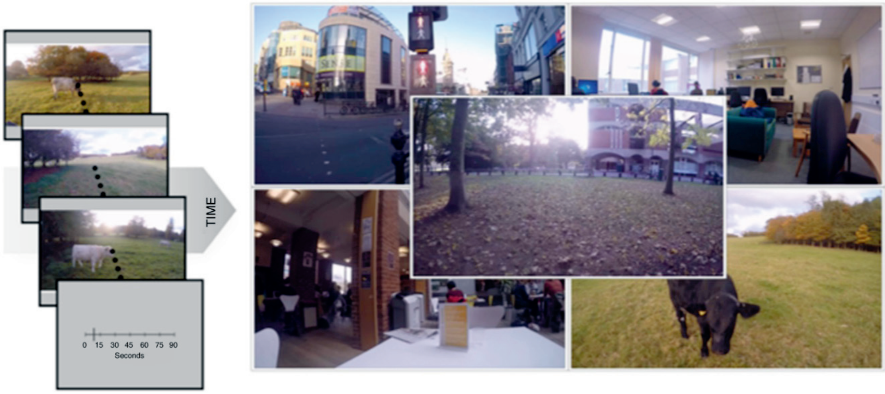

Figure 1. Participants viewed silent movies of natural scenes and then reported how long they thought the video had lasted (in seconds), using a computer mouse to control a visual analog scale. The videos were between 1 and 64 seconds long and could contain a number of scenes from around the City of Brighton or University of Sussex campus, such as a busy city street, a leafy campus, or a quiet office.

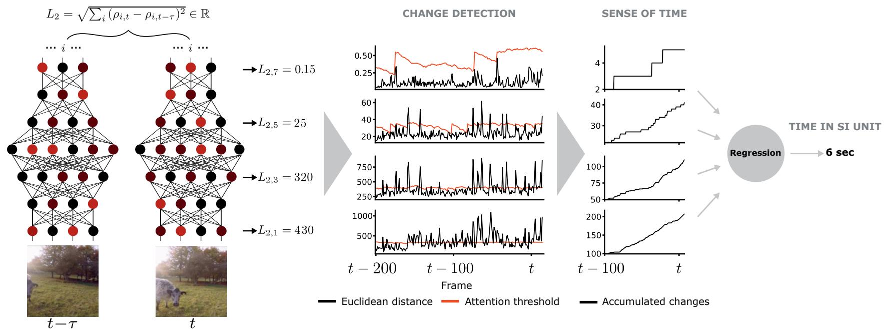

Figure 2. Schematic of the computational model used in (Roseboom et al., 2019). From left to right: Videos are input to an artificial image classification neural network one frame at a time. The change in model activation (estimated as Euclidean distance) between successive frames is recorded for each of several layers and tracked for the duration of the video. The recorded change is compared to a threshold to determine if a given moment of change should be considered salient (Change Detection). Changes that exceed threshold are accumulated and taken as the inner sense of time (Sense of Time). Accumulated salient changes are regressed against the physical duration of the video in order to provide a model-based estimate in seconds to compare against human reports (Time in SI Unit).

The computational model (Figure 2) was designed to implement the idea that estimated duration is constructed from accumulated salient changes during perceptual processing. It is based on a pre-trained multi-layer (deep convolutional) image classification network, known as AlexNet (Krizhevsky et al., 2012). Successive frames of each video clip were presented as input to the image classification network. To estimate time, the model tracked the Euclidean distance between successive activation patterns within four pre-specified hierarchical layers of the network. When this distance exceeded a dynamic threshold, a salient perceptual change was deemed to have occurred at the corresponding layer, and a unit of (layer-specific) subjective time was accumulated. The threshold was implemented for each layer as a decaying exponential, corrupted by Gaussian noise that reset whenever a crossing event occurred. To transform the abstract temporal units accumulated in the model to standard units (seconds), we trained support vector regression to estimate the duration of video clips (in seconds) from the accumulated salient changes in network activity within network layers. Crucially, the support vector regression was trained on the physical duration of the clips, not on the human-provided estimates. Therefore, a correspondence between model output and human data is meaningful because it shows that the computational mechanism reproduces the key biases of human duration estimation, despite not being trained to reproduce these biases.

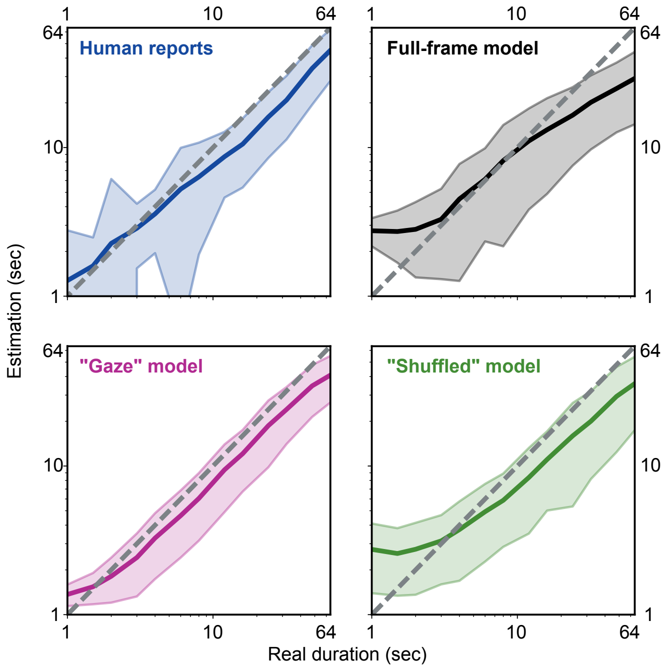

Figure 3. Estimates of natural video duration for human participants and different model configurations (Full-frame; "Gaze"; and "Shuffled") from (Roseboom et al., 2019).

As (Figure 3, Full-frame model) shows, model-derived duration estimates captured key elements of human duration estimation. Trivially, longer clips were estimated (by the model) as lasting longer. More importantly, Vierordt's law was also observed, albeit in an exaggerated fashion, with short durations in particular being more strongly overestimated by the model as compared to human participants.

These initial results were obtained when each frame of the video was processed in full by the network. However, humans viewing natural scenes continually shift their gaze and their attention, focusing on selected portions of the scene in a time-varying way. To examine the influence of this attentional ‘filtering’, we repeated the analysis with an additional gaze-contingent constraint. Specifically, model input was constrained, on a frame-by-frame basis, to a region of the frame centred on human participants’ gaze fixation, measured for each frame and for each participant (see Figure 3, “Gaze” model). Repeating the analysis with this modified “Gaze” model, we found that the model was able not only to match human data with respect to Vierordt’s law much more closely than the “Full-frame” model, it also reproduced scene content biases, such that busy city scenes were overestimated and quiet office/cafe scenes were underestimated.

It is worth mentioning that the good performance of the “Gaze” model did not depend simply on arbitrary restrictions of input data: when fixation time-series were randomly shuffled among video clips (so that the input video data no longer corresponded to the correct human fixation patterns), the model fit to the human data was considerable worse (see Figure 3, “Shuffled” model’). It is also worth mentioning that time estimates based simply on pixel-wise differences between successive video frames i.e., bypassing the classification network) entirely did not reproduce scene content biases. This affirms that it is the dynamics of perceptual processing that is important, not simply the dynamics of sensory input.

Obviously, the model as described only works for visual input. Equally obvious is the fact that humans can still estimate time in the absence of visual input, which does not invalidate the model. Human brains receive all sorts of sensory inputs on which time estimation may be based, both exteroceptive and interoceptive. What we show here is that when human estimates and model estimates are both required to rely primarily (human) or wholly (model) on visual signals, the model is able to closely match human performance (see Suárez-Pinilla et al., 2019 for a discussion of relative interoceptive and exteroceptive contributions).

Altogether, results from this first study substantiate the proposal that accumulating salient changes during perceptual processing provides a sufficient basis for constructing human-like subjective duration estimates of natural scenes. Strikingly, and in contrast to competing approaches, there is no appeal in our model to any kind of inner clock or pacemaker. (In a further control study we altered the internal 'frame rate' of the model - this did not affect results; see Supplementary Information p.2 in Roseboom et al., 2019). Nevertheless, we were able to replicate well-known features (biases) of human time perception, including regression to the mean (Vierordt's law) and the influence of scene content (e.g., busy compared to quiet).

Given the success of this model, and given that the image classification network used bears some resemblance to the functional architecture of visual cortex, the question naturally arises as to whether the activity of perceptual networks in the human brain would also be sufficient for extracting subjective duration estimates. In other words, given that a highly schematized model of perceptual processing can do the job, can the activity of real human brains do the job too? This is the question we turn to next.

3. Model-based neuroimaging of human duration perception

In this second study, a new set of 40 human participants viewed a subset of the (silent) video clips ranging from 1 sec to 24 seconds, and containing only city and office scenes (these being the most busy, and the most quiet). Participants were required to estimate the duration of each video clip they viewed, while neuroimaging (fMRI) data was recorded.

As found in Study 1, behavioural data showed a strong correlation between physical duration and reported duration, confirming that participants could perform the task. We also replicated the biases found in the previous study: city scenes were overestimated and office scenes were underestimated (Figure 4, Human Behaviour). This study focused on replicating these biases.

We next replicated the computational model analysis, following the pipeline described in Study 1 for this new stimulus set. As expected, the network model produced similar scene-dependent biases to those in Study 1, and similar scene-dependent biases to the human participants for the same stimuli: again, the network overestimated city scenes, and underestimated office scenes (Figure 4, Network Model).

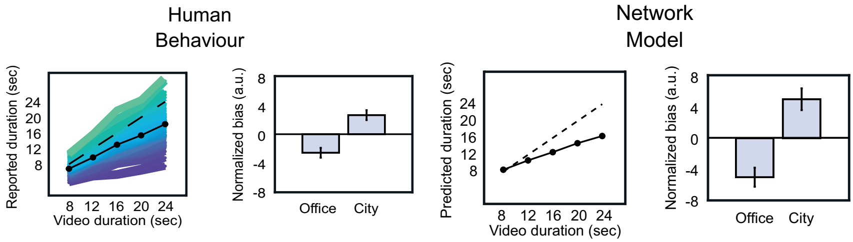

Figure 4. Data from (Sherman et al., 2022) for human participants (left panels) and the artificial neural network based model as described in Section 2 above (right panels). Participants watched natural videos of city or office scenes (between 8 and 24 seconds long) and reported the duration on a visual analog scale. Each coloured line in the first panel is a single human participant and the solid black line is the mean report over participants; the solid black line in the third panel is the mean model-predicted reports.

As mentioned, the image classification network in the model can be interpreted as standing in for visual cortex. The key innovation in the present study was to perform model-based neuroimaging, testing whether we could predict (human) subjective duration estimates by accumulating salient events not in a computational *model* of visual cortex, but from stimulus-driven fMRI BOLD responses *within visual cortex itself*.

We defined three perceptual hierarchies from which BOLD time-series were extracted: visual, auditory, and somatosensory. The auditory and somatosensory hierarchies served as control models. Because the presented videos were silent, we hypothesised that human judgements about the duration of visual video clips should only be well-predicted by activity in visual cortex, and not by activity in auditory cortex or somatosensory cortex.

The analysis proceeded as follows (see Figure 5): For each participant and each perceptual hierarchy (visual, auditory and somatosensory), voxel-wise patterns of BOLD activity were extracted from each time point (TR, or slice) in each hierarchical layer. Then, difference values were computed between successive voxel patterns and summed over the layer, resulting in one value (representing 'change in activity') for each layer and each time point. Difference values were computed using both a Euclidean distance measure (always positive), and a signed difference measure (which can be positive or negative). These change values were then standardized (z-scored) within each participant, and, as for Study 1, compared to a dynamic criterion with exponential decay. Whenever the change exceeded the criterion, a salient event at the corresponding layer was accumulated, and the criterion was reset. Support vector regression was then trained to map accumulated salient events in each perceptual hierarchy to the actual (not reported) duration of each video clip, enabling comparison of model data with human data.

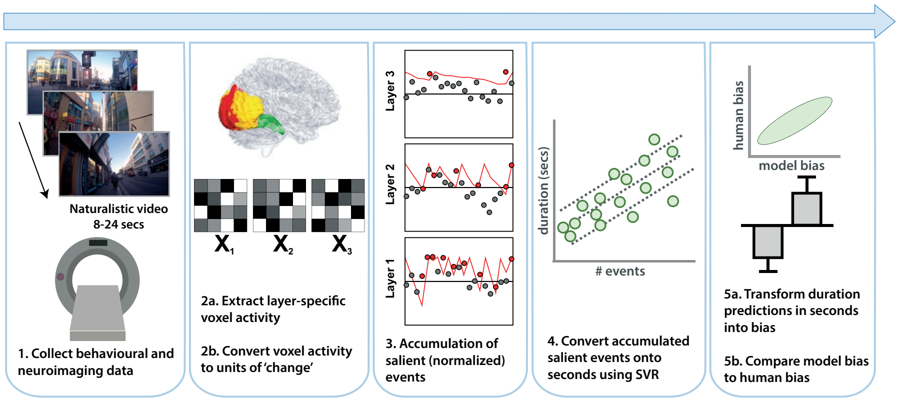

Figure 5. Schematic of the model based neuroimaging analysis pipeline from (Sherman et al., 2022). From left to right: (1) Human participants viewed silent videos of natural scenes (between 8 and 24 seconds long) while laying in an MRI scanner. (2) Recorded brain activity (BOLD) from brain regions involved in perceptual processing (in the example, visual cortex) was extracted at each time slice (1, 2, 3, etc) of the imaging acquisition. These voxel-wise data are represented by the greyscale matrices (X1, X2, X3, etc). The slice-by-slice change values were then summed over all voxels in the layer. (3) Each change (represented as circles) was categorized as a salient event in neural dynamics if it exceeded a dynamic criterion (red line). (4) These salient events were accumulated, and the total regressed against physical video duration to express the estimated 'sense of time' in standard units of seconds, (5) and compare model-based biases with biases in human reports.

Full details of the analysis pipeline are available in (Sherman et al., 2022). Two points are worth emphasising here. First, the easiest way to understand the analysis is simply that we substituted the image classification network used in Study 1 (which can be interpreted as a *model* of visual cortex) with neuroimaging of the actual visual cortex of each participant. Second, the analysis was fully pre-registered, with one (noted) departure being the use of the signed difference measure in addition to the Euclidean distance measure. The rationale for this exploratory analysis was that the signed difference interprets BOLD responses from a predictive processing perspective as already signalling 'prediction errors' (i.e. change). In this summary, we focus on the results from the signed difference measure.

Figure 6 shows model predictions of duration from each of the three perceptual hierarchies we considered. All three models showed strong correlations between model-predicted duration and physical duration, but this is trivial because longer video clips contain more changes in BOLD signal. Critically, only the visual model was able to replicate the scene type bias observed in both the human responses and the network model, underestimating office scenes and overestimating city scenes (Figure 6, Model normalized bias). A further analysis, described in (Sherman et al., 2022) and depicted by the bottom row scatter plots in Figure 6, found that only the visual model was able to successfully predict trial-by-trial subjective time. Taken together, these results underline the specificity of visual cortex activity in predicting subjective time for silent videos.

This second study builds on the first by showing that subjective estimates of duration can be constructed from accumulating salient events in the dynamics not just of a *model* of perceptual (visual) processing, but also from *actual activity* in sensory (visual) cortex. It is worth clarifying that 'salience' as used here is meant purely as a measure of change that exceeds a (dynamic) threshold. There is no necessity that salient changes identified in the sensory cortex should be experienced as being psychologically salient by the participant.

It is also worth noting that we didn't look for neural regions that represent the temporal properties of sensory stimulations - so-called 'chronotopy' (Harvey et al., 2020). Instead, we constructed a model that extracts the relevant temporal properties from the neural activity associated with perceptual processing - an indirect, rather than a direct mapping. In other words, rather than looking for time 'in the brain', we asked how brain activity during perceptual processing can underlie time for the person.

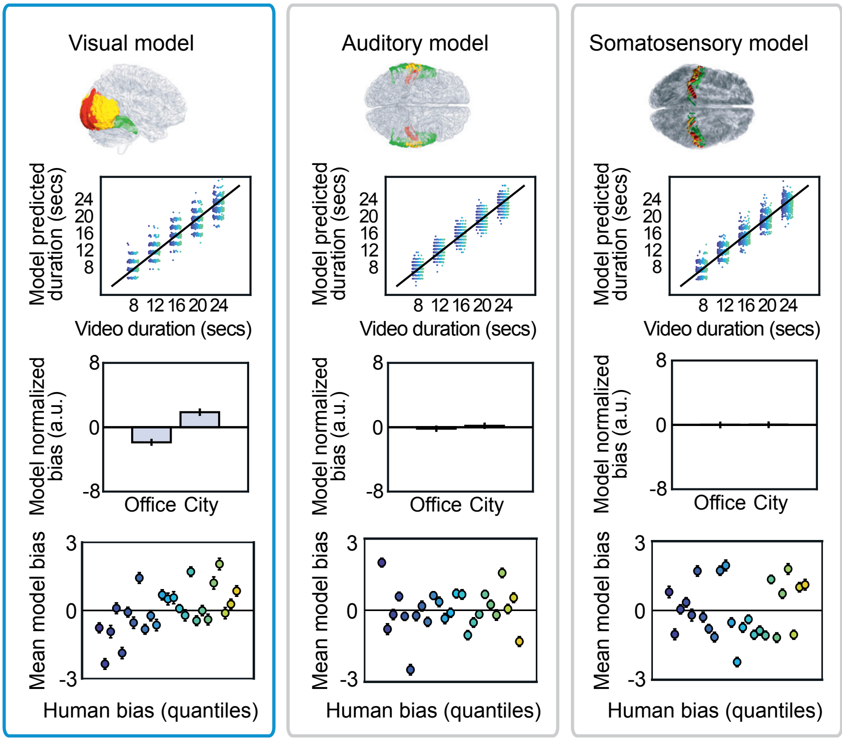

Figure 6. Data for the brain-activity-based models of human time perception from (Sherman et al., 2022). Each model is based on activity in a different perceptual processing hierarchy (Visual, Auditory or Somatosensory; top row) collected while human participants viewed silent videos of natural scenes. Salient changes from all three models can (trivially) reproduce estimates of physical time (second row). However, the overestimation of city scene durations was seen only for estimates constructed from visual cortex activity (third row), and similarly, only biases constructed from visual cortex activity correlated with human biases (bottom row). These results support our prediction that it is the dynamics of *content-specific* perceptual processing that determines subjective time.

Together, Studies 1 and 2 illustrate a novel, pacemaker-free framework for understanding the mechanistic basis of duration perception of natural scenes. Study 1 demonstrated using computational modelling that the framework worked in principle, and Study 2 demonstrated using model-based analysis of neuroimaging that the framework also works in practice.

Earlier, we mentioned that the use of the signed difference measure in the neuroimaging analysis pipeline carried an interpretation of BOLD activation values as signalling perceptual 'prediction errors'. This interpretation contrasts with the basic image classification networks used in the studies so far, which are classical feed-forward deep convolutional networks. This contrast raises the question of how our approach to modelling time perception relates to a full 'predictive processing' framework, which involves the reciprocal exchange of (top-down) predictions and (bottom-up) prediction errors throughout perceptual hierarchy. The third and final study we review addresses this question.

4. Extending the approach: predictive processing and episodic memory

The final study we review here extends the modelling approach described in the previous studies to embrace a full predictive processing implementation of perception, augmented by a model of episodic memory. The resulting model is complex, so we confine ourselves here to a relatively high-level summary of its structure and performance. Full details are available in (Fountas et al., 2022).

The behavioural context for the model is provided by two additional factors that are known to influence time perception: cognitive load, and timing of judgement (prospective vs. retrospective). It has been well established that high cognitive load *decreases* apparent duration for *prospective* estimates of duration (where one pays attention to duration at the time), but *increases* apparent duration for *retrospective* estimates (where one recalls duration after the event) (Block et al., 2010).

4.1. Behavioural results

We first replicated this behavioral interaction in a large-scale online study in which ~13,000 participants each estimated the duration of a single video clip of a natural scene (clips were of durations in the range 1 sec - 64 sec). The clips were drawn from the same library as in the first study, comprising both quiet (office, cafe), intermediate (campus/countryside), and busy (city) scenes. Figure 7 (top row, left) shows the crossover interaction in our data, broadly matching that previously reported by (Block et al., 2010).

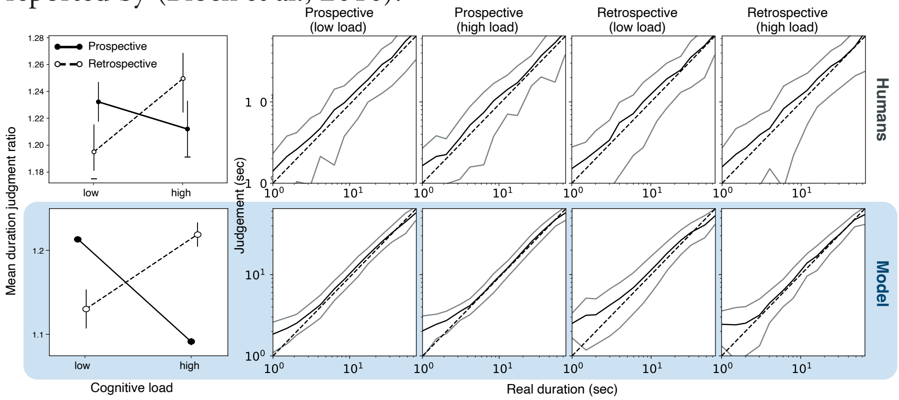

Figure 7. Human participant (top row) and computational model (bottom row) mean duration judgement ratios (leftmost column) and duration estimates (from 2nd to rightmost columns) for high and low cognitive load in prospective and retrospective judgements from (Fountas et al., 2022). Panels in the first column show the overall cognitive load (high/low) by duration task (prospective/retrospective) crossover interaction in duration judgement ratio for both human participant reports (top) and for our computational model (bottom).

4.2. Prospective judgements: From salient change to salient events, to episodic memory formation

Because retrospective time judgements require estimating duration based on the content of memory, any computational model able to account for this interaction must include an implementation of episodic memory. Our model implements memory in the following way (see Figure 8). The first step was to augment the feedforward convolutional network used in the previous studies with a *generative model*, in order to transform the perception model into one having a full predictive processing architecture. In predictive processing, generative models are able to generate predicted sensory signals (at various hierarchical levels) corresponding to some content (e.g., a colour, a geometrical shape, an object, or a whole scene).

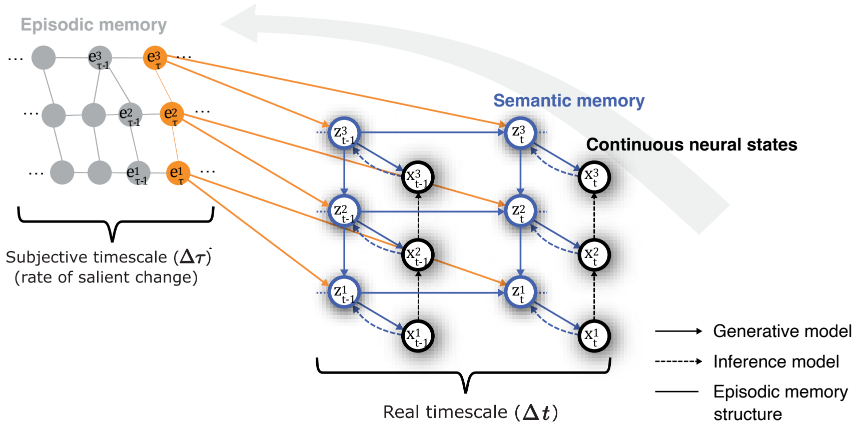

Figure 8. Predictive processing with episodic memory. Probabilistic graphical representation of the model from (Fountas et al., 2022) highlighting a dual hierarchical structure across representations of sensory input (right) and memory (left). Random variable x_t^n corresponds to hierarchical representations of the continuous neural input. Variable z_t^n represents the inferred state, and conceptually relates to semantic memory: it is a categorical, hierarchical representation of the input, such that z_t^1 is the inferred state of a low-level component (or "feature" of the input), and z_t^3 is the inferred state of a higher-level component. z_t^n is conditioned on previous states (z_{t-1}^n) and previously detected salient changes (e_τ^n), so that inference is dependent upon context and previous experience. The leftmost portion of the figure corresponds to the inner episodic structure of experience and forms the basis of subjective time and episodic memory. Here, e_τ^n are the τ^{th} events at n^{th} layers recorded in the episodic memory tree and correspond to the nested elements that comprise an episode of memory.

In our model, a new episodic memory is laid down (i.e., kept as a new memory if it is sufficiently novel, or updating an existing memory if they are similar) whenever the generative model fails to sufficiently predict (hierarchical) sensory input. As in Study 1, "sufficiently" is determined according to a dynamically varying threshold. Consecutive episodic memories are connected in a nested (tree-like) fashion, formed from activity in the generative model cascading down from the hierarchical level at which a threshold crossing occurred (see Figure 9). Through this framework, accumulation of salient events can be viewed as measuring the activity of episodic memory formation. Therefore, in our model, *prospective* duration judgements in seconds are taken as a non-linear monotonic transformation of the number of events recorded in episodic memory.

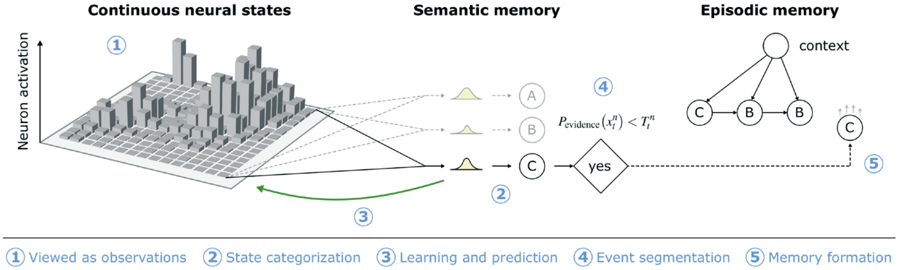

Figure 9. Processes involved in episodic memory formation in the computational model from (Fountas et al., 2022). (1) Continuous neural states from sensory stimulation are (2) quantized via discrete-space semantic memory using prior information. (3) Prior information is used to modulate subsequent neural states via prediction. (4) If activity exceeds a threshold of surprise (comparing predicted and current input), (5) the current quantized state forms an episodic event.

4.3. Retrospective judgements: From episodic formation to (episodic + semantic) recall

When it comes to recall, sequences of episodic memories are recalled through a process of hierarchical reactivation of nodes within the episodic memory network. In the same way that sensory signals (e.g., visual observations) drive bottom-up inference of hierarchical representations in predictive coding, recalled episodic "snapshots" drive inference starting at the corresponding hierarchical level that was originally observed. Through this process, both sensory signals and episodic memories are equally biased towards statistically meaningful priors, which correspond to the *semantic* memory of the model. Due to their nested hierarchical structure, a high-level episodic memory comprises a sequence of lower-level memories that drive inference consecutively. Hence, retrospective duration judgements in seconds are obtained using the same non-linear transformation as for the prospective case, but here based on the number of events recalled rather than those initially recorded.

4.4. Cognitive load: Via attention and effort

As seen in Figure 7, cognitive load affects prospective and retrospective judgements differently. The primary purpose of this third study was to capture this effect in a computational model and to do so, the model included two key parameters: the level of attention paid during memory formation (the level of the 'surprise' threshold beyond which an event is considered salient - as in Studies 1 and 2), and for retrospective estimates, the level of effort put into recall (higher recall effort increases the amount of information recalled from episodic memory versus filled from semantic memory). The levels of attention and recall effort were each controlled by a single, individual hyper-parameter. These constituted the only two free parameters of the model, fitted from the human behavioural data.

4.5. Model training and resulting behaviour

Figure 7 (bottom row, leftmost column) shows that, overall, the crossover interaction between judgement type (prospective/retrospective) and cognitive load (high/low) found in human duration estimates can be replicated by our computational model. Importantly, as in Studies 1 and 2, the number of salient events (in memory formation for the prospective case and recalled from memory for the retrospective case) was mapped to *physical* video durations, again meaning that model estimates of duration are not based on the much more trivial task of mapping directly to human estimates.

4.6. Layer selection: Nested temporal hierarchy

Finally, in post-hoc exploration of the behaviour of the model, we found that the task/cognitive load interaction present in the data overall (see Figure 7) was qualitatively different for different layers of the perceptual hierarchy. This is shown in Figure 10, where we plot the rate of events per second in each layer of the model (because the final duration estimates in seconds cannot be obtained layer-by-layer). The figure shows that the classic crossover pattern is evident in the lower layers of the model (e.g., input and conv1), while at higher layers (e.g., fc7 and output) the effect appears almost to reverse. Strikingly, we observed a modulatory effect like this in the human reports (given in seconds rather than accumulated event rate) - in the model-produced accumulated events we found that the cognitive load by task interaction varied by layer of the perceptual processing hierarchy, while in the human data it varied by scene type (interactions for human data depicted in blue in Figure 10). This qualitative correspondence between human judgements across scene types and model behaviour across hierarchical layers suggests that the perception of duration does not reside simply in a latent 'subjective' timescale of probabilistic belief updates but that this timescale itself has a nested hierarchical structure. Therefore, depending on the context in which duration needs to be estimated, different hierarchical levels may be more or less informative for estimating duration.

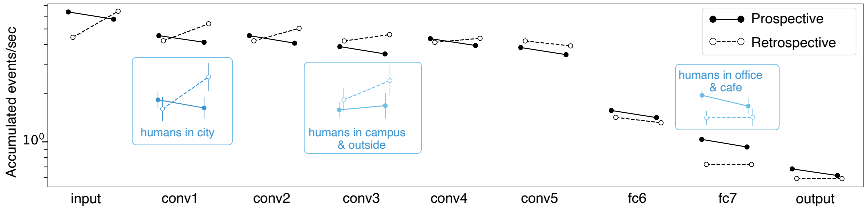

Figure 10. *Black:* The rate of salient events recorded (for prospective tasks) or recalled (for retrospective tasks) per second, separated by task and cognitive load, in each hierarchical level of the model in (Fountas et al., 2022). *Blue:* The cognitive load by duration task interaction in duration judgement ratio for human participant reports (given in seconds), separated by scene type (city, campus/outside, office/cafe). Blue graphs are placed against the model's hierarchical level that shows the highest qualitative similarity in the task/cognitive load interaction and do not correspond to values on the y-axis.

5. Discussion

In psychology and neuroscience, for much of the past half-century, the dominant perspectives on the cognitive and neural basis of time perception have been variants of the internal clock model. Advocates of the internal clock approach propose that the mechanisms underlying time perception ("pacemakers") can be found in clock-like neural operations that attempt to track physical time. Counter to this view, our programme of research demonstrates that such dedicated clock-like processes are not necessary to explain human time perception.

In Section 2, we outlined a computational model of human time perception, applied in the visual domain, and based on tracking the activity in a neural network trained to classify images. We showed that this simple model architecture could produce human-like estimates of time, including biases in time perception for different natural scenes. It has become popular to train neural networks to replicate the specific function of neural systems or processes, or particular aspects of human behaviour [see (Kriegeskorte, 2015; Lindsay, 2021; Ma & Peters, 2020) for reviews]. However, the approach we took was different - rather than training a network to replicate a specific behaviour or process, we took advantage of the properties of an existing network trained in a different domain (image classification) to produce a secondary behaviour: time perception. Using a network trained in a specific domain as part of a broader computational model is a powerful approach, combining the performance of domain-directed training with extended model capabilities (Ma & Peters, 2020).

In Section 3, we described how the principles of our simple computational approach could be applied to model time perception from human neuroimaging data. This pre-registered, model-based analysis showed the value of combining theoretical work developed using cheap-to-make computational models in order to generate specific, testable hypotheses in vastly more expensive testing regimes, such as human neuroimaging (see Guest & Martin, 2021 for a discussion on the importance of computational models in hypothesis generation and theory building). Most importantly, with this method we could predict the moment-by-moment biases in our human participants' reports - biases that characterise the very nature of human time perception and demonstrate how experience deviates from clock time.

The approaches outlined in Sections 2 and 3 were similar; both relied on a proxy measure of "surprise" in perceptual classification network activity (one artificial, another biological). This proxy measure could be taken as a kind of naïve prediction error - the difference between the network state in one moment to the next (naïve because it contained no information other than the previous network state). Basing our model's function on a proxy for prediction error links our work with the increasingly popular and powerful predictive processing approach to perception and cognition (Clark, 2013; Millidge et al., 2022).

Section 4 described our work to escalate this relationship between time perception and predictive processing by building a full model of time perception and episodic memory, based on predictive processing principles. There, we showed that it is possible to use a similar measure of surprise as the mechanistic basis of time perception in either ongoing perceptual processing or in recollection of memories, allowing us to accommodate well established differences in the perception of time in the moment ("prospective" estimates) or from memory ("retrospective" estimates).

Altogether, the studies described illustrate a novel framework, enabling investigations of the neural basis of human time perception to move away from overly simplistic clock analogies. More importantly, because our approach has proven to be effective, it facilitates a variety of interesting and potentially impactful opportunities for linkages with other fields of study - as we briefly illustrate next, for the fields of memory research and machine learning.

5.1. Time perception and episodic memory

Building on the results of (Fountas et al., 2022), we are presently investigating the degree to which our models can predict what is remembered in natural experience by healthy observers. The link between models of time perception and episodic memory is given by the salient events that are identified by our models (see Figures 2, 5, and 9 above). These salient events map onto the notion of event boundaries as developed independently in the episodic memory literature (see Radvansky & Zacks, 2017 for a review). Event boundaries are the transition points between different episodes in continuous experience, and can be defined within a predictive processing framework as prediction errors (Zacks et al., 2007). That our modelling work converged on a similar basis of operation - salient events/event boundaries - as developed in the episodic memory literature demonstrates the potential of our computational approach to reconcile these two large fields of study under a common interpretation, informed by predictive processing. Can we predict what is remembered from continuous experience using our model of time perception? This is yet to be determined, though see https://doi.org/10.31234/osf.io/t6fkg for preliminary results.

5.2. Applications in machine learning

The ideas summarised here can also provide useful insights to the field of machine learning. First, having a principled way of defining event boundaries in natural time series (such as videos) which is motivated by neuroscience, could facilitate the unsupervised learning of latent representations in high-dimensional data. This is particularly useful for models that are designed for downstream tasks that require event detection, such as change point or anomaly detection, two open problems in the literature. Building on the theoretical framework in (Fountas et al., 2022), and deep hierarchical generative models, Zakharov et al. (Zakharov et al., 2022) proposed a neural probabilistic inference architecture that is able to organise latent representations of video features in a temporarily-nested hierarchy, based on their rates of change, thus modelling continuous data as a hierarchical renewal (event-based) process. According to this model, any change in latent representations is an event boundary, including both anticipated and surprising changes.

In addition, having the ability to model state transitions over a *subjective* timescale of an agent, which updates only in the presence of perceived events, is a unique feature for model-based reinforcement learning, where long-term credit assignment is one of the major challenges (Sutton & Barto, 2018). Zakharov and colleagues explored this idea and defined a partially-observable Markov decision process where state transitions occur only between surprising states (Zakharov et al., 2021). The resulting model was superior in a variety of tasks to state of the art agents that relied instead on objective timescales.

6. Conclusions

Time perception, fundamental to human experience, has traditionally been explained by appealing to inner 'clocks' that attempt to track physical, objective time. We have described a programme of work which challenges this traditional view, showing - using a combination of behavioural, computational, and neuroimaging approaches - that accumulated salient change in perceptual processing provides a sufficient basis for human subjective duration estimation. There are no inner clocks in our model, nor any need for such a hypothesis. What we offer instead is a mechanism for time perception which naturally extends into a more general model of perceptual and cognitive processing, based on predictive processing. Future applications of our work will include more detailed modelling of episodic memory formation and recall, event segmentation, and improved algorithms with applications in machine learning.

Acknowledgements

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PALESTRAS

LECTURES

THE PHYSICS OF TIME: CURRENT KNOWLEDGE AND UNANSWERED CHALLENGES

Orfeu Bertolami *

Abstract

In contemporary physics space and time are intertwined entities so that kinematical and dynamical quantities are expressed in the four--dimensional space-time. This formulation seems to contradict our every--day experience and perception according to which space and time are distinct entities. In this brief report we shall discuss these apparently antagonist views and analyse the underlying physical property of time, namely that it evolves from the past to the present, from the present to the future.

...
Time passed, turning everything to ice.
Under the ice, the future stirred.
If you fell into it, you died.

It was a time
of waiting, of suspended action.

I lived in the present, which was
that part of the future you could see.
The past floated above my head,
like the sun and moon, visible but never reachable.

It was a time
governed by contradictions, as in
I felt nothing and
I was afraid.
...
in Averno (2006)
Louise Glück

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1. Introduction

According to the Big-Bang theory, the origin of the Universe is, in fact, the process of creation ofmatter, space and time. Despite its modernity and sophistication, the science that describes this extraordinary event, shares the idea of a primordial beginning with the very first manifestations of rational thinking of distinct civilisations, the so-called myths of creation (see, for instance[1, 2] for extensive discussions). The earliest forms of philosophical thinking, have invariably regarded space and time as essential features of reality, even though quite distinct ones.

Indeed, at first glance, space and time seem to be quite different. Space can be freely experienced as one can move in any direction without restriction. Time however, has a well defineddirection. Past and future are clearly distinct as our actions can affect only the latter. We have memory, but not precognition. Matter, organic or otherwise, eventually decay ceaselessly rather than getting itself organised. As far as we can detect through our most powerful microscopes, the particle accelerators, the fabric of space-time is made of at least three distinct spatial dimensions and only one time dimension[1].

Actually, in physics, time allows for describing the evolution and transformation of systems and processes in a very convenient way, being for this reason an “invisible” or “hidden” dimension. Despite of that, time is similar to space, as both have always been thought as the arena of all manifestations of Nature. Everything lies in space, as well as in time, and the intrinsic and fundamental relationships between the most basic elements of all physical entities could be decomposed into points, straight lines and geometrical figures in two or three dimensions and whose properties were remarkably systematised by Euclid (ca. 330 - 275 B.C.) geometry. These relationships would in turn reveal the intrinsic properties of space itself. These geometrical properties are shared by time with the unification of space and time proposed by Hermann Minkowski [4] in 1908, inspired by Einstein’s Theory of Special Relativity (for a

[1] Notice that if the number of time dimensions were greater than one, one would encounter all types of complications as, on quite general grounds, the Partial Differential Equations that describe the physical phenomena would be ultra-hyperbolic, leading to unpredictability, or to backward causality (see e.g. Ref. [3] for a discussion).

discussion see, for instance, [5, 6]).

On the other hand, by any account, time is a mysterious ingredient of the Universe and has been the subject of continuous philosophical debate over the centuries (we refer the interest reader to the brief discussion in Ref. [5]). Time is intuitively related to change, and it is subjectively perceived as a permeating entity that flows. This view can be traced back as far as to Aristotle (384 BC - 322 BC), who regarded "time as the measure of change". Throughout history, one encounters a wide range of reflections and considerations about the nature of time. For many civilisations, cycles in Nature, were an evidence of the circular and repetitive pattern of time. It was only in the 17th century that Francis Bacon (1561 - 1626) posed the concept of linear time, and through the influence of Newton (1643 - 1727), Barrow (1630 - 1677), Leibniz (1646 - 1716), Locke (1632 - 1704) and Kant (1724 - 1804) amongst others, about the 19th century, the idea of a linear time evolution was the dominant one in science and philosophy (for discussions see, for instance, [2, 5, 7-12]). However, despite all evidence and arguments, for some physicists, Einstein being amongst the finest, the irreversible flow of time is no more than a "persistent illusion".

In what concerns its ontological nature, it is still a matter of debate whether time is a real fundamental quantity or, instead, a composite suitable parameter, like *temperature* to describe the physical laws (see, for instance, Ref. [13] for a discussion in the context of string theory) and to frame, in unequivocal terms, causation. Causation being, of course, a crucial feature not only in physics, but according to some philosophers, like David Hume (1711 - 1776), a fundamental element for the human understanding of reality. In fact, a relevant connection to physics arises here as the decomposition of human perception down to the physiology of nervous tissues, down to its chemistry and then down to the causal character of the physical laws, renders Hume's proposition quite plausible.

Back to physics, one could state that reflections about the nature of time were polarised by Newton's concept of absolute time, who assumed that time flowed at the same rate for all observers in the Universe [14]. For Newton, time and space were an infinitely large vessel, containing events, and existing independently of the latter. This picture was completely changedin 1905 by Albert Einstein (1879 - 1955), through the formulation of the Special Theory of Relativity, in the context of which it was shown, in particular, that time flows at different rates for different observers. Three years later, Hermann Minkowski (1879 - 1909) [4] suggested the unification of the time and space, giving rise to the notion of a fundamental four-dimensional entity, *space-time* mentioned above. The Relativity revolution was concluded in 1915 when Einstein put forward the Theory of General Relativity where it was shown that the *flat* space-time of Special Relativity is curved by energy-matter. Since then the discovery of new forms of energy-matter in physics has given rise to new space-time geometries (see, for instance, [3] and references therein).

The merging of space and time into the space-time concept is particularly relevant and useful for the physical description of any phenomena in Nature independently of the frame of reference used to parametrize change-evolution-transformation. It is interesting that this picture that is so attractive for physicists was strongly rejected, for instance, by the philosopher Henri Bergson (1859 - 1941). According to Bergson, intelligence and intellect can only have a clear idea of discontinuity and immobility, being thus unable to fully grasp life and to think about evolution. For Bergson, intellect tends to represent becoming as a series of states. Geometry and logic, as products of intelligence, must be verified against common sense. He believed that intelligence and the origin of material bodies are correlative and have evolved by reciprocal adaptation. For him, intellect is the power to distinguish different things. However, in reality, there are no separate solid things, only a continuous stream of becomings. Becoming leads to life when it is an ascendant movement, and to matter when it is a descendant one.

For Bergson, space and time are profoundly dissimilar. The intellect is associated with space, whilst instinct and intuition are connected with time. Space, a feature of matter, arises from a dissection of the flux which is really illusory, although useful in practice. Time, on the contrary, is the essential element of life. Mathematical time, according to Bergson, is actually a form of space, but the time, as the essence of life, is what he refers to as duration. Duration merges past and present into an organic whole, where there is mutual entanglement and succession with distinction. To an extensive account of the differences between Bergson's ideas and the ones pertaining physics and the debate with Einstein in 1922 in Paris, the reader is referred to the superb account by Jimena Canales [15] and to her talk at this Symposium.

In what follows we shall further delve in the two main issues related to time. The first one refers to its flow, which concerns the so-called arrows of time, associated to the fundamental and ubiquitous Second Law of Thermodynamics. The second one on whether the fabric of space-time admits reversible motion in time through closed time-like curves (CTCs) or the so-called "time machine solutions" of the field equations of General Relativity.

This brief account about the main physical features of time has the following outline: In Section 2, we discuss the issue of directionality of the time flow. In Section 3, we address the view of the time in Relativity, the CTCs and the ensued putative violations of causality. Finally in Section 4, we briefly discuss some particular issues such as the idea of *time crystals*, of a *Block Universe*, where all moments in past time still exist and not only the present, and the *specious present asymmetry*. Of course, this list is quite short and many other issues could be addressed, such as for instance, the putative connection among the various arrows of time and the problem of time in quantum gravity. They certainly deserve a discussion, however, given their technicality, we refer the interested reader to Ref. [6]. Finally in Section 5 we present our closing remarks.

2. Arrows of time

A fundamental feature of the nature of time concerns its flow. Modern physics describes phenomena through dynamical laws, from which the time evolution is determined after specifying a suitable set of initial conditions. The fundamental dynamical equations of classical and quantum physics are symmetric under a time reversal, i.e., mathematically, one could instead specify the final conditions and evolve the physical system back in time. The resulting would be indistinguishable from the one obtained by the usual procedure. However, in macroscopical phenomena, which are described by thermodynamics, as well as some instances in general relativity and quantum mechanics (at the measurement process), the evolution of the systems is essentially asymmetric in time.

This distinguishes past from future. In the context of the Second Law of Thermodynamics, which states that in an isolated system, *entropy*, a measure of microscopic disorder, is a strictly increasing function of state providing itself a direction for the flow of time. It is an interesting conjecture the one which the Second Law of Thermodynamics and the thermodynamical arrow of time follow from the initial conditions of the Universe, meaning that the flow of time is set by the expansion of the Universe and it would revert in case of contraction.

In fact, an intense discussion on the physics of macroscopic phenomena took place in the second half of XIX century, when Maxwell (1831 - 1879) and Boltzmann (1844 - 1906) became aware of the tension between the linear time evolution and the reversibility of the fundamental equations of motion and later on with the eternal recurrence of motion in the phase space (the composed space of positions and velocities of the particles), shown by Poincaré (1854 - 1912) in 1890.

Before that, in the 1870s, Boltzmann understood that getting an arrow of time out the mechanics of atoms was impossible without using averaging arguments. He eventually obtained in 1872 a time-asymmetric evolution equation, now referred to as Boltzmann's equation, whose solution was a single-particle time dependent distribution function of a set of molecules in a diluted gas. From this distribution function he got a time decreasing function of time, the so-called H-function, which he identified with minus the entropy, obtaining then a solution for the irreversibility problem at molecular level!

The persistent objections of influential opponents such as Ernest Mach (1838 - 1916) and Friedrich Ostwald (1853 - 1932), led Boltzmann into depression and eventually to his suicide in 5th September 1906 at the age of 62 at Duino, the seaside resort on the Adriatico coast nearby Trieste.

After Boltzmann's work, the irreversibility problem was revisited in 1907 by Paul Ehrenfest (1880 - 1933) and his wife, Tatyana Afanasyeva (1876 - 1964), who further developed Boltzmann's idea of averaging over a certain region of the phase space and showed that the averaged H--function would remain strictly decreasing in the thermodynamical limit.

In 1928, Wolfgang Pauli (1869 - 1958) when considering the problem of transitions in the context of quantum mechanical perturbation theory, showed that satisfying the Second Principle of Thermodynamics would require a *master equation*, which confirmed the conviction of Maxwell and Boltzmann that irreversibility should emerge from the procedure of inferring macroscopic behaviour out of microscopic physics.

More recently, Prigogine (1917 - 2003) and collaborators considered the radical proposal that irreversible behaviour should be already incorporated at the microscopic level (see e.g. Ref. [19] for a general discussion). However, this suggestion is not universally accepted.

Of course, besides understanding how the irreversible behaviour of macroscopic systems did arise from microphysics, physicists identified several phenomena whose behaviour exhibit an immutable flow from past to present, from present to future. The British astrophysicist and cosmologist Arthur Eddington (1882 - 1944) [16], coined the term "arrow of time" to refer to this evolutionary behaviour (see also Refs. [17, 18] for an updated discussion). Let us briefly describe and enumerate these phenomena:

1) The direction of the growth of the entropy in irreversible and dissipative macroscopic phenomena coincides with the flow of time.

2) The propagation of electromagnetic radiation, converging from the infinite to a source is not observed, even though this being a possible solution of the Maxwell's equations of the electromagnetic field.

3) The irreversible collapse of the wave function of a quantum system after the measurement process.

4) The exponential degradation in time of systems and the exponential growth of self-organised systems (for a sufficiently abundant supply of resources). The development of complex systems has led some authors to refer to this behaviour as "creative evolution", "arrow of life" or "physics of becoming" [8, 12, 19, 20].

5) The discovery of the CP-symmetry violation in the $K^0 - \bar{K}^0$ system due to weak interactions, allows for inferring from the CPT-theorem, a fundamental cornerstone of quantum field theory, that the T-symmetry is also violated[2] This means that there exists, at a fundamental level, an intrinsic irreversibility.

[2] C, denotes charge conjugation, tha is, article-antiparticle operation; P, denotes parity or mirror image operation; T, means time inversion operation. The CPT-theorem establishes that the result of these three operations together leave states unchanged in local quantum field theories.

It is relevant to point out that the breaking of the CP-symmetry and the violation of the baryon number[3] in an expanding Universe are conditions from which the observed baryon asymmetry of the universe (BAU) can be set up (see, for instance, Ref. [21]). An alternative route to explain the BAU is through the violation of the CPT-symmetry itself. This is possible in the context of string theory (see Ref. [22] and references therein).

6) Psychological time is obviously irreversible and historical. The past can be recognised, while the future is unknown. Presumably this can be related with the issue of causation. A fascinating question is how this fundamental feature of Nature has shaped, through Evolution, the structure of our brain, which is known to have a common cortical metrics for time, space and quantity [23].

7) Systems bound gravitationally exhibit the so-called gravito-thermal catastrophic behaviour [24], that is, their entropy grows as they contract, which in turn implies that their specific heat is negative. This feature is also shared by *black holes*, whose entropy is proportional to their horizon's area. This feature raises the extremely relevant question of determining whether the gravitational field should have an intrinsic entropy [25]. In fact, it has been recently proposed that an entropy should be assigned even to the vacuum [26].

On the largest scales, the expansion of the Universe, which is itself adiabatic, is a unique phenomenon, which was conjectured to be the master arrow of time from which all others should be subordinated via the putative entropy of the gravitational field [25].

3. Time in relativity

The conceptual standing of time in Relativity implies, at first, that it has the same status as space, even though their specific properties are somewhat different. The main consequence of Relativity is that it endows space-time with plastic features. In Special Relativity, it follows from its fundamental tenets that time in a moving frame of reference stretches with respect to the time in a frame of reference at rest. This means that

[3] The number that counts the content of quarks and anti-quarks of a given hadronic particle.

clocks in motion slow down with respect to clocks at rest. Under the same conditions, space contracts. These are purely kinematical effects and follow from the fundamental requirement that the laws of physics are invariant, or are said to be covariant, in whatever frame of reference that move with respect to each other at constant velocity. These frames of reference are called inertial frames.

In the General Theory of Relativity, the covariance of the laws of physics are generalised to frames of reference that are accelerated with respect to each other, that is, the General Theory concerns non-inertial frames of reference. Einstein first showed that these frames are *equivalent* to a gravitational field and this discovery allowed him to turn the General Theory into a theory of gravity. Furthermore, after reasoning that a light ray in an accelerated frame of reference would be seen by an observer at rest as following a curved trajectory, he concluded that the same would happen in the presence of a gravitational field. He went on to conclude that matter-energy curves space-time. It follows that in General Relativity the time flow is affected by gravitational fields.

Special and General Relativity are extremely successful theories from the experimental point of view. General Relativity, for instance, is very well established at Solar System level [27-29] and its predictions are multifold, ranging from the existence of black holes and gravitational radiation to cosmological descriptions, such as the Hot Big-Bang model, in the context of which space-time and matter were created about 13.7 thousand millions of years ago (for extensive discussions, see, for instance, Refs. [30-32]).

3.1. Closed time-like curves and the ensued menace of causality violation

As seen above, General Relativity admits a quite rich lore of conceptual and mathematical solutions. Among them one finds non-trivial geometries where time folds into itself and gives origin closed time-like curves (CTCs). These solutions potentially violate causality as they allow for an observer who travels along this type of curve to return to an event that coincides with the departure event giving origin to time travel paradoxes [33, 34]. Obviously, the arrow of time leads to a forward local flow of time, but globally an observer can, when travelling along a CTC, return to an event in the past.

The existence of CTCs implies paradoxes like the observer that kills an ancestor making his/her very existence impossible as well as the possibility of the flow of information from the future or from the present to the past. These violations of causality have also quite clear implications, for instance, to the issue of free-will.

A great number of solutions of Einstein's field equations contain CTCS, but there are two quite conspicuous types of solutions [35, 36]. Solutions with a tipping over of the light cones due to a rotation about a cylindrically symmetric axis [37-41]; and solutions that violate the energy conditions of General Relativity. The latter admit matter-energy distributions where local observers effectively measure negative energy densities. Although classical forms of matter do not allow for this behaviour, it is argued that quantum fields may admit this possibility. In fact, this condition can be relaxed in alternative theories of gravity (see, for instance, Refs. [42, 43]).

Furthermore one could admit the reverse procedure and consider geometries which could lead, after some simple manipulations, to CTCs [44-46]. These include the so-called traversable wormholes [47, 48], the warp drive [49-51], and the Krasnikov tube [52].

Let us briefly discuss the case *traversable wormholes*. A wormhole is essentially constituted by two mouths at different regions of spacetime connected by a tunnel or handle. Several types of manipulations can give origin to CTCs. The simplest one involves a single wormhole mouth, which is moving with respect to the other mouth so to create a time shift (cf. Special Relativity) without affecting the internal geometry of the wormhole [48]. More elaborate variations of this procedure can be envisaged [53].

3.2. Defusing the causality paradoxes

The existence of CTCs can potentially undo irreversible events at the expense of creating somewhat embarrassing violations of causality. If one keeps the metric nature of General Relativity, hence the only way to avoid these violations is through a veto to CTCs. These curves can be rejected on logical or physical grounds. The latter are obviously preferable. The following solutions have been proposed:

i) In Novikov's *Principle of Self-Consistency* [54], CTCs are admitted if self-consistent, that is, the usual causal structure might be broken, but the future can only influence without changing events in the past. This principle implies that solutions of the laws of physics that are locally admissible are those that are also globally self-consistent.

ii) Hawking's *Chronology Protection Conjecture* is based on the experimental evidence that "we have not been invaded by hordes of tourists from the future" [55]. The physical support for the conjecture lies on the observation that a relevant physical quantity, the renormalised quantum expectation of the stress-energy tensor diverges close to the CTC's. It is argued that the conjecture can be shown in the context of the quantum gravity theory, the theory that will presumably reconcile General Relativity to Quantum Mechanics. The typical scale of energy of this conjectured theory is about 10^{19} *GeV*, about fifteen orders of magnitude greater than the energy of the LHC collider at CERN in Geneva, Switzerland, concentrated at an extremely small region of space, about 10^{-35} *m*.

iii) It has been pointed out the CTCs arise in the limit of theories where sensible physical properties of matter break down [42, 56]. The generality of this situation for most of the solutions would render CTCs unphysical.

Thus, it is clear that the existence of CTCs is still the subject of discussion and the final answer cannot be known before a deeper understanding of quantum gravity. In fact we shall see that the matter of time travelling becomes particularly pressing when considering the idea of a Block Universe.

4. Some relevant open questions

Let us briefly discuss here some ideas about the nature of space-time that are still a matter of lively debate:

Time crystals

Time crystals are quantum mechanical systems in their lowest energy state that exhibit a periodic motion [57, 58], analogously to usual crystals that are a periodic repetition of atoms in space. Their existence are associated to a putative spontaneous breaking of discrete time translational symmetry, which is thought to be impossible in Quantum Mechanics. However, it is believed that evidence of time crystals has been found experimentally in many systems (see Ref. [59] for a review). A recent proposal suggests that time crystals are an emergent feature of phase-space noncommutative quantum mechanics [60].

Block universe

It is assumed that as time evolves, gone events no longer exist, meaning that as the future is not there yet, only the "present" is actual. An interesting alternative description of space-time is the so-called Block Universe, in which a preferred "present" is non-existent and past is equally present. Thus, all points in time are equally valid frames of reference and a specific instant that lies in the past or in the future is frame dependent. In principle, there is no logical contradiction in a space-time block like that, however even though observers can experience the subjective flow of time, a universal present is ruled out by Special Relativity where no simultaneity exists. Common sense and irreversible phenomena seem to contradict the possibility of a Block Universe. Indeed, we refer to Ref. [61] a consistent discussion on the objections to the Block Universe viewpoint.

It is evident that in a Block Universe, the causality paradoxes are particularly pressing and demand for a categoric answer about the existence of CTCs.

Specious present

The so-called "specious present", has been the subject of discussion in experimental psychology and philosophy for quite some time. Our perception of the present is such that is difficult, if not impossible, to precise the span of time it comprises. It is a well established fact that in our experience, objects are given to us as being of the present, but the part of time referred to by the data is a very different one in what it concerns past and future. The specious present has also been encountered in a completely independently way when dealing with the engineering problem of transmission of visual and audio information in a synchronised way.

In fact, experiments show that our brain copes well when a sensory delay between visual and audio information is smaller than 125 *ms* for present-past transmission, but is much shorter, about 45 *ms*, for present-future transmission (see, for instance, Ref. [62] for a discussion). How to interpret this time asymmetry? Does it reflect the fundamental causality discussed by the philosopher David Hume? Is it a consequence of Evolution, which causally wired our brain to cope with sensory data?

5. Conclusions

In this brief report we attempted to discuss in a self consistent way the nature of time and the most conspicuous implications related with various conceptions of this hidden and mysterious ingredient of the physical description. After a short discussion of some specific philosophical ideas about time, we spelled out how the description of macroscopic phenomena through the Second Law of Thermodynamics evolved so to allow us to understanding how irreversibility arises from microphysics, despite the symmetry of the fundamental evolution equations, classical and quantum, under time reversal. Indeed, in the context of Statistical Mechanics[4], it is assumed that the absolute deterministic behaviour is lost as the macroscopic description necessarily averages out the micro-properties of the systems.

We have then discussed how in the Relativity revolution the physical description suggested a merged space-time depiction of the events so to endow space-time with plastic properties. We also elucidated how it followed that time flows at different rates for observers in different frames of reference. As seen, this is radically different from the description according Newtonian physics, where time was assumed to flow at a constant rate for all observers. In the context of General Relativity, space-time is curved by matter-energy and the flow of time is dependent of the strength of the gravitational field. The space-time curvature leads to completely new phenomena such as black holes, gravitational waves and a great variety of cosmological spaces, including the one with a Big Bang, which about 13.7 thousand millions years ago, gave origin to matter and space-time itself.

[4] The branch of physics that describes microphysics and its matching to the macroscopic description achieved through the Laws of Thermodynamics.

General Relativity also admits solutions of its field equations in which time folds into itself, giving origin to CTCs. This surprising possibility can lead, as discussed, to causality paradoxes. We have then presented some putative solutions to these embarrassing paradoxes. Even though, these solutions seem quite sensible as they clearly do the job of protecting causality, presumably, a definite answer about the existence of CTCs requires an encompassing theory of quantum gravity.

Finally, we have closed our report with some brief discussions about topics that are intimately related with the nature of time and how it is perceived, namely, time crystals, the Block Universe proposal and the question about how our brain processes sensorial information, the specious present question, and its well established temporal asymmetry.

As a closing remark we could say that any attempt to encompass all aspects of the problem of time is bound to fail. This author was well aware of this essential limitation and pursued no more than to present, through some broad strokes, a brief account on how physicists approach the fundamental problem of time. The concept of time is at the very heart of the epistemological questions associated with the physical description of phenomena, both at macroscopic and at microscopic scales. However, this is necessarily a partial view of the matter. The ubiquity of time in any form of articulate thinking puts it conceptually at the very heart of any discussion about consciousness and its emergence at biological, physical and philosophical levels. Time, being the History of everything is the horizon of all forms of thinking. The sought for an explanation about the most essential nature of time can only lead us to the source of new questions.

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THE TROUBLE WITH EINSTEIN'S TIME

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Abstract

Debates about time have left "a hole at the heart of physics" (Scientific American, Sept 2002) from which the discipline has yet to recover. The main problem is usually traced to Einstein's theory of relativity, to the notion of a "block universe," and to his famous claim that "the distinction between the past, present and future is only a stubbornly persistent illusion." While some scientists have tried to incorporate elements of our experience of time into our explanations of the universe, others continue to claim that our sense of time is simply illusory. Can these debates be solved by science alone or are they inescapably philosophical, historical and cultural? My talk will explore the origins of this persistent quandary by focusing on the relation of physics to philosophy, history and the humanities.

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RETROCAUSATION AND PRECOGNITION: TAKING TIME SERIOUSLY

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The phenomenon of time has come under unprecedented scrutiny over the last two decades, led largely by advances in quantum physics. Many of its mysteries are related to another phenomenon: consciousness. In this lecture, we examine how each might inform the other in new ways by considering the inherent time symmetry presented in the formalism of physics. In particular, we assert that precognition is likely a manifestation of quantum retrocausation, the reverse of standard causation. This suggests that some facets of the mind or consciousness are quantum in nature.

1. Introduction

Since physics began as a distinct discipline roughly 350 years ago, the quantity called *time* has been the foremost parameter by which change is described. Most important equations in physics utilize this parameter either explicitly or implicitly. In classical mechanics, one has Newton's ubiquitous second law:

$$\mathscr{F} = \frac{dp}{dt} = m\,\frac{d^2x}{dt^2} \tag{1}$$

or, more elegantly, Hamiliton's principle:

$$\delta\mathcal{S} = \int_{t_i}^{t_f} \mathscr{L} dt\,. \tag{2}$$

Here $\mathscr{F}$ is force, $\boldsymbol{m}$ is momentum, $\mathcal{S}$ is action, $\mathscr{L}$ is the Lagrangian

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and, of course, t is time. The primary equation of non-relativistic quantum mechanics, the Schrödinger equation:

$$H\Psi = i\hbar \frac{d\Psi}{dt} \tag{3}$$

is also parameterized by time. (Here H is the Hamiltonian operator and Ψ is the wavefunction.) With relativistic quantum mechanics - the Dirac or Klein-Gordon equations - time is likewise evident. Time was so ubiquitous and useful that it was largely taken for granted, its lack of philosophical and physical underpinnings ignored. Now, however, despite - and perhaps because of - its centrality to physics, the concept and meaning of time are in crisis. Such crises often presage paradigm shifts.

Although time is physics's preferred parameter for describing change, it has long been understood that it is not absolutely required in most physical scenarios; that is, it can be parameterized away. For example, instead of describing the progression of a planet in its orbit as a function of time, it is equally valid to describe this progression simply in terms of angle along its orbital arc. In fact, for many problems, this is the preferred notation. In this sense, time is superfluous. It can be viewed as a generic stand-in for well-ordered correlations between physical parameters. Our attachment to it appears largely a matter of habit, hope, ignorance, and the fear of losing something familiar.

Problems associated with time run much deeper than this, however. One might say that Nature itself does not recognize it. Consider its application to quantum mechanics, which is presumed to undergird all of physical reality. In quantum theory, the average values of measured physical quantities, like energy, linear and angular momentum and spin, are called *expectation values*. In quantum formalism, these are calculated from the system's wavefunction (Ψ) using so-called *mathematical operators*, which are simply mathematical instructions that one can apply to a quantum wavefunction to obtain the value for the physical quantity (e.g., multiplying by a constant or taking a spatial derivative). For instance, the energy operator looks like this: $i\hbar\frac{\partial}{\partial t}$, where $\frac{\partial}{\partial t}$ is a time derivative. While most useful physical quantities have operators, meaning that one can interrogate a wavefunction and get a sensible answer to an inquiry, there are some physical quantities that don't have operators, which usually indicates that either Nature doesn't prioritize, doesn't care, or perhaps even hides them from the curious inquirer. One such quantity is *time*. Remarkably, there is no agreed upon operator for this key quantity. Thus, while you can ask an electron (via its wavefunction, Ψ) what its x-position by using the spatial operator (*x*), or ask it its energy with its time operator ($i\hbar\frac{\partial}{\partial t}$), or its linear momentum with its spatial derivative ($-i\hbar\frac{\partial}{\partial x}$), if you ask that electron what time it is, it will be silent - or maybe it'll just laugh at you. The most parsimonious interpretations of this reticence are that the quantum world doesn't prioritize time or, maybe, that time itself doesn't exist. If so, then what is *time* and how does it emerge?

Adding to these mysteries, there is an existential one that has yet to be adequately resolved: Why does time run forward, but not backward? As nonsensical as this question might seem, in fact, it lurks at the heart of the problem. Moreover, consciousness and some of its unique attributes, for instance, the potential for precognition may hold keys to them all.

This lecture is organized as follows. First, we briefly explore the subject of clocks and time duration, followed by the subject of time symmetry in physics, a remarkable feature in which both time-forward and time-reversed solutions to physical equations are both allowed and, to some degree, required. Second, we consider the issue of causation (the past determining the future by physical means) and its reverse, *retrocausation*, in which the future determines the past. Third, we introduce interpretations of quantum mechanics that not only admit the existence of retrocausation, but use it to more deeply and meaningfully describe the natural world. Fourth, we propose that precognition is a manifestation of retrocausation. Fifth, we speculate that is should be possible to mimic the human capacity for precognition with a physical device, a so-called *quantum oracle*. Lastly, we briefly discuss the quantum oracle for society at large.

2. Clocks and tocks

A first thing to realize is that *clocks don't actually measure time, they measure duration*, the temporal difference between events, be they ticks of a clock, the revolutions of the Earth, or the age of a star from birth to death. This might seem like a fine distinction, but it is critical. By analogy, the position of an object in perfectly empty space is indeterminate. Spatial position is determined only with respect to some coordinate system that is set up and the separation between objects is determined by some ruler system. Likewise in empty space - no clocks, rulers, or observers - time (and its duration) cannot be measured. From the posivitist standpoint, time would not exist.

The measured temporal duration between various events are observer dependent; that is, it depends on circumstances (e.g., velocity of the observer relative to the physical system being observed). As far as we know, there is no master clock for the universe. At best, one can have one's own clock. So, what is a clock? It is a device or process whose operation is trusted as being regular and predictable enough - sometimes a tall order - such that one can compare it to a system of interest and from it, measure a temporal duration between events. For example, the second was once defined as 1/86,400th of a terrestrial day - one rotation of our planet. This was eventually retired because it was imprecise. While the rotation rate of the Earth is fairly steady, it can be affected by a number of internal and external influences, for instance, by torques applied to it by the Sun and Moon, or by earthquakes that redistribute the mass of the planet so as to alter its moment of inertia[1].

It is our belief that *time*, at least as it is normally understood in physics, does not actually exist. Indeed, things happen - there are events - but there is no flow of time, no direction to it. If there is no time, then what is there? As far as we can determine, there are at least two things one can count on: (i) the occurrence of events; and (ii) an ordering of the events (at least within one's own lightcone). The duration between events is measured by some agreed-upon clock, but duration in the time forward direction and that in the time reversed direction is simply a matter of taste, not of substance.

3. Time reversal symmetry

Remarkably, physics itself has always *formally* held time-forward and time-reverse descriptions of the world in equipoise. The equations of physics seem to demand it. If one examines Newton's second law (Eq. (1)), for instance, notice that time appears in it as a square (dt^2). Time running forward corresponds to ($+t$) and time running backward corresponds to ($-t$). When squared, however, both $+t$ and $-t$ give the same equation (Eq. (1)). Newton's second law doesn't care whether time runs forward or backward - both are acceptable - so why should we?

Let's look at a concrete example of this. Consider the scenario in Figure 1 in which a ball is seen to be rolling in the middle of a hill in the present moment. Question: Is the ball in the middle of the hill now because it was at the top of the hill in the past or because it will be at the bottom of the hill in the future? The answer is: Yes.

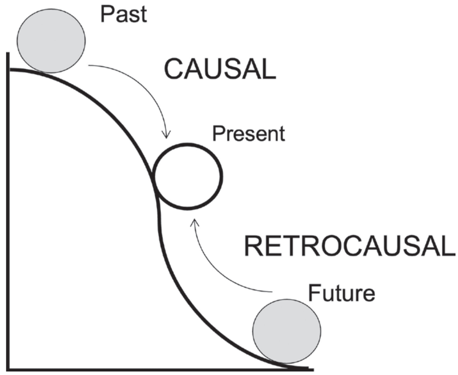

Figure 1. Time sequence of a ball rolling down hill, with past, present, and future labeled. The *present* state of the ball can be calculated from Newton's 2nd law either from past or future states (initial or final boundary conditions).

Let's unpack this. First, it wasn't specified whether the ball was rolling down the hill or up it. In fact, these two scenarios are just time inverses of each other. To verify this, imagine a film sequence of the ball rolling down the hill and then reverse the sequence: the ball rolls up. The ball rolling down or up the hill are both physically reasonable and it's simply a matter of how you look at the film sequence to conclude whether its rolling down or up. Without an outside observer (like you or I) looking at the film, both equally represent the situation. This *time-reversal symmetry* applies not only to this situation but to virtually all fundamental processes in the universe. (By *fundamental* we mean processes at the scale of molecular reactions, proton-proton collisions, and the spontaneous decay subatomic particles.)

At the atomic and subatomic level, Nature doesn't seem to care whether time runs forward or backward. But we care - a lot! And so does most of the rest of the universe that we live in on an everyday basis. For us, time seems to run in a single direction - what we'll call *time forward* - and we rarely, if ever, observe it running in *time reverse*. The reason for this temporal flow asymmetry is because the behavior of single molecules is not the same as the behavior of groups of molecules (e.g., a solid, liquid, or gas). This distinction is analogous to the difference between the behavior of a single person and the behavior of society as a whole. Once there are lots of molecules in play, a new law appears: the *second law of thermodynamics*. This protean law says many things, but one of them is that systems tend to become more complex, more disorganized as they develop. The effects of this law are seen everywhere: in a game of 52-card pick up, the shattering of a glass vase on a marble floor, the mixing of cream in coffee, the damping of sound, in most chemical reactions, through our living and ageing. It is the root of *irreversibility*, the tendency for processes to occur and then being impossible to completely undo. For instance, ink can be mixed into water by stirring with it with a spoon, but it can't be unmixed by stirring in reverse. It's a one-way process. This inescapable, inevitable, inexorable, unstoppable, relentless increase in disorder (entropy) is the root of irreversibility, and this gives directionality to the passage of time. Time continues to flow forward and backward at the molecular level, but at the macroscopic level involving lots of particles, the level at which we exist, this relentless increase of entropy makes it highly unlikely that reversed time flow can occur. Roughly speaking, once a system has maximized its entropy it settles down into a timeless state where nothing further happens at a macroscopic level (i.e., its temperature, pressure, and chemical composition become set). This is called *thermodynamic equilibrium*[2,3].

To summarize, for single particle phenomena, e.g., at the level of individual particles at the microscopic or macroscopic level (Figure 1), the direction of time is not apparent. For multi-particle systems that have not come to thermodynamic equilibrium, temporal flow has a preferred direction that is largely (if not exclusively) set in accord with the second law of thermodynamics.

4. Time symmetry in the quantum world

Both the fundamental equations of quantum mechanics and classical mechanics are time symmetric, that is, they both admit time-forward and time-reversed solutions. For microscopic process, there is no harm - and much benefit - in retaining both kinds of solutions, but at the everyday, macroscopic level time-forward solutions dominate.

The *formalism* of a scientific field - the mathematical machinery used by practitioners - is usually agreed upon and usually presents just mathematical difficulties. The *interpretation* of the formalism, however - the meaning of the mathematics - is often problematic and controversial. This might seem odd, but mathematics is a set of logical propositions and its symbols do not have intrinsic physical meaning. When physics employs mathematics, it imposes definitions on symbols and physical relationships between them. There's the rub. This becomes especially thorny with the subject of time.

Putting aside for the moment the question of whether time even *exists* in a physical sense, let's consider the simple issue of whether to consider both time-forward (causal) and time-reversed (retrocausal) solutions to its fundamental equations (i.e., Schrödinger, Dirac, Klein-Gordon). For most of the dozen or more *interpretations* of quantum theory, time--reversed solutions are allowed but are usually either ignored or eschewed. There are several interpretations, however, most notably the Two-State Vector Formalism (TSVF) and the Transactional Interpretation (TI), that explicitly include both advanced (time-reversed) solutions and retarded (time-forward) solutions to achieve their ends. In our view, they *take time seriously*.

Taking time symmetry seriously garners several advantages over standard, unidirectional interpretations. Much of the mystery and mystique surrounding quantum mechanics is grounded in its non-intuitive description of reality and the many paradoxes that have haunted it since its early days, e.g., Einstein-Podolsky-Rosen, Schrödinger's cat, Wheeler's delayed choice experiment, Einstein's bubble, Wigner's friend, interaction-free measurements. John Cramer, the developer of the Transactional Interpretation, demonstrates that most of the major paradoxes that have plagued quantum theory over the last 90 years can be easily resolved by assuming time-symmetric interactions between particles[4,5]. Interpretational mysteries are also clarified, including an easy shift from the Copenhagen epistemic wavefunction to an ontologically real one. TI also allows for an easy derivation of the Born rule, which had been largely ad hoc. R.I. Sutherland[6] identifies a number of ontological and epistemic advantages, including: (i) restoring locality to entangled states; (ii) preserving ontological consistency with special relativity; (iii) allowing replacement of multi-particle wavefunctions with individual ones; (iv) replacing statistical descriptions of wavefunctions by definite, ontological ones; and (v) facilitating Lagrangian formulation of quantum theory.

In our view, the majority of the so-called interpretational problems of quantum theory are largely resolved and a more solid and satisfying ontological description of the quantum world is purchased for a pittance: simply acknowledging and taking seriously the advanced (retrocausal) solutions that the mathematics offers (even demands). It's an offer that should not be refused.

While time-reversed (retrocausal) effects are often indistinguishable from time-forward (causal) ones at the microscopic level and, therefore, acceptable, once systems contain sufficient numbers of particles that the second law takes hold and the system becomes classical in nature, retrocausal effects tend to disappear. But there are exceptions to this.

5. Precognition and retrocausation

Perhaps the most arresting evidence for retrocausation at the classical, macroscopic level is the phenomenon of precognition (e.g., presentiment, remote viewing, premonitions). Over the last 50 years, controlled experiments have demonstrated with high statistical significance the access to future information by precognitive individuals (e.g., Radin[7];

May[8]; Bem[9]). The literature is too vast to explore here so we will focus on one of the more remarkable studies, the Graff-Cyrus (GC) experiment (2016)[10].

In the GC experiment, thirty-three psi investigations were performed using photographic material that did not exist at the time of the psi sessions. The percipients used both conscious and dream state methods of perception to access the future target information. Results would provide evidence for retrocausation if the future photographs had influenced the sessions' data.

The psi targets were Associated Press (AP) news photographs published in the Reading Eagle, Pennsylvania newspaper on a specific page three days in the future. These photographs were taken one day after the psi sessions. Following each psi session, and prior to the photograph's existence, perceptions were recorded in project records and email transmitted for date validation. Feedback was provided when the photograph was published.

All data were evaluated by an independent judge comparing the psi sessions to the intended photographs using numerical assessment scales and noting unique features. Data from 21 of the 33 sessions (64%) yielded sketches and narratives with medium to high degrees of correlations with the future news photographs.

Figure 2 provides an example of results from a typical high-data correlation session. The remote viewing sketch and description of the photo of the ship bombing are unmistakable. These results, as well as those from many other sessions, indicate that information in the future can be accessed in the present. Many theories have been advanced for this phenomenon, many of them either philosophically dualistic or idealistic in nature. We believe that these results might be explained in part (or entirely) within the physicalist/materialist worldview and standard paradigm of physics.

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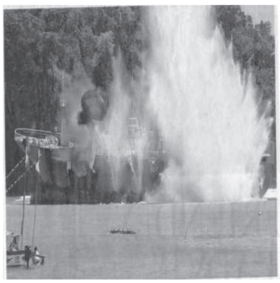
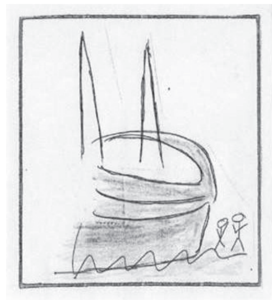
Curving Metal, Large Boat, Shipwreck





Target Photograph
Indonesian Ship Bombing

Remote Viewing Sketch

Figure 2. Graff-Cyrus Experiment - Remote Viewing Session: Indonesian ship bombing. Left: Photograph published by Reading Eagle newspaper on Tuesday (15th March 2016) of bombing of ship in Indonesia on Monday (14th March 2016). Right: Sketch and description of event recorded by percipient on Saturday (12th March 2016).

A preliminary model for precognition can be built using the Transactional Interpretation of quantum mechanics, as depicted in Figure 3. In this spacetime diagram, time runs vertically from past to present to future. Advanced and retarded waves are traded between a future and present version of the percipient. When a transaction is completed, a precognitive event occurs.

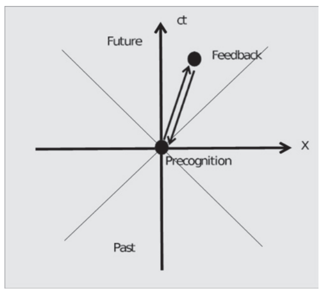


Figure 3. Space-time diagram for precognition in the TI interpretation of quantum theory.

We believe that the existence of remote viewing is the best current experimental evidence of quantum-based retrocausal behavior in the classical, macroscopic world. Because the second law of thermodynamics and classical particle behavior do not admit information exchange backward through time, this leaves remote viewing (pre-cognition) as a quantum phenomenon. In turn, this implies that there is some aspect of the mind or consciousness that is quantum mechanical in nature. (Of course, if one resorts to dualism or idealism, then precognition might become less problematic, though it would no longer be physical, and therefore, would be outside the purview of traditional science.)

If the mind/consciousness is quantum in nature, then it is plausible that quantum behavior should be found in other biological phenomena. Indeed, quantum processes - beyond those of standard chemical reactions - have been explored. Photosynthesis, for example, appears to utilize processes akin to Grover's quantum search algorithm to find the most expeditious route for energy transfer through photosynthetic molecular complexes. Quantum entanglement between electron radical pairs in the molecule cryptochrome has been proposed as a mechanism for magnetoreception in birds and other animals. It has been proposed that the quantum vibrational frequencies of molecules can be sensed by olfactory proteins, contributing to the sense of smell. Truly quantum processes like tunneling are implicated in vision, DNA mutation, and enzymatic activity. Penrose and Hameroff have proposed that gravitation-assisted quantum collapse in microtubules might underlie the phenomenon of consciousness.

Although these quantum biological phenomena are intriguing and significant, all except the latter are intrinsically microscopic in nature. Insofar as precognition (remote viewing) involves the mind and consciousness and, assuming these features are distributed in the brain, this indicates that precognition is a macroscopic quantum process. Indeed, it might involve the activation of a small set of neural circuits in order to precognitively conjure a smell or vision, but even then this would involve billions of atoms per neuron. The Penrose-Hameroff scenario might applicable here.

In recent years we have been exploring the connections between precognition, the second law of thermodynamics and time-symmetric quantum mechanics with a theoretical framework called the *thermodynamic retrocausal* (TDRC) model of precognition[11]. Among its predictions are: (a) under suitable quantum-thermodynamic conditions, future events can affect past ones; (b) precognition should be found across the animal kingdom, perhaps down even to the microbial level; and (c) precognition should be demonstrable by inanimate, non-sentient systems (e.g., complex quantum circuits). Regarding (a), some well-accepted quantum experiments have already been interpreted in terms of retrocausation, perhaps the most famous of which is the Wheeler delayed choice experiment. Regarding (b), animal experiments have indicated precognition. And, regarding (c), it has been proposed by G. Castagnoli that the computational speed associated with quantum computers is due to the time-forward and time-reversed signals operating simultaneously to achieve solutions.

6. Quantum oracle

One of the most exciting potential applications for retrocausation is a so-called *quantum oracle*, a physical device that transmits information from the future into the past in a controlled way. The key qualifier here is *controlled*. After all, if one takes time seriously in the physical sense, then the future is just as connected and influential to the present as is the past, but its effects are simply not as evident because its effects are uncontrolled and are hidden behind the veil of the second law. A quantum oracle would pierce this veil.

It is not known what a quantum oracle would look like. However, insofar as conscious (and perhaps even unconscious) creatures appear to be capable of oracle-like behaviors via precognition, a good starting model might be something akin to neuron circuitry. Also, since theory indicates that quantum computing relies on retrocausal behavior for its computational speed-up, a fruitful avenue of research might be a hybrid of the two.

In TDRC model of precognition, an oracle might consist of a highly complex quantum circuit, let's say something like a random number generator that creates a 25-digit string of random numbers every microsecond. The circuit is not a classical electronic circuit, but one which has a global wavefunction with a relatively long quantum coherence time. It is self-powered and is sufficiently complex that its wavefunction is effectively unique in the universe.

This uniqueness feature is critical. (It also mirrors the uniqueness of neural circuits in the brain: no two brains are the same and even a small neural circuit, with all its connections and microtubule cytostructures are probably unique in the entire universe.) In the Transactional Interpretation, when the unique quantum circuit undergoes a change and radiates an advanced wave into the past, there is no other wavefunction in the universe that can accept the wave except the wavefunction itself, in a past time (Figure 3). A connection might be established then between the future wavefunction and a past version of itself. This might be a primitive example of machine precognition.

This hypothesis could be tested. If the quantum circuit is fed a 25-digit random number in the future and if the circuit transmits this number to itself in the past (e.g., the present), then that 25-digit number would appear in the present. If the number is truly random, then the probability that the future and present number match would be one chance in 10^{25}. Even if the present device generated 10^6 numbers per second for 30 years, the probability that it would accidentally generate that unique 25-digit random number from the future would be only one chance in 10^{10}. Just as presentiment and remote viewing experiments rely on probabilities to make their cases, so too would the quantum oracle.

Quantum physics, biology, and computation, neurophysics and neuroscience have advanced sufficiently in the last decade to make the quantum oracle an enticing research topic. On 20th-22nd July 2022, the University of San Diego hosted the conference *Quantum Time Machines: Design and Development*. This international meeting was the first to consider and take seriously the possibility of building a quantum informational time machine, a device that sends information from the future into the past. These are the first, halting steps toward bring the future alive. Of its fruits, only time will tell.

7. Future of the quantum oracle

A working quantum oracle would likely revolutionize science, spirituality, and technology. It would open the previously-hidden timescape of the future and allow physicists to explore more deeply the physical phenomenon of time. Fundamental questions might be addressed. What are the physical relationships between the past, present, and future? Is the future malleable? Is the past likewise malleable? How much can the present be changed by the future? Under what circumstances and to what degree can the future be changed by getting advanced signals from it? How are the various arrows of time affected by advanced information? The fields of thermodynamics, quantum physics, and general relativity would be especially affected.

Insofar as precognition is a manifestation of retrocausation, the fields of neuroscience, quantum biology, psychology, and neurophysics would be interested. Is the mind truly quantum in nature? What does this say about consciousness? Is consciousness nonlocal? From here many spiritual questions arise.

In terms of technology, a quantum oracle could be a boon. Just as knowledge of the past is mined to improve the present - in fact, one of the central pillars of civilization is *memory*, the ability to tap knowledge of the past - likewise, knowledge of the future might also be mined. For instance, the next pandemic or natural disaster might be anticipated and planned for. One might intervene before medical conditions become serious (e.g., heart attacks). The process of intellectual discovery and invention might be accelerated. Invention almost always relies on past experiences and information to achieve creation in the present. Might the reverse might also be possible, i.e., information from the future being used to create in the present? By accessing the other direction of time (the future), entirely new intellectual vistas would be opened.

Many high-profile human activities depend on predicting and protecting a preferred future, for example, financial investing, national intelligence gathering, and warfare. Almost certainly, the quantum oracle would be turned to these enterprises because they impinge on societal welfare, power, and wealth. Is it better not to know the future? Perhaps. But every technology is a double-edged sword, capable of good or evil, depending on its application. The quantum oracle would be no different.

We predict that oracle technology - if it is indeed possible - will be developed slowly, hopefully slowly enough that its best applications might be accentuated and its worst pitfalls avoided. As creatures of the second law, our own lives have a one-way course to the grave, but this does not mean that our journeys cannot sometimes catches glimpses of the future and, thereby, be made brighter. This is our hope.

Acknowledgements

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[1] The 9.0 magnitude Tohoku earthquake in Japan in 2011 shortened the day by 1.8 microseconds by rearranging the Earth's crust and reducing its moment of inertia. Of course, tidal actions between the Earth and Moon lengthen the Earth's day by roughly 10 microseconds/year.) At present, the second is defined by international agreement as 9,192,631,770 periods of light radiation from the transition of two hyperfine levels of a particular isotope of cesium (Cs-133).

[2] Over the last 25 years, theory and experiment have shown that under certain circumstances the second law of thermodynamics can be bent or broken. This result will not bear heavily on the primary ideas of this lecture and, therefore, will not be pursued further here.

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THE MANY-FACETED ENIGMA OF TIME: A PHYSICIST'S PERSPECTIVE

Bernard Carr *

Introduction

The problem of time is essentially interdisciplinary, involving an overlap between physics, psychology, neuroscience, philosophy and theology. In all these domains, it represents an enigma, as indicated by the following quotes. Feynman (physicist): "We physicists work with time every day but don't ask me what it is. It is too difficult." Whitehead (philosopher): "It is impossible to meditate on time without overwhelming emotion at the limitation of human intelligence." St Augustine (theologian): "What is time? If no one asks me, I know. If I wish to explain it to one that asked, I know not."

In this talk I will be speaking in my capacity as a physicist, but I will also emphasize that physics may need to expand to address issues usually regarded as being in the other domains. Part I will describe the mainstream physics view of time, as it arises in Newtonian theory, relativity theory and quantum theory. I will also discuss the various arrows of time and the (less understood) role of time in quantum cosmology, quantum gravity and higher-dimensional models. Part II will address the most challenging enigma - the passage of time associated with consciousness. I will argue that this goes beyond both relativity theory and quantum theory, so that one needs some new physical paradigm to accommodate it. I present my own (very speculative) proposal for such a paradigm, this invoking higher dimensions and touching upon other controversial topics covered at this meeting.

Various books have influenced me in preparing this talk. As regards the role of time in physics, three important ones are *The End of Time* (Barbour 2001), *From Eternity to Here* (Carroll 2010) and *Time Reborn*

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(Smolin 2013). None of these mentions consciousness but this topic is covered in more recent books, such as *The Singular Universe and the Reality of Time* (Unger & Smolin 2015), *What Makes Time Special* (Callender 2017) and *The Order of Time* (Rovelli 2018). The link with philosophy is described in *Time's Arrow and the Archimedes' Point* (Price 1996) and the link with neuroscience in *Your Brain is a Time Machine* (Buonomano 2017).

Part 1: Mainstream physics perspective

The measurement of time

All clocks depends on the laws of physics, so development in physics have led to ever more accurate time pieces. The first ones - water clocks (3000 BC) and sundials (1500 BC) - depended on very simple physical laws. Later ones - mechanical clocks (1300), portable spring clocks (1450) and pendulum clocks (1657) - depended on more technical laws. The degree of precision culminated with Harrison's sea clock (1735), developed to measure longitude, and mass-production soon gave rise to shelf clocks (1807) and miniaturized watches (1854). Developments in atomic physics then led to quartz clocks (1928) and cesium clocks (1948). The dates (in parentheses) are taken from Whitrow (1972). Strontium atomic clocks have now reached an accuracy 10^{-18}, so time can be measured more accurately than space. There are also natural clocks resulting from radioactive decay and these cover a huge range of time scales: uranium-lead dating of rocks (4.6 billion to 1 million years), potassium-argon dating of clays (4 billion to 100,000 years), uranium-thorium dating of corals and fossilized bones (700,000 to 10,000 years), and carbon-14 dating of organic remains (100,000 to 10,000 years).

Time in classical physics

The arena of Newtonian physics is 3-dimensional space and time, both of which are absolute (i.e. the same for all observers). Newton's paradigm is also mechanistic, in the sense that the future and past are implicit in present. This is emphasized by Pierre Laplace: "An intellect which at a certain moment would know all the forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies in the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes." So this was the start of a trend in physics for time (i.e. the present moment) to become incidental rather than fundamental.

The arena of Einstein's special relativity (SR) is 4-dimensional spacetime, with objects being described by worldlines. Photons travel at 45 degrees in a spacetime diagram, so the observer's visual field at any moment corresponds to part of his past light-cone. Time is still different from space, because the 4D distance in the time direction is imaginary in the mathematical sense, but there is no absolute present and moving clocks run slow. This is demonstrated by observations of cosmic ray muons. These travel at 0.9994c and decay in 2×10^{-6} s in their own frame, so should travel only 600m from the edge of the atmosphere. However, they decay in 0.06 s in the Earth's rest frame, which allows them to reach the ground. The time dilation effect also gives rise to the twin paradox, in which the twin who travels at high speed ages much less than one who stays still. There might appear to be a paradox because velocity is relative, so either twin might be regarded as moving, but it is the twin who accelerates and decelerates who is younger.

Time is more complicated in general relativity (GR) because spacetime is curved by gravity, which affects both space and time measurements. This means there are many individual times, with the duration experienced depending on the space-time path. Clocks run slow in a gravitational field, with objects falling to where time is slowed, and the longest duration is experienced by a freely-falling observer (e.g. an astronaut in orbit). For example, one's head ages more than one's feet by 300 nanosec in 80 years (because the gravitational field is smaller at a greater distance from the centre of the Earth) and someone living in bungalow for a year is a microsecond younger than someone living at the top of a skyscraper. The combination of the SR and GR effect on time has been tested by flying atomic clocks on planes (Hafele & Keating 1972): those going eastwards record 40 nanosec less than a clock on Earth because the speed effect wins; those going westwards record 273 nanosec more because the height effect wins.

Black holes and time travel

The effect of gravity on clocks is most pronounced for a black hole, a region formed when an object undergoes gravitational collapse and falls within its event horizon radius $R_{EH} = 2GM/c^2$ (just 3km for the Sun). Light can never escape from such a region because the light-cones tilt inwards inside this radius, with an 'outgoing' light-ray coinciding with the event horizon. Time stops at edge of a black hole, in the sense that an infalling astronaut appears to freeze there for an external observer. However, time continues to pass in the astronaut's own experience and he may see the whole future of our Universe while falling towards the central singularity.

The slowing down of time due to either SR or GR allows an astronaut to effectively travel into the future. Indeed, he can travel arbitrarily far into the future relative to someone on Earth by hovering close to black hole but not falling inside it. However, time travel into the past is more challenging. In SR it would require tachyons (i.e. objects moving faster than light), which is probably precluded. However, it may be possible in GR because of the existence of solutions with closed timelike curves (CTCs). For example, CTCs arise in a rotating universe (Godel 1949) or they can be generated by a rotating cylinder (Tipler 1974). One can also travel into the past through a wormhole (WH) - different from a black hole because there is no singularity - but only back to a time *after* it was created (Thorne 1994). It is not clear that this is physically realistic since one needs negative energy to hold the WH mouth open and the Chronology Protection Conjecture (Hawking 1992) suggests that time machines are excluded. However, this is not certain and WHs may have been created in early Universe.

Time in quantum theory

Quantum theory (QT) is associated with various enigmas (e.g. the two-slit experiment, Schrodinger's cat, the Uncertainty Principle, entanglement) and has various interpretations (e.g. the Copenhagen, Pilot Wave, Many Worlds and Transactional models). These are discussed by Sheehan and Cyrus (2022), so I will only focus on the issue of time here. Whereas time is fuzzy in GR, it is more Newtonian in QT - in the sense that one needs a preferred spatial hypersurface to explain entanglement - and space is fuzzy instead (corresponding to non-locality). Indeed, time may emerge from the irreversible interaction between the micro-quantum objects and the macro-classical objects that make measurements (Connes & Rovelli 1994). Entanglement may even *generate* time (Page & Wootters 1983). Since QT is limited to isolated systems, the existence of clocks and outside observers requires a deeper theory extendable to the whole Universe. As discussed later, there is also the issue of whether consciousness collapses the quantum wave function (Wigner 1967) and this relates to the nature of time at least indirectly.

Arrows of time and the big bang

There are many arrows of time, each corresponding to some form of past/future asymmetry: cause and effect, birth and death, the cosmic expansion, retarded rather than advanced radiation, quantum collapse. The puzzle is that the laws of fundamental physics are time-reversible apart from a tiny charge-parity (CP) violation. There is also the psychological arrow, associated with consciousness; this is more problematic than the others and will be addressed later. It is often argued that all these arrows arise from 2nd Law of Thermodynamics: entropy is always increasing because the environment is far from equilibrium. Eddington (1928) remarked: "If your pet theory of the Universe is in disagreement with Maxwell's theory, so much the worse for Maxwell's theory. If it is found to be contradicted by observations - well, these experimentalists do bungle things sometimes. But if your theory is found to be against the 2nd Law of Thermodynamics, I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

The most natural explanation for the increase of entropy is that the Universe began in a low-entropy state (the Past Hypothesis), although the reason for this is not well understood. Most cosmologists believe that the Universe began in a highly compressed state (termed the 'Big Bang') around 14 billion years ago, so this raises the issue of the origin of time. This is a topic of long-standing controversy. Aristotle thought there could be no beginning of time, whereas St Augustine argued that God created time with the Universe, but of course neither knew about the Big Bang. Until a few decades ago it was assumed that physics would break down at the Big Bang but recent developments in physics have changed this perspective, so this leads onto the next topic.

Time in quantum cosmology and quantum gravity

According to Hawking (1966), the Big Bang corresponds to a singularity of infinite density. Classical physics breaks down then, so one needs a theory of quantum cosmology (QC) to understand what happens to time. It is sometimes argued that there can be no time in QC because time requires an external observer and there is nothing outside the Universe. However, according to Hartle and Hawking (1983), time becomes imaginary (i.e. like space) at the Planck time (10^{-43}s after Big Bang), corresponding to what they term the 'No Boundary' proposal. Alternatively, the Universe may have undergone an earlier collapsing phase, corresponding to a 'Big Bounce', and one could even have a cyclic model with successive expansion and contraction phases (Tolman 1934).

QC also relates to quantum gravity (QG), which has important implications even when the density is finite. QG effects imply that space and time become granular rather than continuous on the Planck scales (10^{-33}cm or 10^{-43}s), corresponding to some form of spacetime foam (Wheeler 1955). This raises the question of whether space and time are fundamental in QG or just emergent features of the macroworld. There are different views on this, since there are many approaches to QG. Canonical QG implies there is no time (DeWitt 1967) but Causal Set Theory allows the passage of time for localized observers (Sorkin 1991). String Theory suggests the 'final' theory will be like QT (with space being fuzzy), whereas Loop Quantum Gravity suggests it will be like GR (with time being fuzzy). While this might seem the logical endpoint of the history of physics, this having progressively diminished the role of time, Smolin (2013) argues that it is real and a key to understanding QG. In his view, when physics is extended to the whole Universe, laws must emerge and evolve with Universe.

Time in higher dimensional theories

An understanding of all the forces which operate in the Universe suggests that there are extra 'internal' dimensions beyond the four of spacetime. This approach was pioneered in the 1920s with the suggestion that a fifth dimension can provide a unified description of gravity and electromagnetism (Kaluza 1921) if it is wrapped up on the Planck scale of 10^{-33}cm (Klein 1926). Subsequently, it was discovered that there are other subatomic interactions and recent unification theories suggest that these can be explained by invoking yet more wrapped-up dimensions, superstring theory suggesting there could be six (Green et al. 1987). There were originally five superstring theories but it was later realized that these are all parts of a single more embracing model called 'M-theory', which has seven extra dimensions (Witten 1995). These developments are illustrated in Figure 1(a).

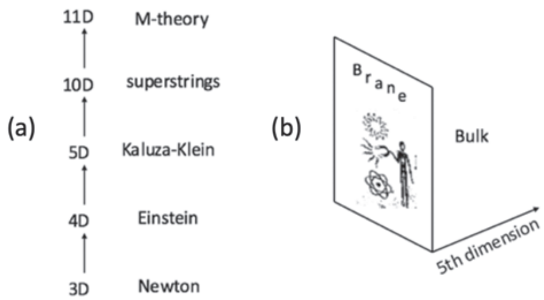

Figure 1. (a) Sequence of dimensional shifts entailed in the unification of physics. (b) The extra dimensions are often assumed to be compactified but one is extended in brane theory.

Although the extra dimensions are usually assumed to be compactified on the string scale (somewhat above the Planck scale), in some models they can be much larger (Arkani-Hamed et al. 2000) and in one variant the fifth dimension is extended, so that the physical world is viewed as a 4-dimensional 'brane' in a higher-dimensional 'bulk' (Randall & Sundrum 1999). This is illustrated in Figure 1(b). The extra dimensions are usually assumed to be spacelike but they may be timelike in some models and this has crucial implications for the discussion below.

Part 2: Extended physics perspective

Time and consciousness

Physics has been triumphant in explaining the multitude of structures in the material world, from the smallest scales of subatomic physics to the scale of the observable Universe. It has also explained and unified the forces which connect the micro and macro domains. Physicists even claim to be close to a 'Theory of Everything'. However, one might be sceptical of this claim when their model makes no reference to the most conspicuous aspect of the world - consciousness and the domain of mind. Indeed, despite the current interest in mindfulness, current physics might be regarded as depicting the triumph of mindlessness.

It is sometimes argued that consciousness and mental experiences are necessarily outside the domain of physics because they involve a 1st person rather than 3rd person perspective. Clearly this is true for classical mechanistic physics but this has now been superseded by the quantum physics and there are hints that consciousness may be important in this context - either because it collapses the wave-function (Stapp 1993) or because the collapse of the wave function generates consciousness via microtubules (Hameroff & Penrose 2014). However, this does not explain mentality, so one probably needs some deeper paradigm that underlies both consciousness and quantum theory. This may also describe the *flow* of time, which is related to the psychological arrow but deeper than a mere arrow (see below).

In considering whether some future paradigm of physics can accommodate consciousness, it must be stressed that the current paradigm is certainly incomplete, since we still need to amalgamate quantum theory and relativity theory and we cannot preclude this involving consciousness in some way. Penrose (1989) anticipates that "our present picture of physical reality is due for a grand shake-up, even greater, perhaps, than that provided by present-day relativity and quantum mechanics". Just as relativity theory links space and time, and quantum theory links matter and mind, perhaps there is also some unification of matter, mind, space and time, as illustrated in Figure 2.

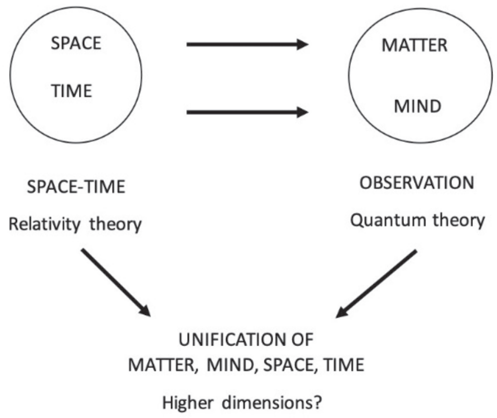

Figure 2. The amalgamation of space and time by relativity theory and of matter and mind by quantum theory suggests a deeper amalgamation of matter, mind, space and time.

My own approach to such a unification is based on the idea that many mental experiences involve some sort of space, albeit distinct from physical space (Carr 2015). The phenomenal space associated with normal physical perception is an obvious example of this and philosophers have long argued about its relationship to physical space (Russell 1948). The traditional view is that the percept is localised within the brain, so that phenomenal space is just an internal mapping of physical space, with a separate one for each observer. However, this results from the outdated view that the arena of reality is 3-dimensional space (S_3). According to relativity theory, the arena of reality is 4-dimensional (4D) spacetime (S_4), so perception is a 4D process, with the brain just being one end of a causal chain. So physical perception corresponds to a sort of extended mind (cf. Velmans 2005), in which conscious experience at any time is associated with the parts of spacetime linked to the brain through a causal nexus of signalling world-lines. The edge of the nexus corresponds to the past light-cone, since no signal can travel faster than light. This is represented in Figure 3(a) and termed the 'outlook tree' by Culbertson (1976).

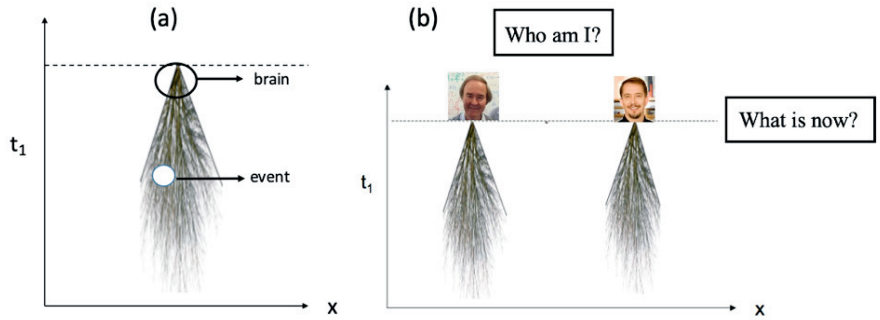

Figure 3. (a) 4D model in which phenomenal space is associated with the space-time region connected to the brain via a nexus of signalling world-lines. (b) Illustrating the link between the problem of identity and the problem of the passage of time.

Note that the nexus is very concentrated near the top because it also represents all the neuronal processes involved in perception. The mapping between physical and phenomenal space is therefore complicated and not just a geometrical projection. Also a more sophisticated 'informational' model would be required to accommodate qualia. This also has interesting implications for the nature of memory. The mainstream view is that memories are stored in the brain, but if percepts are not there, the same must apply to our memories of those percepts. Indeed, Figure 3(a) suggests that memories of physical events reflect the direct access of consciousness to the physical space-time which contains those events. In this case, the brain contains a *tag* rather than a *trace*.

This model raises two questions, both of which will be explored in subsequent sections. The first relates to the passage of time (*What is now?*) and the second to the problem of identity (*Who am I?*). As indicated in Figure 3(b), these questions are closely related. I will also argue that they both have a link with physics, although my proposal certainly does not represent the mainstream view of physicists.

The passage of time

A long-standing problem on the interface of physics and philosophy concerns the flow of time. The point is that relativity theory does not describe the basic experience of 'now' which is such an essential ingredient of our perceptual world. For in the 'block' universe of special relativity, past and present and future coexist. The 3D object is just the 'constant-time' cross-section of a 4D world-tube and we come across events as our field of consciousness sweeps through the block. However, nothing within the space-time picture describes this sweeping or identifies the particular moment at which we make our observations. So if one regards consciousness as moving along the world-line of the brain, like a bead on a wire, as illustrated in Figure 4(a), that motion itself cannot be described by relativity theory.

This is illustrated by two famous quotes. The first is from Weyl (1949): "The objective world *is*, it does not *happen*. Only to the gaze of my consciousness, crawling upward along the life-line of my body, does a section of this world come to life as a fleeting image in space which changes in time." The second is from Einstein's letter to the family of Michele Besso, shortly after his death in 1955: "Now he has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present and future is only stubbornly persistent illusion".

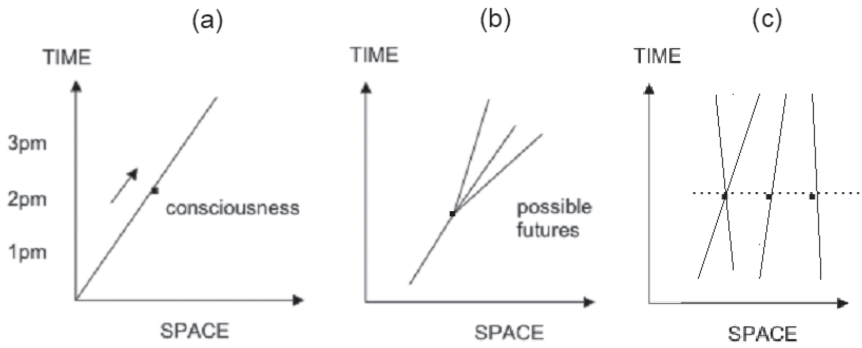

Figure 4. Three problems of consciousness from a relativistic perspective: (a) passage of time, (b) selection of possible futures, (c) coordination of time for spatially separated observers.

This also relates to the problem of free will. In a mechanistic Universe, a physical object (such as an observer's body) is usually assumed to have a well-defined future world-line. However, one intuitively imagines that at any particular experiential time there are a number of possible future world-lines, as illustrated in Figure 4(b), with the intervention of consciousness allowing the selection of one of these. The middle line in the figure shows the unchanged (mechanistic) future, while the other lines show two alternative (changed) futures. This view implies that the past is fixed but that the future is undetermined.

Thus there is a fundamental distinction between *physical* time (associated with relativity and the outer world) and *mental* time (associated with the experience of now and the inner world). Many people have made this point (Broad 1923, Eddington 1928, Brain 1960, Lockwood 1989) and it was the focus of a famous debate between Einstein and Bergson almost exactly a century ago (Canales 2019). Indeed, there is a huge philosophical literature on this topic and an ongoing controversy between the presentists and eternalists (Savitt 2006). Since the passage of time seems to give no extra *physical* information, many philosophers infer that this passage is unreal and just a feature of mind (McTaggart 1908, Putnam 1967, Price 1996). But some philosophers (e.g. Maudlin 2012) and physicists (e.g. Smolin 2013) still believe time is fundamental and this possibility is accentuated if the final theory of physics can accommodate consciousness.

Another question which arises is how the 'beads' of different observers are correlated. If two observers interact (i.e. if their worldlines cross), they must presumably be conscious at the same time (i.e. their 'beads' must traverse the intersection point together). However, what about observers whose worldlines do not intersect? Naively identifying contemporaneous beads by taking a constant time slice, as illustrated by the broken line in Figure 4(c), might appear to be inconsistent with SR, since this rejects the notion of simultaneity at different points in space. On the other hand, the notion of a preferred time is restored in GR because the large-scale structure of the Universe singles out a special 'cosmic time' measured by clocks comoving with the cosmic expansion. There are preferred spatial hypersurfaces with constant proper time since the Big Bang (Ellis 2006).

The failure of relativity to describe the passage of time process and different possible future world-lines may also relate to QT? This is because the collapse of the wave-function to one of a number of possible states entails a basic irreversibility. One way of resolving this is to invoke the 'many worlds' picture of Everett (1957), which is reminiscent of the representations in Figure 4(b). One also needs some concept of simultaneity at different points in space in QT? in order to describe the Einstein-Podolsky-Rosen (1935) paradox. The problem of reconciling relativity theory and quantum mechanics may thus connect to the problem of understanding consciousness.

5-Dimensional reality structure

One way of describing the passage of time - originally suggested by Broad (1923) - is to adopt a growing block universe model, together with a second type of time (t_2), or at least a higher dimension, with respect to which our motion through physical time (t_1) is measured. This is illustrated in Figure 5(a), which represents the progress of consciousness as a path in a 5-dimensional (5D) space. At any moment in t_2, a physical object will have either a unique future worldline (in a mechanistic model) or a number of possible worldlines (in a quantum model). The intervention of consciousness or quantum collapse allows the future worldline to change in the first case or to be selected from in the second case. Since the future is not predetermined in this model, there is an intrinsic difference between the past and the future (Earman 2008).

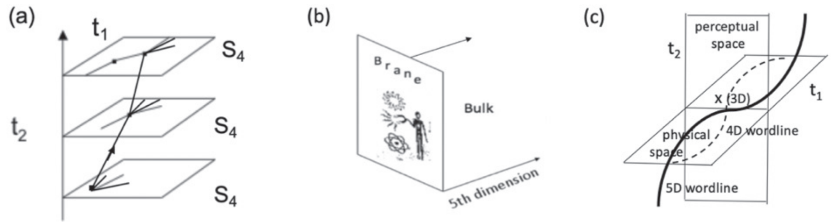

Figure 5. (a) Describing passage of time with a second time dimension. (b) Comparison with brane cosmology. (c) Depicting a unified 5D psychophysical space with 3D phenomenal and physical spaces having distinct times.

This interpretation of the flow of time may also be suggested by the Randall-Sundrum proposal that spacetime is a 4D brane embedded in a 5D bulk. In the simplest case, the brane corresponds to the flat spacetime of SR. However, there is a cosmological version of this picture - called 'brane cosmology' - in which the brane is curved and space is expanding

(Maartens 2004). The cosmic expansion can then be interpreted as being generated by the brane's motion through the 5th dimension, as illustrated in Figure 5(b). This suggests that the 5th dimension could be identified with the extra dimension associated with the passage of time (Carr 2021), thereby using a cosmological model to resolve a long-standing philosophical problem. Several physicists have also invoked two-time models (e.g. Bars 2001, Craig & Weinstein 2009). In particular, Aharanov et al. (2013) have presented a 'two-time' view of quantum evolution, in which each moment of time is viewed as a new 'universe'.

As illustrated in Figure 5(c), the implication of this model is that a complete description of perception must involve a 5D 'psycho-physical' space, with physical space-time (x,t_1) and phenomenal space-time (x,t_2) being different slices of (x,t_1,t_2) space (cf. Smythies 1994). There are two features of this proposal: phenomenal space is *collective* rather just inside our heads; one needs a separate time dimension to describe mental experience. Needless to say, this is very different from the view of mainstream physics and philosophy.

The specious present

The invocation of a second time dimension, as represented in Figure 5, only generates a *global* flow of time and does not describe the sense of individual identity (or 1st person perspective). This is because the *experience* of time - and hence consciousness itself - only makes sense with respect to the specious present (SP), which is the minimum timescale of experience. I will argue that this feature must play a crucial role in understanding the passage of time, although this point seems to be neglected by both physics and philosophy.

This concept of the SP was introduced a long time ago (Kelly 1882) but can be understood in modern times as arising because our physical sensory systems have a resolution time of order 0.1 second, so that we cannot observe a process shorter than this (Hertzog et al. 2016). For example, if a light source moves in a circle around some central point faster than around 10 times per second, then one just sees a continuous circle of light rather than motion. So in some sense time becomes like space on too short a timescale. There is a similar effect for all perceptual processes, whatever the sense mode, and it has been suggested that consciousness itself is associated with a brain-scanning process of 40Hz, which corresponds to a time of 0.025 s (Gold 1999). There is also an *upper* limit to the timescales we can experience since our brains are not aware of changes that are too slow. The upper limit on the timescale for human consciousness cannot be specified as precisely as the lower limit. Since the apprehension of change depends on a comparison of systems at different times, it probably relates to the timescale associated with short-term memory, which is around 10^3 s.

Although the SP is well determined during the usual waking state and roughly the same for everyone, it may change in some circumstances, so that the flow of internal time appears to speed up or slow down relative to external time. For example, in a circus, the SP becomes shorter for a trapeze artist, so that external time slows down and he can catch his partner. On the other hand, it becomes longer for a balance artist, so that external time speeds up and he can hold his pose. The change may be more dramatic in some circumstances. For example, time may slow almost to a halt during an accident (so that external events appear to freeze) or speed up during a fever (so that the rising and setting of the sun appear as a flickering light at the window). Presumably such variations can be described by neuronal processes if the brain has some internal clock whose rate may change. Indeed, there is a huge neuroscientific literature on time perception and its variability (Eagleman 2005).

Some reported changes in the SP are much more dramatic (Wittmann 2018). For example, in a Near Death Experience (NDE) one may see one's whole life 'instantaneously', corresponding to a SP exceeding one's lifetime. In certain mystical states, the changes in the SP may be even more extreme, sometimes shrinking almost to zero, so that only the present moment exists, or expanding almost to infinity, so that the entire history of the cosmos appears instantaneously. Ed Kelly (personal communication) points out a similarity between the description of mystical experiences produced through the stages of *samādhi* characterized by Patañjali and an early anatomist twisting the focus knob on his microscope: "It's as though the meditator is adjusting the focal length of his hyperphysical sensors and encountering systematically different worlds depending on the settings achieved." These states are described by Taimni (1961). It is not clear that these more dramatic SP variations can be explained in neurological terms. Indeed, this may suggest that consciousness can be decoupled from the brain in some situations, implying that the brain is a *filter* rather than a *generator* of consciousness (Bergson 1946).

The fact that we only experience consciousness over a few decades of time (0.1 - 10^3 s) is similar to our only perceiving electromagnetic radiation over the narrow range of frequencies associated with visible light. This suggests that there could be other forms of consciousness in the Universe - not necessarily associated with brains and perceiving the world through organs sensitive to a different frequency range - with a very different SP from humans (Royce 1901). Indeed, since complex physical structures exist over a vast range of scales, it is conceivable that these could also be associated with consciousness (i.e. contain memories and an internal model of the world). For example, if computers develop consciousness, perhaps they would have a SP of order nanoseconds and maybe there are extraterrestrial life-forms with a SP of a thousand times our own. If so, we would have to speed up the recording of their communications a thousand times to listen into any 'conversation'.

The SP notion can also be applied to the parapsychological phenomena of interest to some participants at this meeting. Thouless and Wiesner (1947) argue that the focus of the mind is usually the brain but that processes they term 'psi-gamma' (receptive) and 'psi-kappa' (expressive) can act on surrounding penumbra in space and time. If so, it is natural to hypothesize that the SP gives the scale of the penumbra. Indeed, one might argue that ESP corresponds to an increase in the SP and PK to a decrease. There is also a link with closed timelike loops (since there is no distinction between past and future on a timescale less than the SP), so this relates to the model of precognition presented by Mossbridge (2022).

The nature of self

The notion of the SP is also relevant to the problem of personal identity. Since one's identity is defined by the sequence of unique perspectives of the set of events provided by one's brain (i.e. one's memories), it must be associated with the nexus of spacetime connections shown in Figure 3(a). Clearly myself and Etzel Cardena (my chair) have different nexuses but why am I associated with one particular nexus. To illustrate this, imagine that myself and Etzel were born at exactly the same time in neighbouring beds in the same maternity ward. Our neurons start to fire and we become conscious simultaneously. So why does *my* self become associated with Bernard's body rather than Etzel's?

This question is particularly pressing for the filter model of consciousness. This suggests that mind is a unitary phenomenon, in that "there is one mind common to all individual men…a universal mind" (Emerson 1983), and it differentiates between individual consciousness (small c) and the universal Consciousness (big C) which is being filtered. But this raises the question of how Consciousness can fragment into billions of consciousnesses and why I am associated with one particular fragment. Expanding the nexus to higher dimensions, as in Figure 5, explains why many I's can be aspects of a single I, because worldlines which are disconnected in a lower-dimensional space may be connected in a higher-dimensional one, but not why I am me.

Of course, mainstream scientists will reject this question - and the filter model - at the outset, since it presupposes that there is some form self which is different from the brain. But if consciousness is produced by the brain, there can be no me distinct from the brain. However, the question of identity arises in any theory of consciousness and it is precisely because it is meaningless from the mainstream perspective that I am led to reject that perspective. The existence of an extra time dimension is also relevant. For since physical time t_1 and mental time t_2 are different, what does it mean to say that Etzel and I are conscious at the *same* time? We may both be conscious with respect to external time but 1st personhood presumably relates to internal time.

In addressing this problem, it must be appreciated that there can be no memories on a time scale less than the SP or more than a human lifetime. This implies the dissolution of human identity on both long and short timescales. This also arises in the *spatial* context. For if one were to view an object either on the scale of the interatomic spacing or on such a large scale that it could not be resolved, there would be no indication of a single coherent structure.

It is conceivable that the SP also relates to the higher dimensions of physics. In standard M-theory the extra dimensions are spatial and compactified on around the Planck scale. However, in principle the compactification scale could be much larger and we have seen that one dimension is extended in brane cosmology. One could also consider a model in which the extra dimensions are compactified on a hierarchy of scales and one might even speculate that each dimension is associated with a specious present. One would then have a hierarchy of levels of consciousness, associated with a hierarchy of time dimensions. Of course, this proposal is clearly very speculative and does not represent mainstream physics.

Final words

The above discussion - even the speculations in Part II - have mainly focussed on time and mentality as they relate to the physical world (i.e. phenomenal space and memory). I have stressed that this requires a paradigm going beyond relativity theory and quantum theory. In particular, I have advocated a 5-dimensional model, with the extra dimension relating to mental time and the specious present also playing an important role. A similar proposal, involving both these features, has been made by Schooler (2015). However, there are other forms of mental space, both normal (visualization space, dream space) and paranormal (apparitions, OBEs, NDEs). I have argued elsewhere (Carr 2008) that these might also be identified with the higher dimensional space of physics. But this proposal goes beyond the present discussion and is even more speculative, in the sense that most physicists would not accept the reality of the phenomena. Nevertheless, this illustrates how physics might in principle be extended to accommodate mind and some of the anomalous phenomena of interest at this meeting. This does not depend on the validity of M-theory itself (M-theorists would clearly be uncomfortable with this association) but it does require some form of higher-dimensional model.

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PREDICTIVE ANTICIPATORY ACTIVITY: HOW DO BIOLOGICAL SYSTEMS PRE-SPOND TO FUTURE EVENTS? [1]

Julia Mossbridge [2]

Abstract

The rigorous scientific study of precognition, the human ability to accurately predict future events that are not predictable based on information about the past or from the five senses, spans the last 90 years. This summary describes different types of precognition, underscores the basic principles of precognition research, and discusses the evidence for and potential mechanisms of two very different forms of precognition - largely unconscious precognition with short lead times (e.g., presentiment) and largely conscious precognition with longer lead times (e.g., precognitive remote viewing).

Background

For centuries, the ancient and indigenous idea that we might be able to navigate life by obtaining information from the future has been intriguing to Western mystics and psychologists alike. For example, Rabbi Moses Luzzatto, an 18th century Italian mystic, spoke clearly about how he felt intuition (particularly prophetic intuition) and intellect were related. He stated that, "...one should naturally be able to teach himself, understand and reason with his intellect… However, there exists another means of gaining knowledge that is much higher. This is what we call ruach ha-kadosh [editorial note: "the spirit of the holy one"]... In this manner

[1] A similar peer-reviewed version of this paper is available from the Journal of Anomalous Experience and Cognition at https://journals.lub.lu.se/jaex/article/view/24216

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one can gain knowledge that could not otherwise be gained through logic alone. This includes information including future events and hidden secrets" (Hoffman 2010, p. 54). More recently, the foundational 20th century psychologist C. G. Jung spoke about precognition in a way that brings to mind the classically non-intuitive behavior of quantum particles. "As the relativity of time and space includes the relativity of causality, and as the psyche partakes of relative time-space, it also relativizes causality and therefore enjoys, in so far as it is microphysical, an at least relative independence of absolute causality. (Chinese philosophy says that as long as things are in the North-East, i.e., before they have risen, they can be altered. When they have entered the East, they take their unalterable course)." (Jung 1973, p. 364).

The relatively modest modern controlled experimental study of precognition began with J.B. Rhine in the 1930s (for review, see Radin and Mossbridge 2018), and has continued to ramp up at a non-continuous pace (Figure 1), with discontinuities punctuated by the U.S. intelligence community's classification (1972) and declassification (1995) of their "Star Gate" program focused on accessing distant information in time and space. The pace of precognition research quickened a bit in the most recent decades, but this is also when the phrase "precognitive processing" began to be used by artificial intelligence researchers, cognitive scientists, and neuroscientists to refer to unconscious processing. In the century previous (1900 to 2000), there were only eight references to "precognitive processing" within the text of any materials indexed by Google Scholar, with the earliest in 1978 (Michon). From 2000 to 2020, there were 31 - not enough to account for the increase in precognition papers shown in Figure 1, but certainly contributing to it. In any case, as a result of this dual usage, some disambiguation is necessary. The classical definition of precognition refers to cognition, perception, behavior or physiology that reliably predicts future events that are not otherwise predictable by actually causing the event (direct cause), from sensory input from the known five senses, or inferring the event based on prior information.

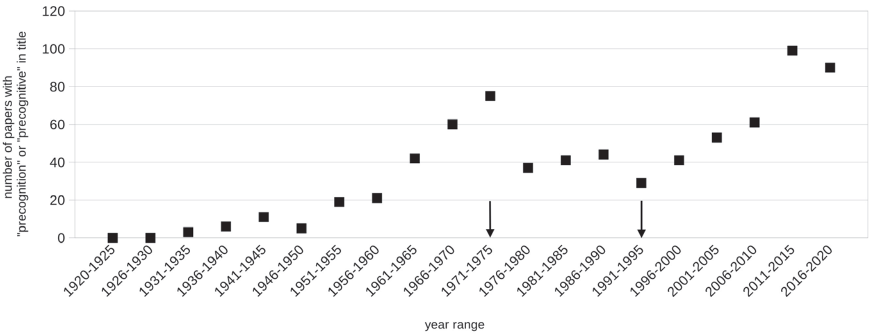

Figure 1. Number of materials with "precognition" or "precognitive" in their titles for each five-year period from 1920 to 2020. Arrows note the date of the beginning and end of the U.S. intelligence community's research program investigating the usefulness of precognition as well as other related phenomena (1972 and 1995).

While interest in precognition arises because it is common to have experiences in which we feel that we have predicted future events, not all types of experiences that seem precognitive are actually precognitive or are easily examined in the laboratory. Precognitive experiences (Figure 2) range from those in which people are completely conscious of the contents of the precognition, like precognitive remote viewing, to those in which there is usually no conscious awareness of the precognition, like physiological presentiment (also called predictive anticipatory activity PAA). Behavioral precognition, such as the type studied in the famous "feeling the future" experiments (Bem 2011), is also mostly unconscious and operates on a similar time frame as presentiment, but the effect sizes are less robust than for presentiment (see Bem et al. 2015 vs. Mossbridge et al. 2012). Compulsive precognition, also called psi-mediated instrumental response (PMIR), describes when someone knows they must take an action but they do not know why. It is completely spontaneous and very impressive to those who experience it (e.g., soldiers evading danger by taking a seemingly circuitous detour), but it is difficult to study experimentally because its real-world need context seems critical to its manifestation (Stanford 2015).

Forced-choice conscious precognition tasks, in which a participant must consciously predict a target between a finite set (usually 2-4) of possible future stimuli or events, often have lead times on the order of compulsive precognition (seconds to minutes), but they are much easier to study in the laboratory. Forced-choice precognition is replicable, but the results of these experiments have very small effect sizes (Honorton & Ferrari 1989; Storm et al. 2012). This may be partially because participants get bored with repeated trials, and partially because conscious deliberation (also called "system 2") overshadows unconscious intuitive decision making (also called "system 1"; Kahneman 2011; Tressoldi 2013). Finally, while precognitive dreaming is the most common precognitive experience, controlled tests of precognitive dreaming have been few and far between (Radin and Mossbridge 2018). Except when a pre-screened skilled participant was used as the dreamer (e.g., Krippner et al. 1971, 1972), the overall results of precognitive dreaming experiments have been equivocal. This may be a result of most people's ability to connect their dream content to future events even when there is only a very weak relationship between them, giving them the belief that they are skilled at precognitive dreaming and providing motivation to enroll in precognitive dreaming experiments. As a result of these caveats about other forms of precognition, it seems that the precognitive experiences at the extremes - presentiment (or predictive anticipatory activity) on one hand and precognitive remote viewing on the other - may be the easiest to study in controlled experiments. By studying the factors that influence these "boundary precognition phenomena," we may be able to shed some light on the mechanisms underlying precognition in general. The remainder of this summary is written with that hope.

Empirical examinations of precognition in controlled experiments require only three fundamental steps. The keys to a rigorous test of precognition include: the proper order of the three stages of the experiment, good selection of experimental stimuli, and sound data analysis. The proper order of the three states of the experiment is to: 1) record the dependent variable (physiology, behaviors, cognitions, perceptions) for a pre-planned period of time, 2) randomly select a stimulus or target from a pool of stimuli or targets and present it, 3) determine whether the values of the dependent variable were correlated to different types of stimuli/targets in some predictable way.

Note that the final determination of the relationship between the dependent variable and the stimulus or target could also be made prior to the selection of the stimulus, as a way to discover whether the stimulus can be predicted on a trial-by-trial basis, and this requires performing the same experiment multiple times so that a relationship between the dependent variable and the stimulus type can be inferred (e.g., Tressoldi et al. 2009). The best practices for all three steps of a precognition experiment depend on the system being studied (human vs non-human; physiology vs behavior vs cognition vs perception) and what is already known about how that system responds to the selected stimuli. Here we will treat presentiment and precognitive remote viewing as case studies in precognition research, and consider what the results of presentiment and precognitive remote viewing experiments teach us about the mechanism(s) underlying precognition.

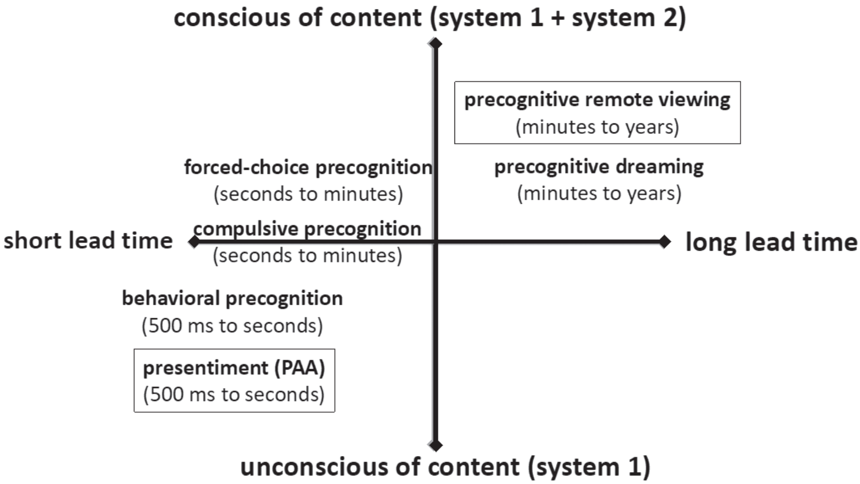

Figure 2. Five common types of precognition in humans organized according to the lead time between the precognitive experience and the related future event ("lead time," x-axis) versus the level of consciousness of the content of the precognitive experience (y-axis). Boxes indicate the two extreme cases examined in greater depth in this article. The labels "system 1" and "system 2" refer to thinking modes described in Kahneman 2011 (system 1 is first, faster, and more intuitive and unconscious; system 2 is second, slower, and more deliberative and conscious). PAA=predictive anticipatory activity; PMIR=psi-mediated instrumental response.

Presentiment

Presentiment (also called predictive anticipatory activity or PAA) is a physiological form of precognition. In presentiment experiments, the physiological system under study is tested to determine whether (and sometimes how) it can predict future randomly selected events of importance to the organism. Because it is a physiological phenomenon, the actual contents of what is predicted - the presentiments themselves - are usually completely unconscious. In the laboratory, presentiment is often studied by using conscious behavioral tasks during which researchers record the unconscious physiological system of interest. The lead time in a presentiment task between the physiological "pre-response" that correlates with a future stimulus and the future stimulus itself ranges from around 0.5 to 15 seconds, and two meta-analyses have estimated an effect size for presentiment at around 0.21 or 0.28 (Duggan & Tressoldi 2018; Mossbridge et al. 2012). Presentiment has been described in multiple physiological systems in humans and animals alike (human: Mossbridge et al. 2012 and Mossbridge & Radin 2018 for review; nonhuman presentiment-like phenomena: Alvarez 2010a,b, Alvarez 2016, Mothersill et al. 2018, Sheldrake & Smart 2000, Wildey 2001). There is some tentative evidence of similar phenomena among non-living systems (Moddel et al. 2011; Mossbridge 2021), supporting the idea that presentiment and rapid time-frame precognitive effects reflect an organism's exploitation of physical mechanisms that allow for some sort of retrocausality or time symmetry (see *Hints about mechanism*, below).

Briefly highlighted here are three presentiment experiments that have not been independently peer reviewed, but may be instructive nonetheless. They examine presentiment as measured by three physiological dependent variables: EEG (electroencephalography or brain wave activity), GSR (galvanic skin response or skin conductance), and IPI (inter-peak interval, related to the inverse of heart rate). These different but related experiments also serve to illustrate some of the methodological issues that can arise as experimenters attempt to eliminate potential confounds.

EEG (Mossbridge 2017). Here non-emotional auditory and visual stimuli were used in a series of 100 simple response trials performed by 40 participants. On each trial, participants saw a number 1 vs. a number 2 on a computer monitor, or a low tone vs. a high tone over headphones; stimulus order was randomized. Participants were asked to press the left button on a mouse if they saw the number 1 or heard the low tone, and the right button if they saw the number 2 or heard the high tone (all participants were right-handed). Because accuracy was easy to obtain with this simple task, participants were asked to be as fast and as accurate as they could be, as a way to motivate presentiment of the response, if it existed. A machine learning algorithm determined whether the current source density-transformed EEG activity in any of the five 25-ms bins *prior* to the time the software presented the stimulus could predict whether the future response should be a left or right button press. The same method was used to determine whether the modality of the stimulus (auditory or visual) could be predicted. The presentiment effect was that the left vs. right response press was predictable based on left frontal and right temporal-parietal activity at approximately 550 ms prior to the stimulus presentation $p<1x10^{-6}$; intriguingly, this effect was at the same time period that a type 1 readiness potential would be expected in this sort of task (Libet 1999). Meanwhile, the same method was not successful in predicting the stimulus type, only the participants' responses. If these results were replicated with a true random number generator selecting the stimuli, it would offer stronger evidence that the type 1 readiness potential in fact is predictive of future responses in a general sense, even in situations where those future responses rely on stimuli that have yet to be determined.

GSR (data shown in Mossbridge et al. 2012). Skin conductance responses and related pre-responses to feedback were investigated in a 4-option guessing task, with the future contrast being correct vs. incorrect trials. The major result was a gender difference, with men showing a significant arousal presentiment effect that matched their skin conductance responses after they learned that they were correct (versus incorrect). Due to concern about expectation bias due to possible physiological effects of previous trials (Dalkvist et al. 2014), only the initial trial of each participant's 40-trial dataset was examined. The effect grew stronger in this single-trial analysis, showing a significant gender interaction with correctness ($p<0.004$, $\eta^2=0.016$) as well as a significant presentiment effect for men during the 10 seconds prior to learning about the first trial's correctness ($p<0.005$, $d=0.359$). Specifically, men showed significantly increased arousal prior to being told that their guess was correct, whereas women showed (if anything) decreased arousal prior to being told that their guess was correct. It was intriguing that with a single trial the original gender difference effect became even clearer, suggesting that additional trials muddied the effect. Further, it was apparent that the physiology in the pre-feedback period in both genders echoed the post-feedback period. It wasn't the stimulus (correctness vs. incorrectness) that influenced presentiment - it was the nature of the response that was correlated with the pre-response.

IPI (Koestler registry 1005). In this experiment Mossbridge tested the idea that the skin conductance result described above would replicate with an inter-peak interval (IPI; inverse of heart rate) measure instead of skin conductance, and with a downloadable app instead of within a laboratory. The "Heart Tracker" application tracked inter-peak intervals using a smartphone's camera during the ~10 seconds before and 15 seconds after participants learned whether they correctly identified a "door" behind which was a $2.00 prize. The analysis, which was pre-registered, showed an effect similar to the skin conductance effect described above (Figure 3a,b), with an equivalent gender interaction and a significant effect for men in the 10 seconds prior to the feedback (men: N=147, $p<0.04$, $d=0.36$; gender interaction: N=292, $p<0.04$, $\eta^2=0.016$). However, a follow-up study (Koestler registry 1018) using a $4.00 reward did not replicate these effects, potentially because the pre- and post-feedback durations were too brief to capture what is likely a much larger and delayed post-response to the feedback (already apparent for men in the $2 version of the experiment; Figure 3a). Again, the idea that some form of time symmetry can explain presentiment (e.g., Bierman 2008) could be considered to be weakly supported by this lack of replication - but of course this interpretation requires an experiment showing that the effect is recovered with longer data collection periods before and after feedback.

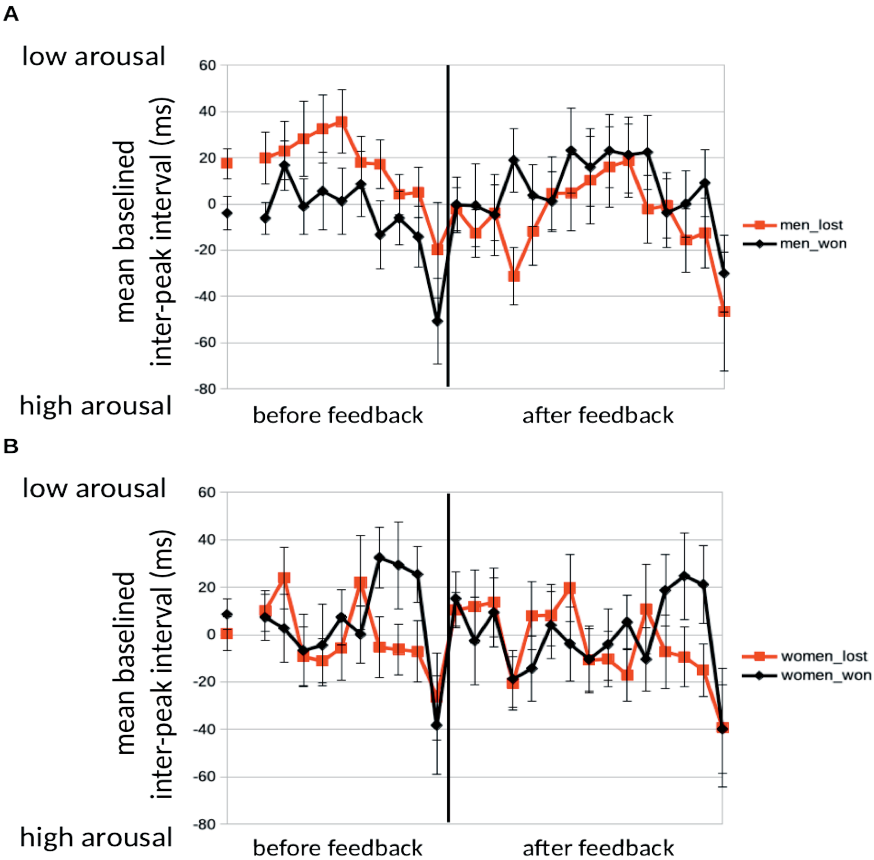

Figure 3. Inter-peak interval (IPI) heart rate data from 147 men (A) and 145 women (B) gathered using a smartphone app. Data are baselined to the first IPI value (not shown). The values at the left of each graph are the grand means of the baselined IPI values in the 10 seconds prior to receiving feedback, for participants who would receive winning feedback (black symbols) and losing feedback (red symbols) at the time indicated by the vertical line. The time series for the 10 seconds prior to feedback are shown as well as the 15 seconds after feedback. Error bars represent +/- 1 standard error of the mean (S.E.M.). Note that negative IPIs represent higher arousal than positive IPIs. Also note that the mean pattern of results matches the skin conductance version of this experiment (Mossbridge et al. 2012).

Presentiment and behavioral precognition operate at a similar time frame and are mostly unconscious, albeit with most behavioral precognition tasks requiring a bit more conscious attention than most presentiment tasks. Thus, it is natural to assume that presentiment mechanisms underlie performance on behavioral precognition tasks. If this assumption were true, what conclusions can we draw about the shared mechanisms governing both types of precognition performance?

In particular from the GSR and IPI presentiment studies highlighted above, one might draw the conclusion that if gender is related to differential presentiment performance, it ought also to be related to differential behavioral precognition performance. This idea was tested using two behavioral precognition tasks requiring two different degrees of consciousness of the content of the precognition (Mossbridge & Radin 2021). They both showed significant overall effects, but gender differences were only found for the largely unconscious behavioral precognition task rather than the task that required more conscious awareness, suggesting that there might be something about largely unconscious processing that is influenced more readily by gender differences.

While the gender difference results could reflect gender-specific learned associations with "winning," they may alternatively suggest that reproductive hormones could be involved in precognitive processing, especially for the brief time frames influenced by presentiment and behavioral precognition. One examination of the reproductive hormone idea used retroactive facilitation of recall (Bem 2011) - a behavioral precognition task with a relatively long lead time (minutes). An investigation of over 2000 online participants performing the task found no overall effect, no gender difference, and no consistent effects of reproductive hormones except for an under-powered observation of consistently better performance for pregnant women on the task (Mossbridge & Bem 2018). The long lead time for this task in particular may drive participants into a more conscious or deliberative state (Bem et al. 2015), and in a follow-up unpublished pilot study, Mossbridge found that pregnant women (4-10 months) performed significantly better than same-aged non-pregnant women on a shorter time-frame but forced-choice precognition task. This effect needs replication before firm conclusions are drawn, and it is important to be aware that it is difficult to recruit pregnant women for such studies. Pregnant women are a protected population for human research in the United States, so obtaining IRB approval for such experiments also requires extra effort.

Overall, current results suggest that performance on presentiment and behavioral precognition tasks can be influenced by gender, perhaps through a mechanism involving reproductive hormones, among other possibilities. Further, it appears that pre-responses prior to a stimulus tend to match or predict post-responses, rather than matching or predicting the nature of the stimuli themselves. This phenomenon, as applied to presentiment, is almost like a "time loop" in that it often appears that the response rather than the stimulus is what drives the pre-response (Wargo 2018; see *Hints about mechanism*, below). Finally, it is worth noting that for presentiment and behavioral precognition tasks in which one trial follows the next, shorter inter-trial intervals may muddy the effect because past responses (and conceivably future ones) can influence responses on any trial. Thus, for these phenomena, it is possible that the best approach when trying to understand the mechanisms underpinning them is to examine single-trial datasets to determine the relationships, if any, between presentiment and potential moderating factors (Dalkvist et al. 2014).

Precognitive remote viewing

Precognitive remote viewing is a form of precognition that is performed as an extended, conscious, 1-trial task with the intention of describing a future randomly selected target or the answer to a question. As such, precognitive remote viewing tasks are a subset of general remote viewing tasks, in which practitioners attempt to describe information that is distant in time and/or space (e.g., McMoneagle 2015; May & Marwaha 2018; Utts 1995). A precognitive remote viewing session can take between two minutes and two hours, at the discretion of the "viewer," who is the percipient or participant in the task. The delay between the session and the target feedback may be from minutes to years, or there may not be any target feedback shared with the viewer.

Precognitive remote viewing tasks are excellent candidates for scientists interested in understanding how various factors relate to precognitive ability, because a viewer's capacity for accuracy is often revealed in the very first session performed by a novice viewer (Targ 2019), making single-trial work generally more consistent (less noisy) than that of physiology or behavioral experiments. This also allows the possibility of online data gathering for precognitive remote viewing experiments from hundreds of people, a sample size necessary to rigorously examine the relationships between interesting factors and precognition performance (Mossbridge & Radin 2018, Mossbridge et al. in prep).

Ever since the U.S. intelligence community declassified their work on remote viewing and precognition in 1995, remote viewing practitioners have experimented with multiple methods of improving their accuracy. Drawing from the relatively well-controlled experiments included in the intelligence community-sponsored research and including anecdotal reports, a few particular claims are repeated with regularity. Here I review four of these claims and briefly describe recent controlled experimental evidence related to them.

Gender difference. The first claim is that unlike for presentiment and behavioral precognition tasks, there is no clear gender difference when it comes to precognitive remote viewing accuracy. In recent work on precognitive remote viewing examining trials gathered online, there was a gender effect only in an experiment in which the precognitive remote viewing task included a necessary forced-choice component (Mossbridge & Boccuzzi in prep). Specifically, when participants were asked to choose one of two targets based on their remote viewing session, there was a gender difference significantly favoring men, though accuracy was not above chance for either gender. However, when a more traditional free-responses precognitive remote viewing task was used, there was an overall significant effect but no significant gender effect in performance; only a very slight tendency for women to perform better than men (Mossbridge et al. in prep).

Feedback. Remote viewers working with law enforcement or with targets that are classified beyond their clearance level claim that feedback is not necessary for them to perceive accurate information about the target (McMoneagle 2015) - whereas remote viewers working to predict targets associated with financial markets claim that feedback is crucial (Katz et al. 2021). The role of feedback is key when it comes to understanding the mechanisms underlying precognition, because if feedback is not necessary for accurate performance, then the idea that a person is pre-responding to their own future experience cannot correctly describe the situation. For forced-choice precognition experiments, meta-analytic results indicate that trial-by-trial feedback supports accuracy (Honorton & Ferrari 1989), so it is not unreasonable to assume the same would be true for precognitive remote viewing. Nonetheless, the role of feedback has only been explored in a few precognitive remote viewing experiments.

In one such experiment, the conscious availability of feedback was manipulated and was shown to have no effect on the accuracy of precognitive remote viewing for participants producing significant performance (May et al. 2014). And a related recent study showed that skilled and pre-screened remote viewers were capable of describing changes in a German stock index (DAX) prior to the realization of those changes, but there was no significant difference in their performance when feedback was available versus when it was not provided (Müller, Müller & Wittmann 2019). Based on these well-controlled studies it appears that feedback may not be required for the *accuracy* of precognitive remote viewing, though it is remains possible that feedback supports viewer *motivation* when performing repetitive precognitive remote viewing trials.

Interesting targets. Another oft-repeated claim among professional remote viewers is that targets with high "numinosity" - that is, greater affect, more information, or more meaning - produce greater accuracy (May et al. 1994a,b, Schwartz 2007; Watt 1988). This claim has been tested in at multiple precognitive remote viewing experiments and has been upheld (Delanoy & Solfvin 1996, Krippner et al. 2019, Mossbridge et al. in prep). In one study (Delanoy & Solfvin 1996), video targets containing more information (and potentially therefore more interesting) were common among targets that were likely to be described well, even if they were not the selected target on a particular trial and instead were used as comparison targets during judging. In a more recent study, Krippner et al. (2019) found that static image targets rated as more numinous by independent judges produced significant precognitive remote viewing performance, while lower-rated image targets did not. Further, the relationship between target interestingness and accuracy was independently analyzed in three data sets (one confirmatory analysis was pre-registered; Mossbridge et al. in prep). All three analyses revealed that photo targets rated as more interesting were more likely to be correctly described - even when those targets were used as comparison targets for judges and never seen by participants. Overall, it appears that precognitive remote viewing tasks are similar to memory tasks in that some feature related to the salience of the target influences accuracy. This same rule has been proposed for forced-choice and behavioral precognition tasks, but thus far it appears that target affect does not seem to have a profound impact on accuracy in these sorts of tasks (Storm et al. 2012).

Self-transcendence. The final claim about precognitive remote viewing performance that I would like to briefly address here is the idea that better performance is obtained when viewers are in a positive or expansive mood (McMoneagle 2000; Swann 2018). Some scientists believe that this effect is motivational because belief in the possibility of precognition and other forms of psychic phenomena impacts performance in forced-choice and behavioral precognition tasks (e.g., Mossbridge & Radin 2018, 2021), and therefore is believed to impact remote viewing performance in general (Subbotsky et al. 2019). But in the only direct study of precognitive remote viewing in which belief was measured, belief was not shown to impact accuracy (Roe et al. 2020), providing another example of the non-equivalence of precognitive remote viewing with forced-choice and behavioral precognition tasks.

Meanwhile, the experience of being in a positive or expansive mood has been shown to be correlated with better accuracy in largely precognitive ESP experiments conducted in the Ganzfeld state (Carpenter 2005), a state in which participants are re-focused on internal stimuli. The Ganzfeld state may also support an experience of self-transcendence, and it seems to lead to significantly higher scoring on precognitive remote viewing (Roe et al. 2020). Along the lines of self-transcendence, the self-transcendent experience of unconditional love might support better accuracy in precognitive remote viewing (Mossbridge et al. 2021). That is, participants self-reporting high levels of unconditional love prior to being hypnotized to experience unconditional love performed significantly better than chance and better than participants who reported low levels of unconditional love in the same time frame. A follow-up experiment modified to be performed online examined the same effect and found the same result (Mossbridge et al. in prep), further suggesting that unconditional love - or perhaps expansive, self-transcendent states in general - support precognitive remote viewing. In fact, environmentally imposed self-transcendence, or what Cameron (2022) calls "alter association" may be the key to understanding why people with a high childhood history of trauma, especially neglect, have been found to score significantly better than those with a lower trauma history on a precognitive remote viewing task (Cameron 2022).

Taken together, it appears that independent tests of these four claims about precognitive remote viewing support the original claims. Although these results could be overturned by the recognition of methodological flaws or the production of multiple well-controlled studies contradicting the existing results, the current data point to the following conclusions about precognitive remote viewing: 1) there is no significant gender difference in accuracy, 2) there is no significant decrease in accuracy when there is no feedback about the target, 3) viewers are significantly better at describing more interesting or information-filled targets (whether they see them or not), 4) high self-transcendence, including greater feelings of unconditional love, produce significantly higher accuracy.

Hints about mechanism

There are some key differences between presentiment and precognitive remote viewing, described briefly above and elaborated upon below, indicating that they are distinct phenomena (Table 1). A few of the entries in Table 1 require further explanation, which I will briefly provide here. Whether feedback about the stimulus is required for presentiment to occur is a semantic question - a presentiment experiment consists of giving the participant the conscious experience of a stimulus and determining what the physiological response was prior to that stimulus, and how that response relates to the stimulus type and the post-stimulus response. While an experiment cannot really be considered a presentiment experiment without a stimulus revealed to the participant, some scientists have examined presentiment-like responses to stimuli that are selected but not shown, and have been able to differentiate responses to "blocked" versus presented stimuli (e.g., Tressoldi et al. 2009). However, since a non-presentation of a stimulus versus a presentation of a stimulus can be interpreted as two different stimuli, this type of experiment does not fully demonstrate that presentiment-like responses can occur without stimulus presentation.

Table 1. A comparison between some of the characteristics of presentiment versus precognitive remote viewing, highlighting their differences.

Characteristic	Presentiment	Precognitive remote viewing
Mostly conscious?	No	Yes
Prediction up to years in the future?	No	Yes
Gender influences accuracy?	Yes	No
Feedback on the target/stimulus required?	Yes	No
Interesting targets help?	No	Yes
Self-transcendence helps?	Not clear	Yes

Two other entries in Table 1 require explanation as they relate to presentiment: interesting targets and self-transcendent states. While the comparison classes in presentiment experiments are often between emotionally engaging versus neutral targets, this does not have to be the case to get a presentiment result. What is required, it seems, is to create a situation in which the post-stimulus physiological response is different between two stimuli (Mossbridge et al. 2015). This can be done with stimuli that differ in their arousal response and therefore their level of "interestingness" to the physiological system in question, or it can be done with neutral stimuli that do not differ in interestingness but do differ in their meaning within the context of the task (as in examples 1 through 3 above). Thus it is not interestingness per se but rather the contextual interpretation and response to the stimulus that determine the presentiment effect - this is best illustrated in example 1, in which the EEG pre-responses predicted the participants' responses but did not predict the stimulus types themselves.

As to self-transcendence and presentiment, to my knowledge there is no experiment in which either presentiment or behavioral precognition tasks have been examined in an environment like the Ganzfeld to examine whether self-transcendent states support these effects. Some experimenters note that meditation practice, associated with self-transcendence, increases accuracy in some conscious forced-choice precognition tasks (Roney-Dougal et al. 2008, Roney-Dougal & Solfvin 2011, Varvoglis 2019), but for presentiment tasks the results may depend on the nature of the stimuli. For example, when the stimuli are from two neutral classes as in a study of EEG pre-responses to auditory and visual stimuli (Radin et al. 2011), meditators may perform better on presentiment tasks than non-meditators, as they may differentiate events in time less rigidly. But as Bierman (2002) noted, meditators are adept at suppressing arousal response to challenging or erotic stimuli, and this may explain worse performance by meditators on presentiment tasks in which some of the stimuli are meant to produce emotional arousal. Therefore, the jury is still out on whether presentiment effects are improved when participants are in a self-transcendent state.

Assuming that human capabilities with sharply different characteristics are likely to be served by different mechanisms, it appears that presentiment is likely served by a mechanism that is at least partially separate from the mechanism underlying precognitive remote viewing. While hypotheses about physical mechanisms governing precognition have been offered in the past, they generally have treated precognition as a somewhat unitary phenomenon. That is, they have either tailored their models to explain results from a particular type of precognition and no other type, or they combined presentiment, precognitive remote viewing, and other forms of precognition into one conceptual lump (e.g., multiphasic model: Marwaha 2018, Marwaha & May 2015; CIRTS model: Bierman 2008, 2018; thermodynamic retrocausal model: Sheehan & Cyrus 2018). In contrast, an important psychological model of precognition does a good job of separating forms of precognition (Carpenter 2004, 2005), but it primarily focuses on the relationship between precognition and other aspects of unconscious processing, rather than trying to describe physically how the information revealed in precognition experiments arrives from the future. Elements of all of these influential theories are almost certainly reflective of some aspects of each of the mechanisms underlying presentiment and precognitive remote viewing. Here I speculate in very broad strokes about potential physical and non-physical mechanisms, including the theories mentioned already, that might underly presentiment and precognitive remote viewing (Figures 4a,b).

Presentiment and the PTS model. Let us first consider the case of presentiment and other largely unconscious forms of precognition that occur on a brief time frame. The consciousness restoration of time symmetry (CIRTS) model of Bierman (2008, 2018) was designed largely to explain early presentiment results. The idea here is that the information processing that occurs during conscious awareness of a stimulus or target restores time symmetry to physiology, providing the retrocausal effect of presentiment. According to this idea, if there is no conscious processing of the stimulus, there is no presentiment.

Taking the CIRTS idea and imposing the physical portion of it on a completely physical system is possible, and that is what I call a "physical-time-symmetry" (PTS) model of presentiment (Figure 4a). The proposition of this toy model is that presentiment and other short time-frame, largely nonconscious precognitive phenomena act through physical time symmetry in the 3 dimensions of space and one dimension of time, within the human body and brain. A stimulus must be present to induce the post-stimulus response, but if the stimulus can induce this post-stimulus response without consciousness, then consciousness is not necessary for this model. The PTS model is very similar to the thermodynamic retrocausal model (Sheehan & Cyrus 2018), although their model is more detailed than PTS and it seems to be enhanced by conscious awareness of the feedback (but only as a mechanism to boost post-feedback responding). The benefit of such a model is that only time symmetry need be proposed, a concept already available in classical physics (Sheehan & Cyrus 2018). Further, the fact that gender and potentially hormone differences influence these unconscious, short time-frame forms of precognition is consistent with the idea that they are strictly physical in nature. Similarly, the lack of long time-frame access to information about future events is consistent with a solely physical mechanism, because physiological mechanisms responding to many forms of future input would get exponentially noisier the greater the distance between the pre-response and the future event. Finally, the dual findings that presentiment effects are retrocausal responses to future internal states of the percipient and that presentiment effects themselves are largely unconscious both support the idea that consciousness and other potentially non-physical phenomena are not required for these effects to occur.

Precognitive remote viewing and the PUC model. The two other currently influential models of precognition, the multiphasic model and the thermodynamic retrocausal model, are both based almost entirely on precognitive remote viewing and precognitive dreaming results. For the thermodynamic retrocausal model, feedback is required because it is the feedback itself creates a retrocausal impact on the past perceptions of the experimental participant (Sheehan & Cyrus 2018). In contrast, for the multiphasic model information arises from an unknown external source distant in spacetime and is transferred through sensory means to the human brain and body (Marwaha 2018, Marwaha & May 2015). This process does not seem to require specific feedback about the target, and various factors including information content and the state of the remote viewer can influence the reception of the information through sensory means. These features of the multiphasic model match the existing precognitive remote viewing results better than the thermodynamic retrocausal model does. However, the missing piece of the multiphasic model, as the authors themselves explain, is how the information gets from somewhere/somewhen distant in spacetime to the percipient.

I too am unable to satisfactorily explain how information gets from somewhere/somewhen in spacetime to a percipient in the here and now, but I will speculate nonetheless, with the goal of creating a testable toy model of precognitive remote viewing and other largely conscious forms of long lead-time precognition. I call this model the "pervasive-universal-consciousness" model (PUC; pronounced like the character "Puck" in *A Midsummer Night's Dream)*. The source of the information retrieved by the precognitive remote viewer arises from a universal consciousness (e.g., James 1909, Barušs & Mossbridge 2017), an information-rich and pervasive nonlocal "field" not confined to an individual's local spacetime. If one makes ancient assumption that this universal consciousness permeates everything (because it is not constrained to local spacetime) and stores all the information in the universe regardless of the space or time from which it originated (e.g., Akashic records; Nash 2019), then the question becomes how a viewer can receive specific information appropriate to a given precognitive remote viewing task when so much information is available. This question actually has two parts: 1) how does the percipient communicate to the universal consciousness what information is needed, and 2) how does the universal consciousness provide that information?

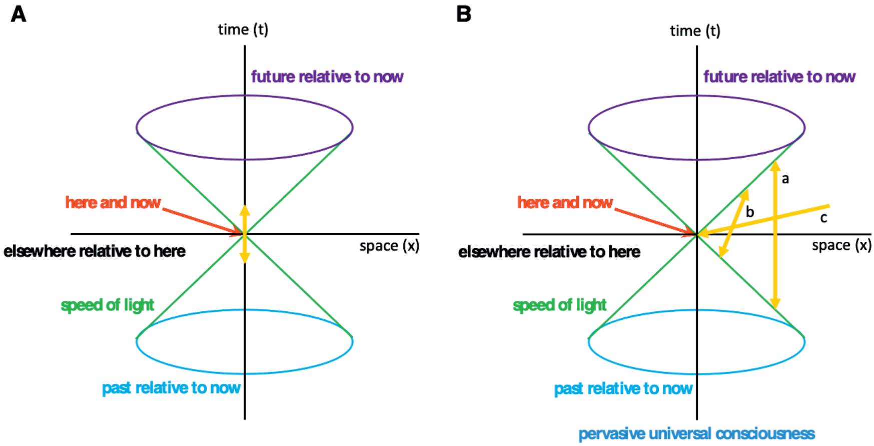

Figure 4. Schematics showing physical and non-physical aspects of two proposed precognition mechanisms (yellow arrows) on and beyond a research participant's light cone. A) The physical-time-symmetry (PTS) toy model describing presentiment and other short time-frame, largely nonconscious precognition acts through time symmetry in the 3 dimensions of space and one dimension of time, within the human body and brain. B) The pervasive-universal-consciousness (PUC) toy model describing precognitive remote viewing and other long time-frame, largely conscious precognition arises from non-physical, consciousness-based, outside-of-local-spacetime source. This information is contained throughout the pervasive universal consciousness, is selected via intention, and is transmitted to the percipient via the electromagnetic boundary of the percipient's light cone. Three examples are shown: a) transferring intention from the percipient forward in time and information backwards in time to the percipient's light cone at its electromagnetic boundary, b) the same as (a) but asymmetrically relative to "now," and c) transferring both information and intention unidirectionally, from the pervasive universal consciousness to now (as in spontaneous precognitive dreaming). For both graphs, horizontal axes represent space (x), vertical axes represent time (t), red arrow point to the local "here and now," speed of light is given as the boundary of the light cone in green, past light cone relative to the local "now" is below, and future light cone relative to the local "now" is above. Only one dimension of space is shown, but three dimensions of space are alluded to by the oval cone-like cross-sections above and below.

Continuing to speculate in the service of creating a model that may eventually be falsifiable, I propose that the percipient uses intention to communicate to the universal consciousness what information is needed. Intention as the carrier of this request is proposed for several reasons: 1) multiple anecdotal reports suggest that the success of precognitive remote viewing is driven by intention, 2) intention is a conscious experience and therefore can be thought of as having both a physical (brain/body) and nonphysical (mental) component, providing two media with which to communicate with pervasive universal consciousness, 3) we use intention in our physical everyday actions to help us select our sensory inputs (e.g., if I intend to eat blueberry pie I am more likely to eat blueberry pie). In terms of how the universal consciousness provides the information, I propose that if the information originates outside the light cone, the information is transferred by the PUC to the electromagnetic boundary of the percipient's light cone and can, from there, be perceived by the percipient (Figure 4b). This odd assertion arises from examining a precognition-like effect in a quantum optical system (Mossbridge 2021), in which it appears that both presentiment-like behaviors (i.e., registering the future state of the system) and precognitive remote viewing-like behaviors (i.e., registering information not in local spacetime) are being displayed by the photons in the experiment. From this comes a tentative proposition that light - or electromagnetic radiation - can be seen as a translator between universal consciousness and local spacetime. While not essential to the PUC model, it is an intriguing detail that could potentially be tested (see below, *Testing the models*).

How does the intention piece work? In precognitive remote viewing in which no one including the experimenter knows the answer to a question being posed in the target, which is often the case in operational precognitive remote viewing, the intention communicated to universal consciousness would be something along the lines of "please get the information required for this tasking and communicate it to me effectively." For instance, if the tasking is to address an unknown future question that turns out to be a future scientist's query about how to create a time machine, then it is up to universal consciousness to first access the future scientist's query, then find the answer to the question, and then deliver the answer usefully to the percipient. Thus the intention provided to universal consciousness is very different from the information content coming back to the percipient; there is an essential asymmetry in that the PUC knows the question and the answer and must provide it, while the percipient only holds the intention that it be provided to them. Further, in the case of spontaneous precognitive dreaming in which there is no clear intention on the part of the dreamer at all, the intention and the information seem to go in only one direction - as if the universal consciousness has its own intention as well as the information matching that intention, and these is transferred to the dreamer through elements of their dream (e.g., Figure 4b, arrow c).

The PUC toy model described here is consistent with the characteristics of precognitive remote viewing, but the PUC component is of course the most speculative. It is necessitated by three key results. First, precognitive remote viewing can be used to accurately describe structures, people, and events distant in space as well as far in the future and past without feedback - in other words, outside the light cone of the percipient. Any model explaining precognitive remote viewing must explain how information from outside of local spacetime gets into local spacetime. In other words, a wormhole or other exotic physical process must be postulated to send and receive information to the percipient, or nonphysical processes like a PUC must be considered. Second, the fact that in precognitive remote viewing targets that are interesting to a viewer are more likely to be described accurately than other targets suggests that there is a type of two-way communication between the percipient and the source of the information, rather than a mechanical one-way flow of information. Finally, the fact that self-transcendent states support accuracy in precognitive remote viewing tasks suggests that there is an aspect to the mechanism that is more accessible from a mental state that explicitly involves moving oneself beyond the boundaries of the personal. In the PUC model the pervasiveness of the universal consciousness reflects this result.

Testing the models

PTS model. Each of these two models could potentially be tested. For the PTS (presentiment) model, a way to elicit presentiment or at least behavioral precognition responses without de facto stimuli would be the most obvious way to test the claim that the phenomenon does not require consciousness and relies on post-feedback responses. If pre-responses associated with non-displayed feedback occurs when there are no stimuli presented (ever) within an experiment, there is no feedback of any kind (e.g., stimuli are selected but not shown), and there are no post-feedback responses (e.g., responses after the time of the non-feedback), then the physical-time-symmetry model cannot explain presentiment. In that case, presentiment would have to be explained by something like the PUC model. Another way to test the PTS model would be to introduce a general anesthetic just before a stimulus is delivered (in a single-trial experiment) and determine across participants if pre-responses matched post-responses regardless of conscious awareness of the stimulus. The PTS model predicts that if there is a post-stimulus physiological response, there should be a pre-stimulus response in the same physiological system (regardless of conscious awareness of the stimulus).

PUC model. The first step to ruling out the PUC model would be to demonstrate methodological flaws in the precognitive remote viewing experiments showing precognitive access to information that is never given to the percipient, and the second step would be to repeat such no-feedback experiments and find the result that feedback trials were significantly more accurate than no-feedback trials. Of course, ruling out that there is a personal and individual communication of sorts with some kind of nonlocal source of information would be key. One experiment designed to rule out the human side of this sort of communication is to ask a group of skilled precognitive remote viewers to obtain information about the future state of someone they love versus a stranger, and to compare the accuracy of both types of sessions. If there is no difference in accuracy, the PUC model is likely wrong, because it proposes an intentional connection between the PUC and the viewer. Along those lines, while it is difficult to test whether a universal consciousness has intention toward us, it might be useful to investigate implicit and explicit human intentionality and observe how each type of intentionality influences precognitive remote viewing performance. Another feature of the PUC model is that there is no causal closure - specifically, there is something about the pervasive universal consciousness that can influence physical reality. In the PUC model, that influence is on the electromagnetic force. If electromagnetic phenomena, including biophotons, can be tested in the presence of a precognitive remote viewing session and there is never any association between electromagnetism and session accuracy, this would suggest that the PUC model requires another method to transfer from the nonphysical to the physical. If precognitive remote viewing performance does not depend on human intentionality, the PUC would be incorrect.

Next steps

Regardless of what will eventually be uncovered about the mechanisms underlying precognition, given existing data it appears that at least some forms of precognition will have to be explained either by what is currently considered exotic physics or by nonphysical or extra-physical means. As explained above, this does not mean that these models are untestable, just that they may be easier to understand and to rigorously test for those scientists who acknowledge that the scientific method does not rely on a materialist worldview (Barušs & Mossbridge 2017). In the meantime, it is useful for those interested in practical applications of precognitive phenomena to keep in mind that each type of precognition might be explained by slightly different mechanisms, so understanding and characterizing the features of the phenomenon that works best for a given application is key to making practical progress.

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TIME TO PLAY: PREFRONTAL SPECIALIZATIONS FOR PLAY BEHAVIOR

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Abstract

Play is arguably the least understood class of mammalian behaviors. We do not know its exact function, the brain circuits that drive play have not been identified and we lack an understanding of the neural activity patterns in playing brains. We think that our ignorance of play is rooted in philosophical and religious (Calvinist) prejudices that view play as dispensable, childish and primitive. We played with animals and find that these assumptions are wrong. Rats playing 'hide and seek' games engage in complex role-play behaviors that exceed in complexity other behaviors known in these well-studied animals. Animals and humans can enter 'play realities' and have complex communication strategies that coordinate play reality across players. Children, when heavily engaged in play, lose track of time. In rats, the prefrontal cortex, a high-level brain area, is intensely engaged during play and we review the connection of prefrontal cortex and play. In some circumstance, but not in others, observing play also engages cortical circuits. We conclude that our brains have unique capacities for play and that our children need time to play.

1. Play behavior

From a neuroscientific perspective, play is one of the least understood classes of mammalian behaviors. The behavioral function of play is hard to delineate and the brain circuits that drive play have not been identified. More than that, we lack an understanding of the neural

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activity patterns in playing brains. We think that our ignorance of play is rooted in philosophical and religious (Calvinist) prejudices that view play as dispensable, childish and primitive. Specifically, in John Calvin's parish in Geneva, there was capital punishment for dancing and playing. In this article, we will discuss the neuroscience of play and the prefrontal cortical circuits in play control.

Play is an important element of children development. We often observe children engaging in behaviors that simulate adult activities, like driving a cardboard box, fishing in an imaginary pool, or covering a doll with a blanket. Play is a spontaneous and inherently rewarding behavior that is not fully functional, but mimics the more serious version of it; it appears repeatedly during childhood and needs a context free of stress to develop (Burghardt 2012). This type of game, in some cases called "pretend play", is believed to prepare children to adult life by promoting the development of the cognitive abilities and skills associated with each specific game. As expected from its rewarding dimension, children that engage with pretend play have more chances to display positive emotions (Rao and Gibson 2021); and the evidence so far shows that pretend play at least can promote reasoning, language, narrative, and emotion regulation in children (Lillard et al. 2013). An important, yet self-contradictory aspect of play is the requirement for both freedom and rules (Huizinga 1980). Specifically, individuals will not enter play, if they don't feel free. Yet the violation of the rules of the game (no matter how arbitrary they are) leads to the termination of play.

Rats and other mammals engage in play during development (Panksepp 1981; Pellis and Pellis 2007). Rats in particular, engage in rough and tumble play, which shares the main characteristics of human play: It is repeatedly performed in young animals, it differs from serious fighting and it is rewarding in itself (Pellis and Pellis 1987; Panksepp 1981; Humphreys and Einon 1981). During play rats compete for access to each other napes, in a series of alternating nape attacks and defense movements. During defense, rats can either evade the upcoming attack, or face the attacker back and try a counter maneuver. If the later succeeds, then the attacker/defender roles are reversed and the game continues. Play fighting markedly appears in young rats at 18-20 days, reaches a peak around 32-40 days, and is reduced as animals become adults following an inverted U-shaped curve (Panksepp 1981). This play fighting behavior differs from serious fights, where attacks are directed to the torso or head instead of the nape (Pellis and Pellis 1987), and is accompanied by the emission of positive valence (50 kHz) vocalizations (Burgdorf et al. 2008). The presence of high frequency calls, and the fact that playful behavior can act as a reinforcer in T-maze tests (Humphreys and Einon 1981), confirm that play is a joyful activity in rats.

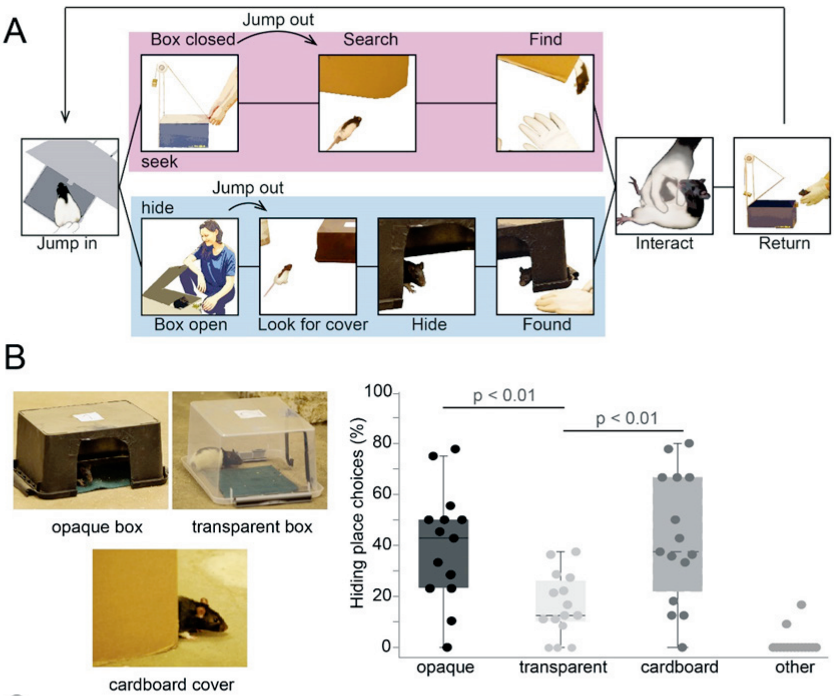
As in humans, play in rats is necessary for the later regulation of emotions and social behavior. For example, rats deprived of play react more negatively to stressful (Frijtag et al. 2002) or anxiogenic (Arakawa 2003) situations. During an interaction with an aggressor rat, play deprived animals respond with a more inadequate behavior, as the aggressor rats display more agitated behavior and inflict greater number of injuries toward play deprived animals than to the socially reared ones (Frijtag et al. 2002). Similarly, animals isolated during the critical play period tend to avoid the center of the maze during an Open Field paradigm compared with socially reared animals; indicating that these animals show increased anxiety during the execution of the task (Arakawa 2003). Consistently, play can also promote a resilient response against stressful events. Rats regularly exposed to rough and tumble play can reverse the effect induced by chronic stress paradigms (Burgdorf et al. 2017). These results together suggest that the social interaction during the critical playful periods, and especially the exposure to rough and tumble play, have a central role in the development of emotional and social regulation.

2. Complex play in animals: Rat and human hide and seek

Play is observed in mammals with varied levels of complexity. In non-human animals reports of play refer mostly to locomotion play, object play and social play, the later encompassing more complex game dynamics, as rough and tumble play in rats. Social play is present in several forms and can also show different degrees of complexity as it includes more or less behavioral elements. For example dolphins play chasing each other and mimic others playful behaviors (Mackey et al. 2014), elephants wrestle with their trunks or push each other (Lee and Moss 2014) and great apes engage in wrestling or pick-a-boo with their infants (Kerrie P. Lewis 2005), among other behaviors. It has been found that play complexity is related to brain size (Iwaniuk et al. 2001) when performing between-order (in opposition to within-order) comparisons; carnivores and primates show greater elaboration, and smaller brain animals, as shrews, more simpler social games like chasing each other. This is consistent with the hypothesis that more complex games require more complex computations, and thus bigger brains. One limitation of this approach, is that the results are limited by the repertoire of play behaviors in animals reported so far. As example, we now know that rats can engage in games of greater complexity than previously described in the literature (Reinhold et al. 2019).

As social games increase in complexity, they can include role reversals and more elaborate cognitive processes. In humans successfully playing Hide and Seek correlates with the children's ability to keep a secret, to take others perspective, and with executive function scores (Peskin and Ardino 2003). This is consistent with the dynamic of the game, where executive function may be needed for switching between seeking and hiding roles; and were finding successful hiding spots may benefit from perspective taking. In fact, children engage theory of mind to define a place as a hiding location, or as a spot to seek (Street et al. 2018).

Surprisingly, rats can also engage in this game (Figure 1A) and show an understanding of it (Reinhold et al. 2019). In this inter-species version of the game, hide and seeking roles are reversed between players. Each round of the game starts with the animal inside the starting box located in the center of the room. In seek trials, the rat is locked inside the starting box while the experimenter selects one of the three cardboard panels to hide behind. Once hidden, the experimenter remotely opens the starting box and the animal begins the search. Once the animal finds the experimenter, a playful interaction is initiated and then the animal is returned to the starting box. After a few trials, roles are reversed, and after leaving the rat inside the starting box a hide trial starts instead. On these trials, the rat is not locked inside the starting box, but is free to leave the box, explore the room and hide during the next 90 s in one of the seven hiding locations (3 cardboards, 2 transparent boxes and 2 black boxes), while the experimenter waits next to the starting box. When the rat hides properly, the experimenter initiates a playful interaction and returns the animal to the starting box. Under this condition, rats show some understanding of the game. First of all, animals avoid hiding in transparent boxes and will prefer to hide under opaque boxes or behind cardboards (Figure 1B). Also, the pattern of vocalizations varies between roles. When seeking, rats produce vocalizations when finding the experimenter but reduce the number of calls when the experiment is about to find them during hide trials; in general, they show lower call rate during hide (Figure 1C). These observations show that rats display behaviors consistent with the role assigned in each of the rounds of the game, and that they can coordinate their behaviors with the human player and share the "play reality".



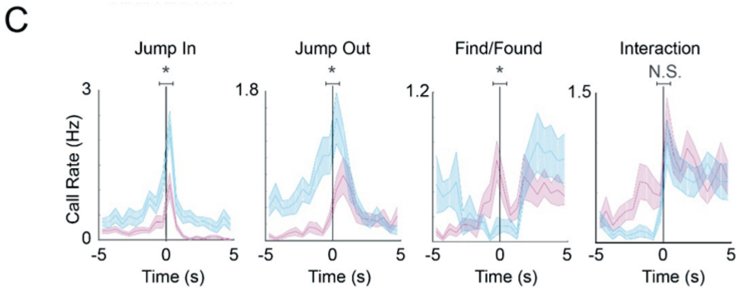


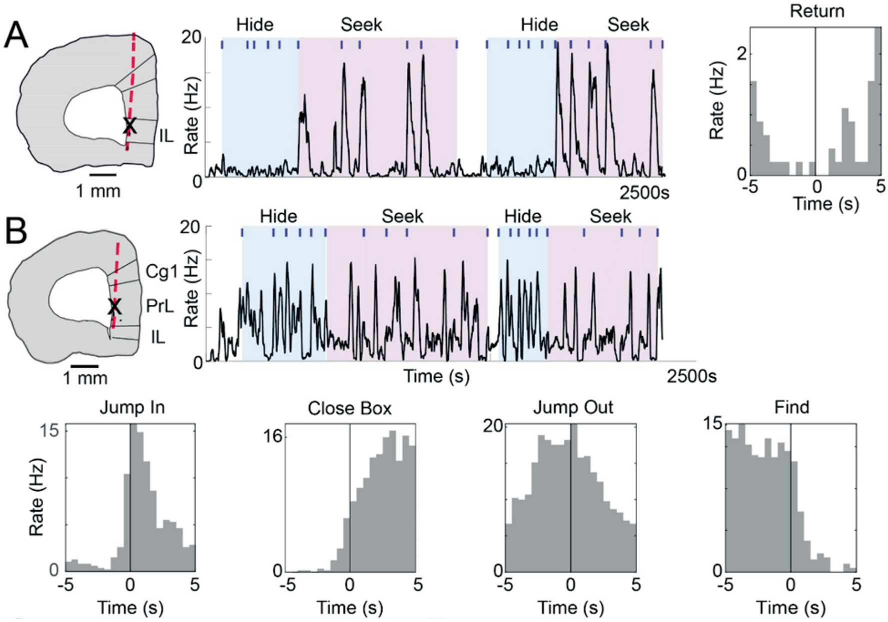
Figure 1. Rats show an understanding of Hinde and Seek.
A. Schematic of the events of the human rat Hide and Seek.
B. Left: Hiding locations. Right: Percentage of choices for each of the hiding locations.
C. Event triggered vocalizations rates for four different events of the game (* represent $p<0.0001$).
Modified from Reinhold et al. 2019.

3. Prefrontal cortical activity in hide and seek

During Hide and Seek, mPFC shows responses tuned to specific game events (Figure 2). Reinholds et al (2019) also recorded mPFC neurons during Hide & Seek, and observed that neurons activate during a specific behavior (Figure 2A), or across multiple ones (Figure 2B). This results were confirmed by a later replication (Concha-Miranda et al. 2020). In this second version of the experiment, an observer rat was added to the experimental design (Figure 2C). Under this paradigm, an "observer" rat observed a "demonstrator" rat play Hide and Seek, and later engaged in the game itself. As expected, while playing mPFC was activated following the different game events (Figure 2D-E). Since in humans Hide and Seek relies on perspective taking strategies to choose hiding and seeking locations, this experimental design allowed to test if mPFC activation followed the execution of the game or rather perspective taking processes.

As observed in Figure 2E, mPFC showed a global increase of neural activity when playing, in a way that neurons which showed a response during play events where not modulated when observing the same behavioral event. This result suggests that mPFC is engaged in the execution of the game rather than on observing others playing. This also argues against a role of mPFC in perspective taking processes during play, although some limitations of the design, as limited interaction between the observer and the game, may have prevented the activation of this area. Consistent with the former interpretation, unsupervised detection of brain states on mPFC point towards a global change of state between observing and play (Bagi et al. 2022), which rather indicates that mPFC cortex gets activated when animals enter into the "play reality".

The fact that mPFC is strongly engaged during play, is consistent with previous literature on play. First mPFC is a structure especially sensitive during development and is shaped by social interactions and play. If play strongly engages mPFC, then this could explain why play deprivation may affect the normal development of mPFC and generate the concomitant behavioral alterations during adulthood. Second mPFC is one of the structures that has been particularly associated with the more complex dimensions of rough and tumble play, which is consistent with the pattern of activation of mPFC observed during the different events of Hide and Seek. In the next section we will briefly review the literature on these two lines of evidence, that is, play and mPFC plasticity and the effect of mPFC manipulations on rough and tumble play.



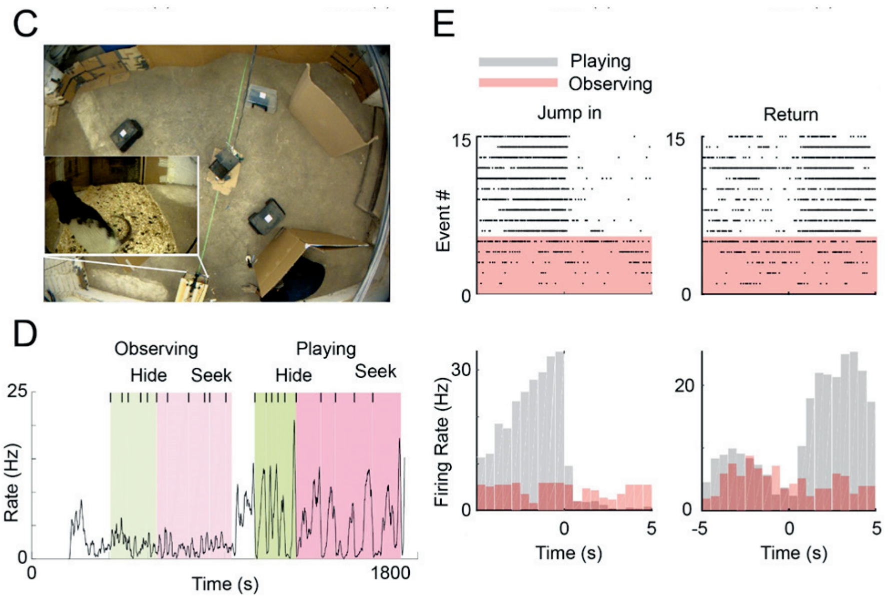


Figure 2. mPFC engage in playing Hide and Seek but not in Observing to Play.

A. Left: Schematic representation a coronal section with tetrode track (red) and recording site (X) in rat IL. Middle: Firing rate of an IL neuron through the whole game session. Right: Peristimulus time histogram of the same neuron aligned to start-box closure.

B. Upper left: Schematic representation a coronal section with tetrode track (red) and recording site (X) in rat PL. Upper right: Firing rate of an PL neuron through the whole game session. Bottom: Peristimulus time histogram of responses to events in "seek" trials. Cg1, cingulate area 1; PrL, prelimbic cortex; IL, infralimbic cortex.

C. Image depicting the experimenter hiding behind one of the cardboards, the playing rat (in the left corner of the cardboard) about to find the experimenter, and the observer rat inside the observing cage (in the boxed marked with white).

D. Firing rate of a single neuron in mPFC during observing Hide & Seek (first half, semitransparent green and pink) and playing Hide & Seek (second half, green and pink). The white space in between represents the transition period.

E. Top, raster plot for an example neuron aligned to Jump in (left) or return (right) onset during seek trials (white background for playing on top, red background for observing play on the bottom). Bottom: PSTH for the corresponding events when playing (gray) and when observing play (red).

Modified from Reinhold et al. 2019 and Concha et al. 2020.

4. Prefrontal cortex and play: general review

It has been suggested that play may act during development by promoting plasticity in the mPFC (Burleson et al. 2016; Bell et al. 2010; Himmler et al. 2013). It is known that mPFC goes through continuous remodeling during development, which is needed for cognitive flexibility and the regulation of conditioned fear during adulthood (Klune et al. 2021). Given that rats show changes in analog behaviors when deprived from play during maturation, mPFC may be one of the structures carrying these alterations of development into adult life. In fact, it has been shown that neurons of the mPFC reduce their complexity when juvenile rats develop in an "normal" environment, that is, with peers available to play with (Bell et al. 2010). Animals that were reared with non-playful animals had more dendritic length and more complex apical dendritic arbors than the ones that had access to playful peers. This result has been confirmed in later experiments (Himmler et al. 2013), where it was additionally shown that mPFC neurons of play exposed animals had also a greater response to nicotine exposure in adulthood. This was interpreted as an enhancement of the plasticity of the mPFC circuits caused by early play experiences, since nicotine had a separate effect that was increased in play exposed animals. Experiments performed in hamsters also confirmed disrupted dendritic morphology in mPFC neurons in play deprived animals, who also showed inappropriate aggressive behavior (Burleson et al. 2016). This series of experiments point to mPFC as one of the brain structures that are shaped by play during development. This is consistent with the fact that mPFC is recruited during play and is needed for the execution of more complex features of play (as will be discussed in next paragraphs), which may explain how mPFC is shaped as a consequence of young rats' play.

Experimental manipulation on mPFC has shown that this cortical region is relevant, although not necessary, for play in rats. Even though decorticated rats still can express play and show an inverted U shape increase and decrease of the frequency of play (Pellis et al. 1992), more complex characteristics of play are altered (Bell et al. 2009; Schneider and Koch 2005; van Kerkhof et al. 2014; Achterberg et al. 2015; Pellis et al. 2006; Kamitakahara et al. 2007). A series of specific cortical lesions, showed that different cortical regions may play a different role in play. For example, motor cortex ablations suppressed the age-relate change in play tactics observed during normal development (Kamitakahara et al. 2007), while orbitofrontal cortex lesions limit the ability of rats to modify their behavior with respect to the identity of the play partner (Pellis et al. 2006). Importantly, the changes observed after motor cortex lesions are not present in orbitofrontal lesions, and vice versa. Medial prefrontal cortex lesions also produce changes in play behavior, although the changes are of a different nature than the ones just described (Bell et al. 2009; Schneider and Koch 2005). Young rats with neonatal excitotoxic lesion of the mPFC are less likely to show rotations during defense, and show more partial rotations instead; while adult rats initiate less attacks (Schneider and Koch 2005). Similar result where obtained after neonatal ablations of the mPFC (Bell et al. 2009). During development, neonatally ablated animals exhibited fewer playful responses after an attempted attack of the partner, and showed less rotations during defense; again, as in the previous report, adult rats also showed a decrease in the number of attempted attacks.

Medial prefrontal cortex is subdivided in the medial agranular (Agm), the anterior cingulate (AC), the prelimbic (PL) and the infralimbic (IC) cortices, and no study has assessed their respective roles in play systematically. We know that infusion of methylphenidate or atomoxetine in AC and IC inhibit play, but not injections in PL (Achterberg et al. 2015). It has also been shown that inhibition of some of the mPFC regions through a mix of GABA-A and -B receptor agonists also inhibits play (van Kerkhof et al. 2013). Inhibition of both PL or IL decreased the frequency of pinning, pouncing and total play duration, and the effect was stronger than the one reported after neonatal lesions. Nevertheless, in the later experiments the effect of AC inhibition was not tested, and none of these two experiments manipulated Agm. Taken together, the evidence so far shows that although mPFC is not strictly needed for play, it does participate in the more complex dimensions of it, as reflected in the altered proportion of attacks and defensive behavior after lesions or acute manipulations.

The evidence presented so far is consistent with the more general role of mPFC in the regulation of social behavior (Franklin et al. 2017;

Himmler et al. 2014; Levy et al. 2019). Medial prefrontal cortex can encode the social identity of stimuli, by responding differently to social and non-social stimuli (Levy et al. 2019). Moreover, mPFC is important for the regulation of social behavior. For example, mPFC projections into dorsal periaqueductal gray (dPAG) regulate the behavioral avoidance of aggressive rats, probably by keeping different inhibition levels over dPAG neurons responsible of the social avoidance behavior (Franklin et al. 2017). Similarly, it has been shown that mPFC is necessary for the regulation of inter-animal coordination (Himmler et al. 2014). Rats with bilateral lesions in the mPFC were less successful in protecting their food from robbers and failed to keep an appropriate inter-animal distance, without showing signs of other motor or sensory deficits. These results are in line with the impairment on social regulation against aggressive rats observed in play deprived animals (Frijtag et al. 2002). Finally, it has been shown that the activity of PL and IL (two mPFC regions) is related to approaching and leaving behaviors in rats (Minami et al. 2017). When animals approach and contact a conspecific, PL neurons increase their firing rate, while when they finish the interaction and leave, IL neurons decrease their activity. More importantly, animals reared in isolation didn't show the characteristic reduction of IL activity when leaving. If we extrapolate these results to play behavior, it could be implied that the long effects observed after play deprivation may be caused by changes in the mPFC neural dynamics during social interaction.

The fact that the more complex behavioral dimensions of play are related to mPFC function, is consistent with the more general role of mPFC in action control and goal directed behavior. One way in which medial prefrontal cortex is involved in action control is by regulating impulsivity or behavioral inhibition (withholding an action) in waiting tasks (Dalley et al. 2011). For example, it has been shown that inactivation of AC, IL and PL consistently reduce the waiting times in a delayed reward task (which in this case signals increased impulsivity). Furthermore, Agm, the more dorsal portion of the mPFC, showed a clear encoding of the moment of action (Murakami et al. 2017). We can understand then the importance of mPFC for play, if we considered that an essential part of rough and tumble (and games in general) is the need of withholding actions to allow a balance of the roles between players, in a way that the behavior is kept within the limits of play. Additionally, goal directed behavior, another essential components of play, also strongly engage medial prefrontal cortex (Woon et al. 2019). It has been shown that the dorsomedial prefrontal cortex can encode simultaneously sensory, motor and outcome components in a go/no-go task, displaying cell type specific responses among inhibitory neurons (Pinto, Dan 2015). Consistently, AC, PL, and IL can encode the reward difference between two options, and show an increase of activity immediately before animals actual choices (Sul et al. 2010). Taken together, the study of action control and goal directed behavior under controlled experimental setups is consistent with the findings on play even under the more unrestrained experimental conditions of rough and tumble or hide and seek.

Conclusion

Our understanding of the neural mechanisms of play is still limited. What is clear, however, is that both humans and animals have amazing capacities for complex play. Prefrontal cortical circuits contribute to such capacities. To fully develop such abilities our children need time to play.

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CIRCADIAN CLOCKS AND THEIR IMPACT ON METABOLISM, AGING AND LONGEVITY

Joseph S. Takahashi *

Abstract

Genetic analysis of circadian behavior in mice has revealed that the molecular basis of circadian clocks involves an autoregulatory transcriptional network that oscillates with a 24-hour periodicity. In mammals, the discovery of "clock genes" led to the realization that circadian clocks are cell autonomous and are expressed in the majority of cells and tissues in the body. The master circadian pacemaker located in the hypothalamic suprachiasmatic nucleus sits at the top of a hierarchy of oscillators in the body, but peripheral oscillators can and do respond to more proximal signals such as nutrients and metabolites. Thus, the "circadian system" in mammals is a multi-oscillatory hierarchy. In addition to controlling the timing of behavior and physiology, the clock gene network interacts directly with many other pathways in the cell. These include metabolism, immune function, cardiovascular function and cell growth to name a few. With respect to metabolism, the timing of nutrient consumption is critical, and we and others have shown that restricting the timing of feeding has many health benefits. The lecture will also discuss the role of time-restricted feeding as a critical factor for aging, health span and longevity.

Introduction

In the 1990's, my laboratory discovered the first circadian clock gene in mammals and this discovery eventually led to the description of the molecular mechanism of the circadian clock in mouse and

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humans (Antoch et al. 1997, King et al. 1997, Lowrey & Takahashi 2011, Takahashi 2017b, Vitaterna et al. 1994). Circadian clocks are transcriptional/translational 24-hour negative feedback loops that drive rhythmic expression of thousands of genes, dynamic epigenetic modifications of chromatin and are embedded within metabolic pathways (Bass & Takahashi 2010, Green et al. 2008, Takahashi 2017b). In the mouse liver, there are genome-wide transcriptional and epigenetic programs driven by the circadian transcriptional activators, CLOCK and BMAL1, that occur each day (Figure 1) (Koike et al. 2012). Importantly, there are many links between the circadian system and aging. High-amplitude circadian rhythms correlate with well-being (Froy 2013, Froy 2018, He et al. 2016), whereas clock dysfunction leads to metabolic disorders, premature aging and reduced lifespan (Dubrovsky et al. 2010, Kondratov et al. 2006, Lamia et al. 2008, Marcheva et al. 2010). During normal aging, rhythms decrease in amplitude and often exhibit a shift in phase (Chaudhari et al. 2017, Froy & Miskin 2010, Gibson et al. 2009, Hofman & Swaab 2006, Sato et al. 2017, Scarbrough et al. 1997, Yamazaki et al. 2002). We have found a marked decrease in circadian cycling genes in young vs. aged mouse liver gene expression. These age-related decreases involve both the number and amplitude of core circadian clock genes, metabolic pathways as well as genes involved in longevity pathways. Thus, these indices of circadian gene expression can be used as biomarkers of aging. Importantly, the circadian system is upstream of the majority of metabolic pathways implicated in longevity (Asher & Sassone-Corsi 2015, Di Francesco et al. 2018, Fonseca Costa & Ripperger 2015, Froy 2013, Lopez-Otin et al. 2016). Molecules known to regulate lifespan by dietary restriction, such as insulin/IGF-1, SIRT1, NAMPT, AMPK, PGC-1α, mTOR, GSK3β are all intricately involved in the molecular mechanisms of circadian clocks (Asher et al. 2008, Asher & Schibler 2011, Bass & Takahashi 2010, Bellet et al. 2011, Harada et al. 2005, Hirota et al. 2008, Lamia et al. 2009, Liu et al. 2007, Nakahata et al. 2008, Nakahata et al. 2009, Ramsey et al. 2009, Zhang et al. 2009). Among these gene targets are key metabolic regulators and rate-limiting enzymes in every fundamental metabolic pathway in the liver (Koike et al. 2012, Panda et al. 2002, Rey et al. 2011). Nutrients can also regulate the clock, introducing interlocking loops in which rhythmic outputs can feed back to modulate the core clock loop (Kohsaka et al. 2007).

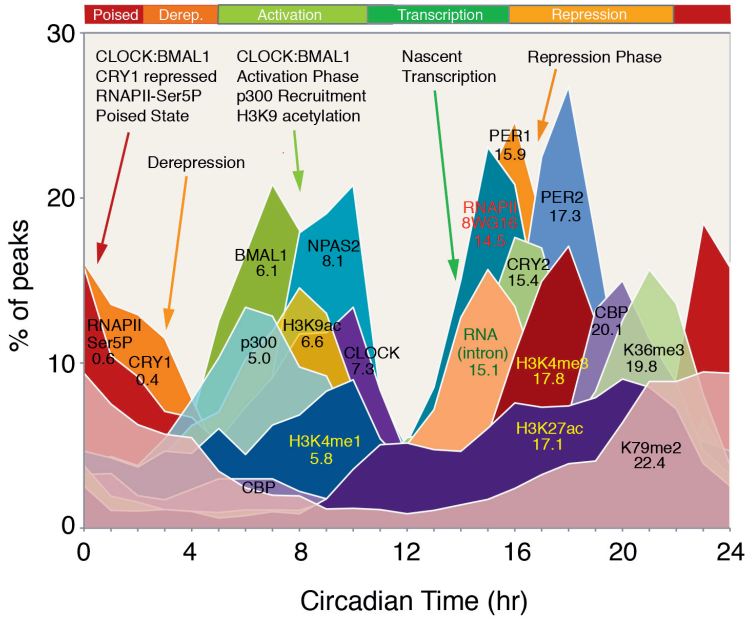

Figure 1. Circadian transcriptional and epigenomic landscape in the mouse liver. The circadian clock drives a genome-wide program in time-dependent pattern of core circadian transcription factor binding, RNAPII occupancy, RNA expression and chromatin states. Histograms show the phase distributions of each factor as a function of time of day (from Koike et al. 2012).

Mechanism of the Circadian Clock in Mammals

The circadian system controls 24-h physiological and behavioral processes, including the regulation of sleep, feeding, hormones and metabolism. Circadian clocks are transcriptional/translational negative feedback loops that drive the rhythmic expression of thousands of genes in mammals (Takahashi 2017a). The circadian clock mechanism consists of an autoregulatory negative feedback loop in which the transcriptional activators, CLOCK and BMAL1, drive transcription of the *Period* (*Per*) and *Cryptochrome* (*Cry*) genes (Figure 2) (Bass & Takahashi 2010). The protein products of these genes, PER and CRY, form complexes with each other and translocate back to the nucleus where they interact with CLOCK:BMAL1 and repress their own transcription (Takahashi 2017a). Regulated degradation of PER and CRY, in the cytoplasm and nucleus, maintains the proper timing of repression and thus determines the period of the oscillation. In addition to generating the negative feedback loop that makes up the core loop of the clock, these circadian activator and repressor proteins also regulate the expression of thousands of other genes (Takahashi 2017a). Among these gene targets are key metabolic regulators and rate-limiting enzymes in every fundamental metabolic pathway in the liver (Koike et al. 2012, Panda et al. 2002, Rey et al. 2011). Various signals (such as nutrient status) can also regulate the clock, introducing interlocking loops in which rhythmic outputs can feed back to modulate the core clock loop (Eckel-Mahan et al. 2013, Kohsaka et al. 2007). Of particular significance, several of the signaling pathways and proteins that have been implicated in aging are rhythmic and also directly regulate the core components of the circadian clock (Figure 2). For example, SIRT1 is a NAD^+-dependent histone deacetylase, thought to modulate gene expression according to the metabolic state of the cell, but is also part of the main transcriptional complex of CLOCK:BMAL1 that drives the core circadian loop and is rhythmically expressed (Asher et al. 2008, Nakahata et al. 2008, Nakahata et al. 2009, Sato et al. 2017). AMPK senses AMP/ATP ratios (and hence energy state) and included in its targets are the main circadian transcriptional repressors, CRY1/2 (Lamia et al. 2009). mTOR is a key component of a signaling pathway that plays a critical role in regulating energy metabolism and glucose homeostasis and has also been implicated in entrainment of the core circadian clock in the mouse brain (Zheng & Sehgal 2010) and levels of TOR help determine the circadian period in *Drosophila* (Cao & Obrietan 2010).

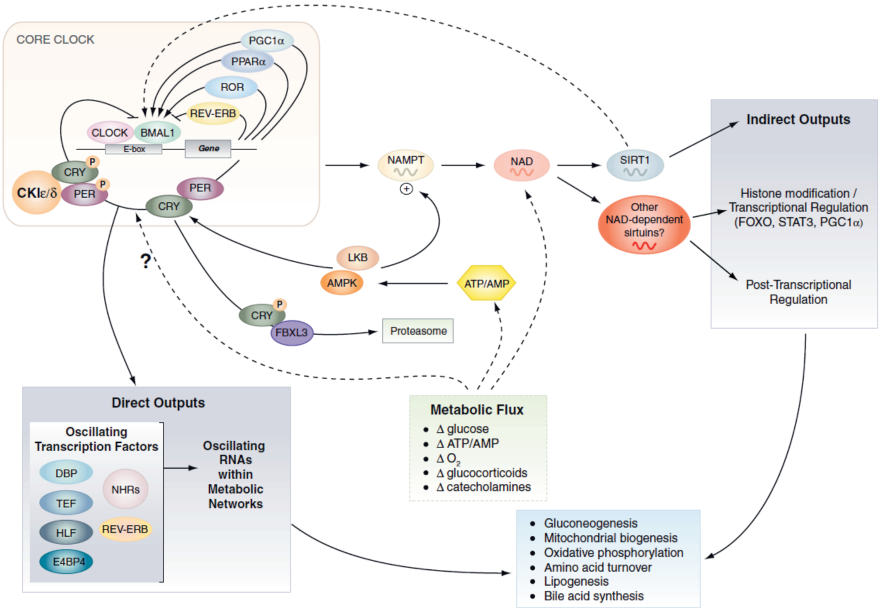

Figure 2. Molecular mechanism of circadian clock (from Bass & Takahashi 2010).

In the intact animal, the central clock located in the hypothalamic SCN controls many aspects of behavior and synchronizes the cell autonomous clocks located in tissues throughout the body through humoral and neural signals that are still largely uncharacterized (Mohawk et al. 2012). This system is synchronized to the local environment by direct photic input from the retina to the SCN, but other environmental signals can also entrain the various oscillators. One of the most powerful non-photic entraining agents is food (Mistlberger 2009, Stephan 2002). Maintaining mice on a time-restricted feeding (TRF) paradigm, where food access is restricted to a few hours in the day (a time when nocturnal rodents normally eat only sparingly) causes anticipatory activity a few hours before the time of food accessibility and causes the circadian clocks in the peripheral tissues such as liver to shift in phase by many hours with little or no effect on the SCN (Damiola et al. 2000, Vollmers et al. 2009).

The changes caused by TRF can have profound effects on the animal. For example, mice fed a high-fat diet only during the light phase gain significantly more weight than mice fed the same diet only during the dark phase (Arble et al. 2009). In another study, mice were fed a high-fat diet restricted to an 8-hour window during the night and compared to a group of mice fed *ad lib*. The TRF mice consumed the same amount as the *ad lib* mice, but were protected against high-fat diet-induced obesity, hepatic steatosis, hyperinsulinemia and inflammation (Hatori et al. 2012). More recently, TRF has been shown to be effective against diverse nutritional challenges (Chaix et al. 2014), as well as preventing obesity in circadian mutant mice (Chaix et al. 2018). Thus, temporally restricted feeding at night is beneficial over a wide range of nutritional challenges and in circadian mutants.

Circadian rhythms and aging

High amplitude circadian rhythms correlate with well-being (Froy 2013, Froy 2018, He et al. 2016), whereas clock dysfunction leads to metabolic disorders, premature aging and reduced lifespan (Dubrovsky et al. 2010, Kondratov et al. 2006, Lamia et al. 2008, Marcheva et al. 2010, Turek 2005). During normal aging, rhythms decrease in amplitude and often exhibit a shift in phase (Chaudhari et al. 2017, Froy & Miskin 2010, Gibson et al. 2009, Hofman & Swaab 2006, Sato et al. 2017, Scarbrough et al. 1997, Yamazaki et al. 2002). Aged animals also have defects in entrainment to environmental signals such as light-dark cycles (Zhang et al. 1998). In addition to a decline in circadian rhythms, aging is characterized by a deterioration of homeostatic processes, which leads to increased susceptibility for disease and death (Anderson & Weindruch 2010, Bishop & Guarente 2007, Canto & Auwerx 2009, Lopez-Otin et al. 2013, Lopez-Otin et al. 2016, Masoro 2005, Mattson & Arumugam 2018, Mercken et al. 2012). Many molecules involved in nutrient sensing functions have been shown to regulate lifespan (Anderson & Weindruch 2010, Barzilai et al. 2012, Canto & Auwerx 2009, Kenyon 2010, Wang et al. 2011, Zhang et al. 2012), and, interestingly, many of these are also intricately involved in the molecular mechanisms of circadian clocks (Asher et al. 2008, Asher & Schibler 2011, Bass & Takahashi 2010, Bellet et al. 2011, Harada et al. 2005, Hirota et al. 2008, Lamia et al. 2009, Liu et al. 2007, Nakahata et al. 2008, Nakahata et al. 2009, Ramsey et al. 2009, Zhang et al. 2009). Furthermore, administration of hormones associated with metabolic function (insulin, corticosterone and prolactin) at specific times of day to mimic rhythmic patterns in young rats can reverse age-related increases in insulin resistance and body fat in older rats (Cincotta et al. 1993). Additionally, a natural flavonoid compound, nobiletin, acts as a clock-enhancing molecule, which prevents body weight gain without altering food intake, stimulates energy expenditure and circadian activity, enhances glucose and insulin tolerance, and diminishes lipid content in mice (He et al. 2016). In addition, nobiletin significantly improves metabolic fitness in naturally aged mice fed with a regular diet and enhances healthy aging in mice fed with a high-fat diet by optimizing skeletal muscle mitochondrial respiration (Nohara et al. 2019). Thus, interventions that improve circadian rhythms, and, in particular, metabolic rhythms, may prolong life.

Effects of caloric restriction on feeding behavior

Caloric restriction (CR) is the most effective non-pharmacological intervention that improves lifespan in model organisms (Anderson & Weindruch 2010, Canto & Auwerx 2009, Di Francesco et al. 2018, Fontana et al. 2010, Gonzalez-Freire et al. 2020, Le Couteur 2018, Lopez-Otin et al. 2016, Mercken et al. 2012, Most et al. 2017). A major confounding aspect of the CR regimen is that it causes a change in both the amount of energy and the temporal pattern of food intake (Froy 2013). We have found that CR protocols cause mice to eat each daily allotment of food as soon as it is available, and in this case, in a 2-hour window of time (Acosta-Rodriguez et al. 2017). This severe self-imposed time-restricted feeding pattern suggests that a circadian component could contribute to the beneficial effects of CR (Froy 2013). Although a reduction in energy intake is commonly thought to be the critical factor that extends lifespan and well-being in the CR regimen, it is possible that the timing of the food intake is also a key component.

Circadian alignment of feeding under caloric restriction maximizes lifespan

In order to disentangle the contribution of calories, fasting and circadian alignment of eating on longevity, we have recently completed a compelling longevity study (Acosta-Rodriguez et al. 2022). We demonstrate that CR is sufficient to extend lifespan but that the pattern and circadian-alignment of feeding under CR acts synergistically to extend lifespan. Calorie reduction alone increases lifespan only by ~10%, while time-restricted CR during the active phase extends lifespan more than 3 times longer (35%) (Figure 3). Circadian alignment of feeding enhances CR-mediated benefits on survival independently of fasting duration and body weight. Aging promotes widespread increases inflammation and decreases in metabolism in the liver from *ad lib* fed mice; whereas CR at night ameliorates these aging-related changes. Thus, circadian interventions promote longevity and provide a new mechanism for the treatment and management of aging.

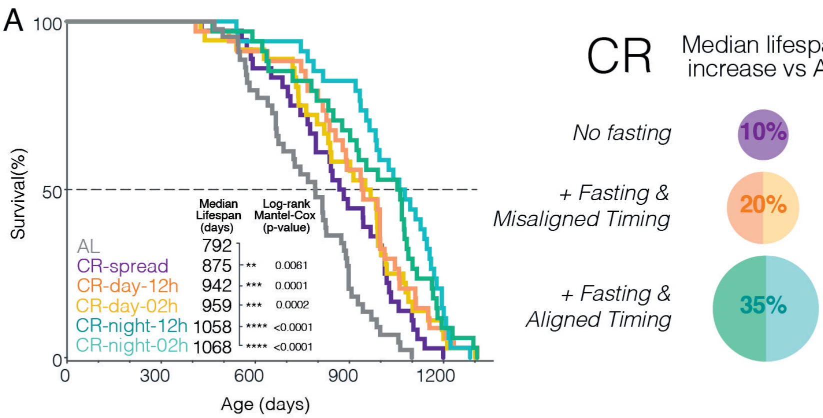

Figure 3. Effects of CR on lifespan depend on feeding time. (A) Survival curves for each group (n = 43 for AL and n = 36 for each of the CR) are shown in left panel with median lifespan (days) inset. Right panel summarizes the results, showing the increase in lifespan from timed feeding with the largest increase when food is restricted to night (from Acosta-Rodriguez et al. 2022).

Summary

Aging of the human population on earth is one of the major risk factors for morbidity and chronic disease. Recent work has shown that time restriction in humans leads to benefits in health span measures (Chaix et al. 2019, de Cabo & Mattson 2019, Redman et al. 2018, Sutton et al. 2018, Wilkinson et al. 2020). Note that the optimal time for humans is during the daytime when we are normally awake and active. Our new results suggest that both caloric restriction and circadian phasing of nutrient intake work synergistically to extend lifespan in mice and perhaps these principles will also apply to humans.

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TIME AS CONSTRUCT AND IMPLICIT CODING SPACE. A NEUROBIOLOGICAL PERSPECTIVE

Wolf Singer [*]

Introduction

"If you do not ask me, I know what time is but if you ask me, I do not know". This statement is ascribed to St. Augustin, reproduced here in the translation of John Locke.

I believe, the same holds for consciousness. "If you do not ask me, I know what consciousness is but if you ask me, I do not know".

Both terms designate immaterial phenomena that are amenable to shared experience, that are perceived as realities and that are measurable. Both share properties with the many immaterial phenomena that mankind has identified as real in the course of cultural evolution and identified as sufficiently distinct to deserve a name. Both share properties with the phenomena that John Searle addressed as social realities; realities that have the status of mental constructs, have been brought into the world in the course of cultural evolution and became an integral part of our world.

Interestingly, the two phenomena "time" and "consciousness" have commonalities also with respect to their respective neuronal representations. There are no specialized processing structures in the brain that could mediate the experience of time nor of being conscious. This is in stark contrast to all other perceivable realities. The brain possesses centres devoted to the analysis of signals from all five senses, for the programming of executive functions, for planning actions, for the representation of space and for the generation of emotions and feelings; but so far no distinct area has been identified that is devoted to the processing of time. Nor is it possible to identify an area whose function is devoted to the mediation of conscious experience.

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The structure of neuronal representations

The various areas of the cortical mantel that deal with specific functions have to closely cooperate and interact with one another in order to generate coherent polymodal percepts, to program coordinated motor responses and to bind past experiences into integrated memories. Accordingly, the prevailing principles of their connectivity are very dense reciprocal coupling, distributedness and a rather flat hierarchy. It is possible to travel along neuronal pathways from any given area to any other area mostly through direct connections or with only one or two switching stations. This organization resembles that of small world or rich club networks and raises the fascinating question, how perceptual objects, whether they are visual, auditory or tactile, are represented in the cortical mantel. There is obviously no single place where a particular object could be represented, in particular if it has properties that are processed by different sensory modalities and need to be bound together in order to form a coherent percept. Rather it appears as if the representations of cognitive objects are non-local and consist of highly complex spatio-temporal patterns of neuronal activity that are distributed over many different areas, each of which processes only one particular aspect of the perceptual object. The question how the various attributes of such coherent percepts are bound together if there is no convergence on a distinct site is still a matter of controversial discussion. One proposal is, that the tag of relatedness, the glue that binds it all together, consists of the temporal coherence of the respective neuronal activity patterns (*Singer, 1999*). Unity would thus be achieved by convergence in time rather than convergence in space.

Given this organization one is tempted to hypothesize that time and consciousness might also be represented in such a holistic way; that the perception of time and the awareness of being conscious are an emergent property of distributed processing and do not require a particular locus for their representation.

Although the temporal dimension does not seem to be explicitly represented it is of course implicit in virtually all cognitive processes. Our senses sample information sequentially and sequence order defines causal relations. Accordingly, all molecular learning mechanisms are sensitive to temporal correlations and sequence order. Navigation requires the notion of the what and the where, and in particular of the when. Programming of movements, planning of future acts and predicting anticipated events all require the parsing and estimations of time. Hence, it is obvious that cognitive systems care about time but it is still a matter of intense investigations whether and how they exploit the temporal dimension for computations.

Time as coding space

I shall approach the question how the temporal domain is used in information processing by contrasting natural with artificial cognitive systems. The reason is that the former actually exploit the temporal dimension for processing while most of the artificial systems known to us today do not.

All cognitive systems have to evaluate and encode relations because the structure of the world is modular. The virtually infinite variety of objects is due to the variable recombination of a limited number of components. Not the difference between components but the variation of the relations is the main cause of diversity. Less than 100 atoms suffice to generate the diversity of the physical world and the 26 symbols of the Latin alphabet suffice to compose the world literature. Therefore, cognitive systems need efficient strategies for the encoding of components and in particular the relations among components in space and time.

For nervous systems the simplest way to encode relations among components is to generate neurons that respond to components or elementary features of composite objects and to connect these neurons to a second order neuron. By appropriately adjusting the gain of these connections and the threshold of the second order neuron one can make sure that the latter becomes active only if the respective set of feature/component selective cells is active. Thus, the response of the second order neuron indicates the presence of a particular constellation of components and thereby encodes the relations among these components. This strategy is realized in virtually all natural systems and is also the prevailing principle in artificial systems, such as the very popular deep learning networks. In the domain of artificial intelligence this strategy is implemented as the Perceptron architecture. The output layer of these systems contains an array of conjunction specific neurons, each of which signals the presence of a particular constellation of features/components. Because these conjunction specific neurons always signal the same constellation, this coding scheme is also addressed as "labelled line" coding. In such systems the flow of activity is unidirectional. Activity is routed from the input layer over a number of hidden layers to an output layer that contains the readout units and through a learning algorithm known as back propagation, the weights of the connections from the input layer over the many hidden layers to the output layer are adjusted such that a particular input vector gets mapped onto a particular output unit. Once the network is trained, a particular pattern presented to the input layer will activate a particular and if possible, a sole output unit. (See Figure 1).

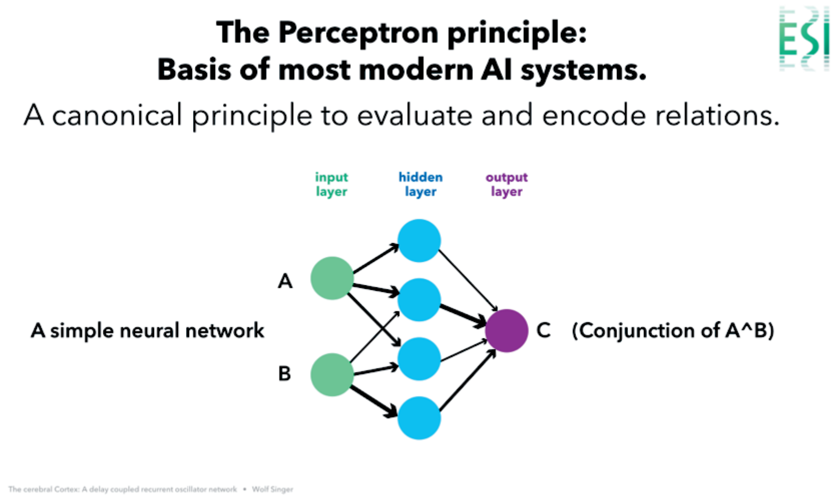

Figure 1. A relation between input features A and B is established by feed-forward connections to the conjunction specific neuron C. Appropriate adjustment of the gain of the feed-forward connections assures that C is activated only if input neurons A and B are active. This principle is iterated over many "hidden layers" in Deep Neuronal Networks.

The limitations of representing relations by such conjunction specific units in a labelled line code are obvious. One problem is addressed as the combinatorial explosion. One needs as many output units as there are distinguishable objects and one needs a large number of hidden units in intermediate layers in order to account for the very large number of possible combinations of input signals. The entirety of possible relations among components needs to be represented explicitly by the combination of convergent connections. Another limitation is the inability of such feed forward systems to analyse and represent temporal relations. All computations are serial and follow the rhythm of the computer clock. Hence, time is not used as coding space and temporal relations are not considered as informative. It is probably for this reason that nature has opted for an additional strategy to encode relations; a strategy that exploits not only space but also the temporal domain for computations.

Time as coding space in natural systems

In natural systems relatedness is expressed by the temporal correlation of activity, rather than spatial contiguity. This is intuitively plausible as we tend to relate events with one another that are temporally contiguous. This coding strategy requires that neural activity is endowed with temporal structure. The simplest strategy to parse time is the implementation of oscillatory mechanisms, a principle used in virtually all clocks. Once one has rhythmic responses, one can modulate their synchronicity and encode relations by variable degrees of temporal correlations. In this way, one can establish transient associations of neurons that code for related features. Or in other words, one can establish relations between components by making the neurons that code for these components synchronize their activity in time. There is indeed ample evidence that neurons in the brain and small circuits of neurons engage in oscillatory activity and when the components that are encoded have some semantic relations the neurons activated by these components synchronize their rhythmic discharge patterns (for review see *Singer, 2021*). The mechanism through which such synchronization is achieved is based on reciprocal interactions between neurons that have the propensity to oscillate. These interactions are mediated by connections whose gain is adjusted by experience. Coupling strength among neurons increases to the extent that these neurons have in the past been activated frequently in temporal contiguity. The mechanism that allows an increase in the coupling among neurons has been described and postulated in the early 40s by *Donald*

Hebb (1949), and since then is called the Hebbian mechanism. The rule is simple: Neurons wire together if they fire together. As a consequence, neurons that are frequently activated in temporal contingency strengthen the coupling of their reciprocal connections. Thus, neurons responsive to components or features in the outer world that happen to cooccur frequently, become coupled more strongly. The consequence is that if these neurons are activated by the presence of their respective features, they engage in transient synchronous firing patterns, and this temporal contiguity signals the relatedness of the respective components. In other words, statistical regularities in the composition of the outer world, the consistent relations among object defining features get inscribed in graded coupling strengths of reciprocal connections and are eventually recoded in temporal relations. Such a code allows for a flexible association of different feature selective neurons at different times depending on the respective constellation of features in the outer world. Thus, in contrast to a labelled line code, this is a combinatorial code. It is much more versatile, can cope with the combinatorial explosion problem and requires much less hardware investment, because the same neurons can be used at different times to encode different relations. However, in order to realize such a code, it is necessary that information is not only processed in simple feed forward networks but that neurons within the same layer interact reciprocally, they need to be coupled recurrently. Another advantage of such a wiring scheme is that reciprocally coupled networks develop very interesting very complex, very high dimensional dynamics that can be exploited for computations. A prototypical example of the recurrent network realized in the superficial layers of the cerebral cortex is depicted in Figure 2.

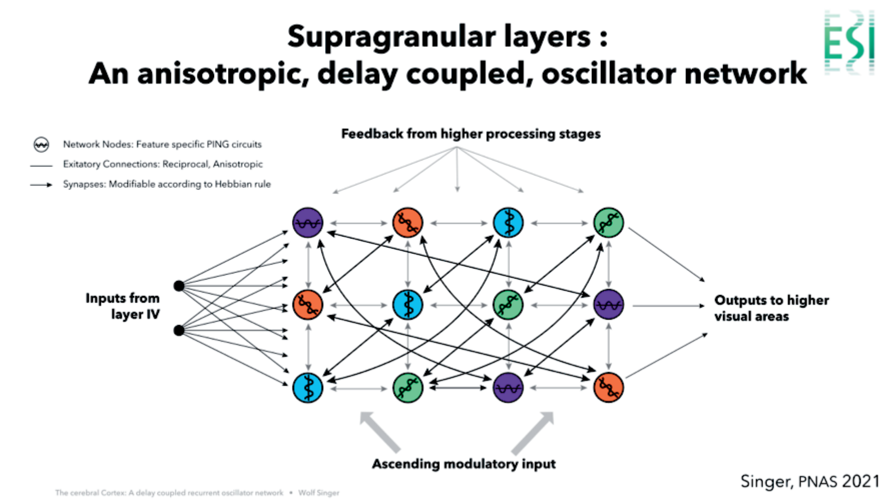

Figure 2. A schematic wiring diagram of the recurrent network realized in the cerebral cortex. Network nodes (coloured) are tuned to particular features of sensory input, have the propensity to oscillate and are reciprocally coupled. The coupling connections between nodes tuned to features that often cooccur in natural environments (indicated by similar colours) are stronger than those between nodes coding for unrelated features (modified from *Singer, 2021*).

Properties of recurrent networks

Recurrent networks respond to perturbations with reverberating activity. In a sense, their dynamics can be compared with the properties of a liquid in a reservoir. This is why computations performed on the basis of recurrent networks are sometimes addressed as reservoir computing or liquid computing (for review see *Singer, 2021*).

Here is an intuitive example. Imagine a pond of water into which one throws a series of stones, large and small stones at different places with different impacts. Each of these stones will cause a perturbation of the liquid which gives rise to a traveling wave that expands across the pond. Since there were several events, the result will be a very complex interference pattern of waves caused by the various impacts of the different stones. It is possible to reconstruct from this very high dimensional dynamic pattern the exact sequence of events that caused these traveling waves. It suffices to measure at three or four different places in the pond the amplitude, the wavelength and the frequency of the waves, i.e. the phase of the oscillations, to reconstruct what has happened in the past. This exemplifies that reservoirs or recurrent networks have a memory function, the so-called fading memory. Thus, they can code for sequences and this property can be exploited in order to encode sequential information and temporarily store this information until it is read out. As long as the reverberation lasts and before the damped oscillations have faded completely, the information about the events that caused the perturbation can be retrieved. This example is only a crude approximation of the recurrent networks realized in the cerebral cortex because the coupling between the molecules of the water is homogeneous while the coupling between neurons is mediated by connections that are modified by previous experience (see Figure 2). Neurons, coding for particular features get coupled preferentially if those features cooccur frequently in the natural environment. In this way, the characteristics of statistical regularities of the environment get stored in the coupling connections of this recurrent network. Hence, the recurrent network in the cerebral cortex is not a homogeneous medium like the water in the pond, but it is a highly anisotropic specifically coupled medium whereby the coupling strength reflects statistical regularities of the environment. Thus, the recurrent network can be considered as a store for structural regularities of the world that can be used as a-priori information, as prior, for the processing of sensory signals that arrive from the outer world.

Perception is a constructivistic process

It is well established that perception is a constructive or reconstructive process whereby sparse sensory signals are compared with a huge amount of stored information about the likely constellation of the world. And this information is used in order to interpret the particular constellation of features provided by the sensory evidence. Hence, the resulting percepts are a reconstruction based on both sparse sensory evidence and the comparison of this evidence with stored knowledge. This matching operation is called predictive coding. It is noteworthy that recurrent networks are particularly suited to accomplish such matching operations. The recurrent networks in the brain are permanently active and produce spontaneous activity patterns. These patterns are high dimensional continuously changing landscapes. A fairly realistic metaphor of the very high dimensional dynamics of spontaneous activity of cortical networks is the surface of the ocean with its irregular interference patterns of waves with shallow slopes and large amplitude into which smaller quisling waves are nested. If sensory evidence is provided to recurrent networks by input from the sense organs and if there is a good match with some of the stored priors, ongoing activity undergoes a very rapid restructuration. The very high dimensional activity pattern collapses towards lower dimensional substates that then corresponds to the match between the respective sensory evidence and the stored knowledge. These lower dimensional sub-states can, thus, be considered as the result of a Bayesian matching operation. This interpretative operation is one of the major tasks that cortical networks need to achieve and they use the temporal dynamics of recurrent networks to accomplish the complex computations (for more details see *Singer and Lazar, 2016; Singer, 2021*).

In summary, the dynamics of recurrent networks whose nodes are oscillatory are extremely complex and high dimensional and therefore provide fascinating options for computations. The high dimensional state space permits the storage of vast amounts of information and its superposition as mentioned above in the example of the water reservoir. It allows for parallel search of matches between sensory evidence and a-priori information that is stored in the graded coupling strength of connections between nodes; and for the same reason it allows for ultra-fast readout. The collapse of the system from a high dimensional resting state into a lower dimensional sub-state that is equivalent with the result of a matching operation is very fast. It takes only a few 100 milliseconds in the nervous system for this operation to be accomplished. Finally, because of the very high dimension of this coding space, representations of different objects can be separated very well into different regions of this high dimensional space. Consequently, different representations can be classified easily by linear classifiers. Objects or contents that would be overlapping and superimposed in low dimensional space can be segregated in high dimensional space and then separated by linear surfaces, which is the strategy that linear classifiers apply.

Another benefit of exploiting the non-linear dynamics of recurrent networks is the conversion of spatial relations into temporal relations. Disturbing a recurrent network with an input pattern leads to travelling waves and hence to sequential activation of nodes, whereby the sequence of the sequential activation is stimulus specific. One particular stimulus could lead to a sequential activation of nodes A, B, C, and D, while another stimulus would cause a sequential activation of the very same nodes but in a different sequence C, D, A and then B, and so forth. This allows generation of a very versatile code whereby the same nodes can be used to encode different stimulus patterns. Moreover, this code allows for fast read out because the sequences are short. A classifier that uses sequence order rather than the vector of graded discharge rates can identify a particular stimulus within a few 100 milliseconds. The classifier does not have to integrate the discharge frequency of different nodes over long periods of time. Because the discharge rate of neurons in the cerebral cortex is low, activity would have to be integrated over long intervals before the amplitude of the responses can be assessed reliably. In case of a sequence order code the classifier only needs to determine the onset of a response and then analyse the sequence of activations of different nodes.

Conversely, such networks are also well suited to analyse sequential input such as is produced for example, by language or music. It suffices e.g. to distribute the output signal of a microphone onto a subset of nodes. If different nodes are tuned to different frequencies they will be activated at different times. The sequence of different frequencies in the utterance will be converted into a stimulus specific sequence code. This makes recurrent networks particularly well suited to analyse stimuli that have a temporal structure.

Yet another highly interesting and valuable property of recurrent networks is their ability to reproduce the information that they have been processing recently. As mentioned earlier, the coupling connections among the nodes of the networks, the neurons, are adaptive and change their efficiency as a function of the correlated activity of the interconnected nodes. Because of this experience dependent change in the coupling among neurons, the network structure adapts to the statistics of previously processed stimuli. This has an attractive consequence: during resting state, when the network is idling, when it is just spontaneously active and not processing sensory input, it can reproduce stimulus specific spatio-temporal patterns, just as if it had been activated by this particular stimulus. One can train classifiers to analyse the spatio-temporal patterns in the high dimensional vectors of the activity produced by the network nodes to particular stimuli, and then search in resting activity, whether one can retrieve this information. It does turn out that the network after having been familiarized with a particular stimulus, tends to reproduce the patterns that it had generated while it was processing this particular stimulus. The network replays stimulus specific information, it has a memory of the past and this memory is engraved in the weight distributions of the coupling connections that change all the time while the network gains more experience. And because of the high dimensionality of the dynamic state of this network it can store an immense number of different patterns and replay them sequentially. We don't know yet in which order these stored representations are replayed and whether the sequences recapitulate stimulation history or pop up at random (for details see *Lazar et al., 2021*).

In summary, the representation of a stimulus consists of a highly distributed spatio-temporal pattern, a high dimensional landscape of peaks and valleys with high and low activity that differ not only in their amplitude but also in the degree of synchronization and phase shifts. By implementing network nodes that function as damped oscillators, nature has found an elegant way to exploit the full range of the dynamics offered by coupled oscillator systems such as synchronization, phase shifting, entrainment and resonance in order to translate relations among component features into complex correlation structures.

Simulation of a delay coupled recurrent oscillator network

In order to arrive at those conclusions, we performed a large number of electrophysiological studies in awake behaving monkeys, but I shall not recapitulate the results of these studies in detail but rather refer the reader to recent review articles and original publications that are available under open access rules (*Gray and Singer, 1989; Gray et al., 1989; Singer, 1999; Singer and Lazar, 2016; Singer, 2021)*.

Most often electrophysiological studies only allow one to establish correlations between measured neuronal activity and behaviour. It is notoriously difficult to determine causality and to ascertain that the observed phenomena are really causally relevant for particular functions rather than being just an epiphenomenon. One of these problems was the identification of the functional role of oscillatory activity. The question was whether these oscillations really play a functional role or are an epiphenomenon of some other processes such as gain control by recurrent inhibition. The challenge is that it is virtually impossible to selectively manipulate the oscillations without at the same time interfering with other variables of the neuronal responses. Therefore, we started with a large-scale simulation study, implementing step by step features that we knew were realized in the cerebral cortex. This taught us that the implementation of oscillatory processes was actually essential for the functions of these simulated networks. Once we configured the nodes of the network as damped oscillators our networks became extremely efficient in processing patterns and encoding stimulus specific information in a way that permits fast and unambiguous identification. This was the first evidence that the implementation of oscillators into recurrently coupled networks is beneficial for their functions. The reason is that the interactions among reciprocally coupled oscillators allow for analogue computations. These computations can fully exploit the temporal dynamics of such interactions: resonance, entrainment, synchronization, desynchronization, phase shifting, reverberation and fading memories. We then also implemented an important feature of natural networks which is delays in the coupling between the oscillating nodes. Neuronal pathways have a finite conduction velocity. They transmit electrical signals with a speed of five to fifty meters per second, rather than light speed. To our surprise, introducing coupling delays further increased the performance of the simulated network. The reason is that coupling delays increase the dimensionality of the dynamic space that the network can explore and use for its computations.

In a next step we examined the changes in network architecture induced by learning. Although we implemented an artificial learning algorithm called "backpropagation through time", we found that the network adapted the gain of its coupling connections as one would predict if the connections were allowed to change their gain according to the Hebbian correlation rule. "Neurons wired together if they fired together". Once the network was trained to perform pattern recognition tasks it turned out that it outperformed state of the art recurrent networks with respect to the investment in hardware, learning speed and noise tolerance. The biologically inspired network required much less variables to achieve the same performance as the published solutions. It was surprisingly noise tolerant and could still solve recognition problems that other networks had great difficulties to cope with. And it required much less learning steps.

Because it is easy to manipulate in a controlled way artificial networks it is now possible to identify the mechanisms responsible for superior performance. The main reason is, that the biologically inspired network uses time as coding space and that the implementation of nodes functioning as damped oscillators permits analogue computing. Another outcome is that heterogeneity is beneficial. It expands coding space and kick starts the learning process.

As expected this network also reproduced most of the dynamic phenomena that one encounters in electrophysiological data obtained from the cerebral cortex and assigns distinct functions to them. These include the already mentioned synchronization phenomena, the fading memory, the superposition of information, replay of learnt patterns and travelling waves. It was also able to convert spatial information into response sequences and conversely, transform sequential sensory evidence (time series) into classifiable low entropy substates.

Some of the computational operations actually resemble strategies that are also used in quantum computing. As mentioned already, the network has the property to rapidly descend from a high dimensional resting state into a low dimensional sub state when provided with sensory evidence. The network dynamics collapse towards a state that provides the most likely solution for the match between incoming sensory evidence and priors - priors that are stored in the anisotropic coupling among the nodes. This collapse can be understood as an Ising process. A system of interacting nodes with particular spins - in our case defined by oscillation frequency, phase and amplitude - strives in a self-organized way towards a state of minimal free energy. The network compares simultaneously a large number of probabilistic variables by letting them interact with one another through the recurrent connections. Computations are thus analogue and completely parallel and this explains why natural systems can solve complex computational problems with such high speed despite the slow time constants of their hardware. A publication describing this biologically inspired recurrent network is in preparation (*Effenberger et al., 2022*).

Concluding remarks

In conclusion it appears as if evolution had discovered a way to realize computations that, at least in certain aspects, resemble those accomplished by quantum computers with neuronal networks functioning on the basis of classical physicochemical processes. This is the likely reason why our brains are particularly good in solving computational problems that require the simultaneous comparison of a huge number of variables. This applies for all cognitive operations that require the analysis of complex structures characterized by a multitude of nested relations among the components. Prominent examples are scene segmentation and speech recognition. Numerous questions still await answers. Thus, it is still unresolved, how hierarchical relational constructs can be dealt with such as "the bug on the leave which is at the end of the most distal branchlet of a branch that belongs to a tree standing in the meadow which is surrounded by mountains". Such hierarchically ordered nested relations need to be analysed and encoded on the fly in order to understand complex scenes. These are functions that neuronal systems accomplish with great elegance and speed and very low energy consumption and are very challenging for conventional artificial networks.

The interpretation of brain functions offered in this contribution has perhaps also interesting epistemic implications. We have no intuition for the complex, high dimensional processes that underly the working of our brain. Our cognitive functions have not been optimized to deal with the dynamics of high dimensional non-linear systems. Therefore, it is difficult for us to accept that the neuronal representations of real-world objects that appear as concrete and solid should consist of highly dynamic, high dimensional and widely distributed clouds of neuronal activity. However, since thoughts, feelings and last but not least the experience of time are likely to be represented in the same format, this novel view of the brain might help to alleviate the apparent dichotomy between matter and mind.

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THE BRAIN IS A TIME MACHINE: THE NEUROSCIENCE OF TIME

Dean Buonomano [*]

Few questions are as perplexing and profound as those that relate to time. Philosophers ponder what time is, and whether it is a single moment or a full-blown dimension. Physicists grapple with why time appears to flow in only one direction, whether time travel is possible, and even whether time exists at all. Neuroscientists and psychologists, in turn, struggle to understand what it means to "feel" the passage of time, how the brain tells time, and why humans are uniquely capable of mentally projecting ourselves into the future. And time is at the heart of the question of free will: is the future an open path, or preordained by the past?

Although time remains a mystery that transcends scientific fields, it is clear that time lies at the core of neuroscience because the brain is an inherently temporal organ. For example:

The brain is an information processing device that remembers the past in order to predict the future. Over hundreds of millions of years, animals have engaged in a race to predict the future. Animals foresee the actions of prey, predators, and mates; they prepare for the future by caching food and building nests; and they anticipate dawn and dusk, spring and winter. The degree to which animals succeed in divining the future translates into the evolutionary currency of survival and reproduction.

The brain tells time across a wide range of scales. From the tens of microsecond interaural delays used for sound localization, to the milliseconds and seconds needed to generate movements that underly motor coordination, to the biological clocks that govern circadian and seasonal cycles. But the neural circuits that tell time are not simply passively telling time like man-made clocks, they are implementing computations. We may refer to the clock that governs our daily rhythms

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as the circadian clock, but it is actually a prediction device: it anticipates changes in the external environment.

The brain creates our subjective sense of time. Unlike vision or hearing, we do not have a sensory organ that detects time. Time is not a form of energy or a fundamental property of matter that can be detected via physical measurements. Yet, much in the same way that we consciously perceive the color of objects (the wavelengths of reflected electromagnetic radiation), we consciously perceive the passage of time. The brain creates the feeling of the passage of time. Like most subjective experiences, our sense of time undergoes many illusions and distortions. Subjectively, the same duration - as measured by an external clock - can seem to fly by or drag depending on a multitude of factors. But distorted or not, the conscious perception of the passage of time, and that the world around us is in continuous flux, is among the most familiar and undeniable experiences of all.

Mental time travel. Humans have the unique ability to understand the concept of time and mentally project themselves backwards into the past and forwards into the future - that is, to engage *mental time travel*. We mentally re-experience the joy or sorrow of past events, and run alternate simulations of those episodes to explore what could have been. In the other direction we jump into the future every time we dread or daydream about what may come, and we simulate different plotlines of our future lives in the hope of determining the best course of action in the present. The human brain is unique in its ability to conceptualize time along a mental timeline and engage in mental time travel. This form of cognition allows us to engage in species-defining future-oriented activities, such as agriculture, science, and art.

Telling Time Across Scales

The brain is a product of natural selection, and was thus "designed" to survive in a harsh and continuously changing world. As it turns out, one of the best ways to prosper in such a world is to be able to predict *what* will happen in the future, and *when* it will happen. So, the brain is both an anticipation machine, and a machine that tells time. It quantifies the passage of time across a range of over twelve orders of magnitude -

from the tiny differences in the time it takes a sound to arrive at the right ear vs. the left ear, to the ability of some animals to anticipate the seasons.

Close your eyes and focus your attention on some sound in your environment - perhaps the hum of an appliance. You can easily tell if the sound is coming from your left or your right. But how does your brain figure out where in space the sound is originating? A sound coming from the left takes a bit more time to arrive at your right ear than your left. These so-called interaural time delays are a function of the speed of sound and the size of your head. For humans, detectable delays can be around ten microseconds - one thousand times less than the resolution of the chronometers used to time the 100 meter sprint in the Olympics. The parts of your brain responsible for processing sound must measure these delays to calculate the location of sound sources. Evolution has exploited the fact that because the speed of sound is fairly constant, space and time are complementary - thus telling time allows us to "tell" space.

On the intermediate scale of tens of milliseconds to seconds, our ability to tell time is at its most impressive. Within this range, we can not only estimate the interval between two events in time, but also parse and interpret the complex temporal patterns of music and speech. For example, the duration of syllables or pauses in speech help mark the boundaries between words, such as *grade A* versus *gray day*. The duration of words and the speed of speech also contribute to *prosody*, which conveys the emotional state of a speaker - consider the sluggish speech pattern of a clinically depressed individual versus the brisk delivery of an excited teenager. The same is true in music. As the terms *grave* and *allegro* imply, slow and fast musical tempos can be used to convey sadness and happiness, respectively. Much like our ability to see a face in the relationship between the dots of a Seurat painting, we are able to grasp the whole from the temporal relationship between of the parts of speech or music. But we can only detect such temporal patterns on the very narrow time scale of around a second. If you slow speech down too much, it becomes unintelligible, and if you speed a musical piece up too much, it ceases to be music.

The first biological clocks, the circadian clocks, operated on the time scale of hours. They evolved to allow living organisms, to anticipate the external changes in light and temperature imposed by the rotation of the

Earth. These clocks are relatively well understood, they are biochemical rather than neural. That is, they rely on the molecular mechanisms of gene translation and protein transcription, and don't even require a brain - plants and bacteria have circadian clocks. On even longer scale many animals have *infradian* rhythms. Many animals have reproductive rhythms with a period of weeks or months, including the human menstrual cycle of approximately four weeks. And much as almost all animals track the rhythm of the sun, some animals track the rhythm of the moon as well. Most notably, some marine invertebrates synchronize their development and mating behavior to lunar cycles. In natural environments the moon is the primary source of light at night, and a full moon enhances the ability of predators to see potential prey, so the most vulnerable phases of the life cycles of some animals occur out of phase with the full moon. The presence of a circalunar clock can be demonstrated in sea worms that exhibit a 30-day reproductive cycle even when kept in laboratory conditions under a constant day-night cycle.

Neural Population Clocks

There is not single mechanism underlying the brain's ability to tell time across the range of time scales above. Rather the brain used multiple different clocks for different time scales. Evolution has endowed the brain with a multitude of mechanisms to tell time. These different clocks for different time scales strategy - the *multiple clock principle* - stands in contrast to man-made clocks. Even the simplest of digital wristwatches can accurately measure hundredths of a second, seconds, minutes, hours, days, and months. In the brain, however, the neural circuits responsible for timing Beethoven's Fifth have no hour hand, and the circuits that govern our sleep-wake cycle have no second hand (Buonomano, 2007; Buonomano, 2017). Here I focus primarily on the neural mechanisms underlying timing on the intermediary scale of seconds.

Timing is critical to most forms of learning, behavior, and sensory-motor processing on the scale of seconds (Mauk and Buonomano, 2004; Buhusi and Meck, 2005; Coull et al., 2011; Merchant et al., 2013). Converging experimental and computational evidence indicates that on the scale of seconds, that the brain relies on intrinsic and general properties of neurons and neural circuits to tell time. Two general model that are supported by experimental data include ramping models and neural population clocks.

Ramping models (e.g., Durstewitz, 2003; Simen et al., 2011; Balci and Simen, 2016) propose that time is encoded in monotonic changes in firing rate, and that timed actions are produced when the firing rates reaches a threshold value. Such ramping neurons have been observed in a wide range of brain areas during timing tasks. There is abundant data showing that during interval motor timing tasks, neurons in the parietal cortex (Leon and Shadlen, 2003; Janssen and Shadlen, 2005; Jazayeri and Shadlen, 2015), prefrontal cortex (Niki and Watanabe, 1979; Kim et al., 2013; Emmons et al., 2017; Kim et al., 2017), and premotor and motor cortex (Mita et al., 2009; Murakami et al., 2014), all exhibit approximately linear ramping of firing rates during motor timing tasks. It is generally the case that a timed motor response is generated when a population of ramping neurons reaches a given firing rate threshold. Importantly, the slope of the ramp generally decreases as the interval being timed increases, while the peak firing rate remains approximately the same (Leon and Shadlen, 2003; Murakami et al., 2014; Jazayeri and Shadlen, 2015; Merchant and Averbeck, 2017).

Neural population clock models propose that time is encoded in the changing patterns of activity in a large population of neurons (Buonomano and Mauk, 1994; Mauk and Donegan, 1997; Buonomano and Laje, 2010). Neural population clocks rely on a general property of neural circuits: their internal neural dynamics. We can think of a population clock as a neural trajectory in N-dimensional space, where N is the number of neurons participating in the population clock and each point on the trajectory codes for a moment in time. If these patterns are reproducible and unique at each moment in time, it is possible for downstream neurons to readout elapsed time. Neural population clocks can take the form of sparse neural sequences in which distinct neurons are sequentially activated, or complex patterns in which neurons can have complex multipeaked temporal profiles.

Critical to the notion of population clocks is that the trajectories emerge from dynamics of the neural circuits, that is, the patterns occurring early in the trajectory are causally responsible for the later patterns. Thus, a simple array of non-interconnected neurons, each firing at different latencies (e.g., a labelled line model), would not constitute a population clock because the activity of the neurons firing later are independent of the activity of the neurons firing earlier. Population clock models propose that a given neural trajectory encodes time from the onset of a given stimulus, or relative time depending on the context (e.g., producing the same motor pattern slowly or quickly may rely on very similar neural trajectories evolving at a fast or slow speed, respectively). In other words, one stimulus might elicit neural trajectory T_1 and another stimulus a distinct trajectory T_2 - thus the same population of neurons encode time from the onset of each stimulus. The advantage of these stimulus-specific "clocks" is that the population encodes not only time but the stimulus - in other words temporal and spatial processing are intertwined. Computationally, this offers many advantages. For example, the first population clock models were proposed in the context of the cerebellum in which the changing population of granule cells encode time since stimulus onset (Buonomano and Mauk, 1994; Mauk and Donegan, 1997) in order to account for the timing of conditioned responses. Since population clocks are inherently capable of encoding both the stimulus and elapsed time, it is relatively easy to account for the ability of distinct stimuli to elicit differentially timed response.

Population clocks can potentially take various forms, from sparse chain-like sequences of neural activation, to complex trajectories in which neuron can exhibit monotonic and nonmonotonic temporal activity profiles. Evidence for both sparse and complex population clocks have been observed throughout the brain, including parietal cortex (Stokes et al., 2013; Crowe et al., 2014), premotor and motor cortex (Carnevale et al., 2015), frontal cortex (Wang et al., 2018), prefrontal cortex (Bakhurin et al., 2017), basal ganglia (Jin et al., 2009; Gouvea et al., 2015; Mello et al., 2015; Bakhurin et al., 2017), hippocampus (Pastalkova et al., 2008; MacDonald et al., 2011), and in song birds (Hahnloser et al., 2002; Lynch et al., 2016) - although in most of these cases it is not known if the dynamics is generated within the circuit being recorded or rather driven by upstream circuits. But in many of these experiments, as mentioned above, it has been demonstrated that the speed of the population clocks co-varies with behavior - i.e., when the population clock runs early in relation to the mean, so does the timed behavior (Crowe et al., 2014; Gouvea et al., 2015; Bakhurin et al., 2017). Furthermore some studies suggest that the individual neurons that compromise a population clock may reflect Weber's law, e.g., the half-width of the peak response can increase with the time of this peak (Mello et al., 2015; Tiganj et al., 2017).

Computational models have proposed that sparse population clocks (in which each neuron is active only once during a trajectory) are produced by synfire chains or functionally feed-forward patterns of activity (Goldman, 2009; Liu and Buonomano, 2009). In these sequential trajectories, readout is very straightforward, as each neuron represents a given amount of elapsed time (or a "time field"). A number of models have proposed how sparse population clocks can emerge in a self-organizing manner (Buonomano, 2005; Liu and Buonomano, 2009; Fiete et al., 2010; Miller and Jin, 2013). The general idea being that homeostatic and/or associative forms of plasticity lead to the emergence of recurrent neural networks with an embedded feed-forward architecture. More complex population clocks can take the form of patterns in which the temporal profiles of neurons is distinct and a given neuron might be active multiple times during trajectory - thus resulting population histograms that do not result in a simple diagonal line of latency-sorted neurons. Models of complex population clocks rely on relatively strong feedback inherent to recurrent neural networks. Specifically, networks with strong recurrent connections are capable of generating continuously changing patterns of self-perpetuating activity, and when the recurrent weights are appropriately tuned the resulting neural trajectories can robustly encode time (Laje and Buonomano, 2013).

The experimental and computational evidence in support of raming and neural population clock models highlights the key principle that timing is so diverse and important to brain function that it would not be effective to rely on a single mechanism. And thus that ultimately the brain evolved a diverse set of mechanisms to tell time across different temporal scales and computational tasks.

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REMEMBERING THE FUTURE: FACILITATING THE RECALL OF FUTURE EVENTS

Chris Roe *

Introduction

I'd like to thank the BIAL Foundation for this opportunity to introduce you to a line of research in parapsychology that seems to challenge some of the assumptions we have about our relationship with time. The field of parapsychology is concerned with 'impossible things' - reported events or abilities that conflict with what the philosopher C.D. Broad (1949, p. 291) called the 'Basic Limiting Principles' of science, tenets that have been "so overwhelmingly supported by all the empirical facts … that it hardly enters our heads to question them". Broad's four principles can be summarised as follows:

– Effects cannot come before causes.

– A person's mind cannot produce any direct change in the material world except those caused via the brain / sensorimotor system.

– Any mental event is an event in the brain of a living body, and cannot occur in the absence of a functioning brain.

– All knowledge of the world comes to us through our conventional senses or by inference from known facts.

However, there is widespread belief in and reported personal experience of phenomena that prima facie are exceptions to these principles, which seems to be independent of culture, creed or historical period (e.g., Castro, Burrows & Wooffitt, 2014; Dagnall, Drinkwater, Parker & Clough, 2016). Examples of such phenomena include:

– Premonitions such as dreams that refer to (or are 'caused by') a future event.

– Psychokinetic events such as the movement or distortion of objects, or the production of wellbeing changes in another organism as a result of

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mental intention alone.

– Out of body experiences, where the centre of experience seems to be located away from the body; or near-death experiences, in which mental events seem to occur when the brain is apparently incapable of sustaining conscious activity.

– Telepathic and clairvoyant experiences, in which people seem to be able to acquire information from the mind of another person or directly from the environment without the mediation of the known sensory systems.

Parapsychology represents our best attempt to account for these phenomena, either in terms of existing constructs (such as misperception, errors of recall, and deception) or by invoking new constructs that can accommodate them. Given the theme of this symposium, I shall focus on the first of these, apparent violations of the cause-effect temporal relationship. With only limited space, I shall restrict myself to just one line of research that has been loosely (and rather inaccurately) labelled 'feeling the future'.

To begin with, I would like to say a few words about the originator of this line of work, Daryl Bem, who was initially scheduled to give this talk but unfortunately is unable to join us through ill health. Before he turned to parapsychology, Bem had already established an impressive reputation in more traditional areas of Psychology. Two psychological theories are named after him, accounting respectively for attributions people make to themselves to explain their own interpersonal behaviour, and for observed differences in triggers of sexual attraction. He was sufficiently well-regarded to be invited to co-author a number of editions of the standard undergraduate Psychology textbook, known colloquially by generations of students as 'Atkinson and Hilgard'. Bem was also a longstanding member of the Association of Psychic Entertainers, and it was his expertise in sleight of hand and the art of deception that led to him being exposed to parapsychological research. In 1983 Charles Honorton invited him to review the protocols he had developed to test for ESP using the ganzfeld method, to see if the security precautions could be overcome by an expert magician. Bem was sufficiently impressed that he agreed to co-author a paper with Honorton if the protocol delivered above-chance results. The findings were highly significant, and so Bem co-authored a summary report that was published in *Psychological Bulletin* (Bem & Honorton, 1994).

The response to this article was mixed, and suggested that some colleagues in psychology had a problem in accepting the testimony of Bem and Honorton regarding the empirical evidence they were producing, perhaps in part because the methods used to gather data were relatively unfamiliar to them. To address this, Bem set out to develop a 'Holy Grail' - "a straightforward, transparent laboratory demonstration of psi that could be replicated by any competent experimenter" (Bem, 2003, p. 6). This would involve a 'standard' psychology protocol that would be widely recognised as robust and valid, and thus in theory would be immune to methodological criticism since such criticism would equally apply to that mainstream work. It was also intended to encourage colleagues to test the claim directly for themselves rather than rely on the testimony of others; if the effects are real, then they should be reproducible in the same way as any other psychological effect. Finally, the standard protocol must involve a sequence of elements so that it could be adapted to produce a precognition design.

Bem's time-reversed protocols

Bem's first experiment of this type focused on the 'mere exposure' effect, which refers to the tendency for people to develop a preference for stimuli to which they have been exposed previously. In the mere exposure protocol, the participant would be repeatedly exposed to a stimulus and, when later presented with two stimuli and asked to make a judgement as to which is more likeable, they would tend to select the previously exposed stimulus over the novel one. The effect occurs even where initial exposure is degraded or below the level of conscious awareness (for example, with very low illumination levels, or very short exposure times); indeed, effects may be even stronger where the participant has no conscious awareness of which stimulus they have been exposed to. The effect has been described in more than 200 research articles and occurs in animals as well as humans (Monahan, Murphy & Zajonc, 2000).

Bem converted this into a precognition task by having participants make their judgement as to which of two images they preferred *before* they were repeatedly exposed to one of the two images (see Figure 1). Since the target image is selected randomly by the computer shortly *after* the participant has registered their preference, there is no obvious conventional mechanism to account for any effect. Nevertheless, Bem reported that data from more than 400 trials conducted by a number of researchers had yielded strong support for the increased liking for negative stimuli (52.6% selection rate rather than chance expectation of 50%) that they would be exposed to in the future.

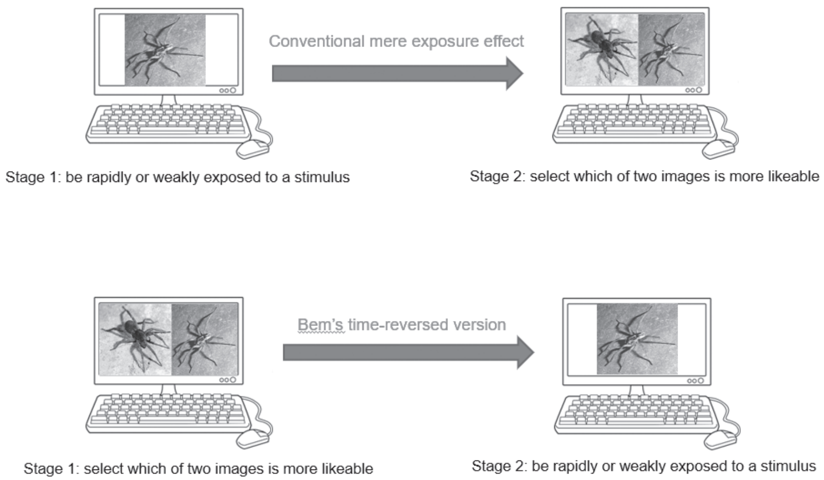

Figure 1. Conversion of the mere exposure protocol into a precognition task.

Emboldened by this initial success, Bem sought other protocols that included elements that could be time reversed so as to produce a precognition task. In a standard priming task the participant is presented supra-liminally with a target image and is asked to respond as quickly as possible (but without errors) to indicate whether the image is positive or negative, for example by pressing respectively a left key or a right key. Immediately before the image is presented, a positive or negative word (known as the 'prime') is presented, usually so briefly that the participant reports only seeing a flash of light rather than recognizing what word has been presented. Nevertheless, the meaning of the prime affects the participant's reaction times in responding to the image: where the prime is congruent with the overt image (for instance, the word 'beautiful' followed by an image of some flowers) the participant's reactions are typically quicker than they would be without a prime; where the prime is incongruent (for instance the word 'disgusting' followed by an image of some flowers), the correct response is slowed down relative to reaction times without a prime. Such 'semantic' priming effects are well established and considered to be robust (cf. Van den Bussche, Van den Noortgate & Reynvoet, 2009). Bem included a 'classic' priming task in his experiment, but also a condition in which the elements were reversed so that participants were presented with the image first, and *only after they had reacted to it* were they presented with a subliminal prime - by which point, of course, it would be too late for the prime to affect reaction times by any conventional means. Nevertheless, Bem reports that data from 100 participants showed that they were on average 15 milliseconds faster on congruent trials than on incongruent trials for the time-reversed (precognitive) version of the task.

A third experiment looks at the effects of practice on word recall. A staple of psychology undergraduate research methods classes, the basic effect is that participants recall more items on a list of presented words if they have had an opportunity to 'practise' them, particularly if they process them more deeply, such as by finding ways in which the words might be linked semantically, a technique known as clustering (Lockhart & Craik, 1990). This can be demonstrated by only allowing participants to practise some of the presented words and then showing that they recall more of these than the words that are presented but not practised. In Bem's time-reversed version, participants are given a chance to practise with 24 of 48 presented words, but only after they have completed the recall task. This seems akin to sitting an exam and then revising for it afterwards. Nevertheless, Bem again reports evidence of a precognition effect, with his 100 participants recalling more of the to-be-practised words than the control words.

These experiments were reported in a summary paper that was published in the *Journal of Personality and Social Psychology*, which encourages papers that report on experimental series rather than individual studies. Bem (2011) described nine formal experiments that included exploratory and confirmatory tests of the three protocols I have described, as well as some others, including a detection of erotic stimuli task that is not really a time-reversed standard protocol but is based on traditional forced choice ESP testing methods.

Reaction

Despite Bem's clear rationale in choosing experimental designs that would be more appealing to mainstream psychologists, the scientific community's reaction to the article's publication was mainly negative. A *New York Times* article (Carey, 2011) noted that "the decision may delight believers in so-called paranormal events, but it is already mortifying scientists", and quotes Ray Hyman, Emeritus Professor of psychology at the University of Oregon, "It's craziness, pure craziness. I can't believe a major journal is allowing this work in". Jarrett (2014) included Bem's study among the "10 most controversial psychology studies ever published", alongside notorious research such as Zimbardo's Stanford Prison Experiment and Milgram's "Shock Experiments". Engber (2017) described the research as "both methodologically sound and logically insane" and quotes University of Amsterdam professor Eric-Jan Wagenmakers' experience of reading Bem's ESP paper, "I had to put it away several times … Reading it made me physically unwell." In the same article, Uli Schimmack, a psychologist at the University of Toronto asserted "I don't have to believe any of these results because they're clearly fudged."

In attempting to explain this vociferous rejection of Bem's findings, Lacsap (2010) observed, "after speaking to quite a few of my colleagues about this [paper], I realize that the willingness to take these results seriously - as opposed to dismissing them out of hand - is a function … of the PRIOR probability that such effects exist… *People were bugged by the result, not the methodology*. As a matter of fact, the experimental approach (with several substudies) would have passed muster in most fields, including psychology, without a second thought if the results had been more in line with expectations. No one would have batted an eye, no one would have attempted a replication. This should give those with a concern for the state of the field pause for thought. How many results that are wrong do we believe because we expect them to be true?"

Wagenmakers Wetzels, Borsboom, and van der Maas (2011) asserted that the statistical approach adopted by Bem (and common to most psychological research) overstates the evidence against the null hypothesis, particularly where sample sizes are relatively large. They prefer a Bayesian analysis which gives an estimate of the prior probability of a given effect and calculates how that probability shifts as a result of the observed data. Of 10 critical tests they conducted, three yielded "substantial" evidence in favour of the null hypothesis, six provided evidence in favour of an effect that was only "anecdotal", and only one (Facilitation of Recall II) gave "substantial" evidence for an effect, leading them to conclude that "Bayesian reanalysis of Bem's experiments … demonstrated that the statistical evidence was, if anything, slightly in favor of the null hypothesis" (p. 431).

Bem, Utts and Johnson (2011) responded, arguing that Wagenmakers et al. incorrectly selected an unrealistic prior distribution for their analysis and that a Bayesian analysis using a more reasonable distribution yields strong evidence in favour of the psi hypothesis. The arguments are technical, but essentially psi studies tend to give an average effect size in the range .15-.25, which is broadly comparable to effect sizes for psychology as a whole, whereas Wagenmakers et al. assumed that if the null hypothesis were false (i.e. there was a real effect size) there was more than a 50% likelihood that the effect size would be greater than 0.8. When a more realistic "knowledge-based" prior is used, five of the nine experiments gave either "strong" or "substantial" evidence in favour of an effect, and the combined Bayes factor greatly exceeds Wagenmakers et al.'s criterion for "extreme" evidence in favour of an effect.

First wave replications

Many of the concerns raised about Bem's experiments can be resolved by independent replication. A high-profile failure to replicate was reported by Ritchie, Wiseman and French (2012a). They focused on retroactive facilitation of recall, with each author overseeing an independent study involving 50 participants. All trials were conducted in-person, either by the author or a research assistant, as was the case for Bem's original experiments. All three experiments are reported to be nonsignificant; in two cases this is because the mean difference in recall for practice words and control words is very small, but replication 2 gives a 1-sample t-test value of 1.57, which is a suggestive effect. The authors regard this as nonsignificant because it is in the opposite direction to prediction (participants recalled more of the control words than practice words) and so would be rejected by a 1-tailed test. However, it seems an odd decision to adopt 1-tailed tests given that they echo criticisms of Bem for using them, especially when experimenter effects linked to their scepticism of psi (versus openness to it) have been observed for other psi experiments - see Roe (2016) for a fuller consideration. The uncorrected weighted mean recall score gives $t = 3.09$, which for a sample of 50 participants would give a highly significant ($p < .005$) missing effect even if corrected for multiple analyses. Nevertheless, it is clear that none of these replication attempts confirmed Bem's original findings.

Ritchie et al. submitted a report for publication in the *Journal of Personality and Social Psychology*, but were surprised when it was rejected. They attributed this to journal editors having little appetite for publishing failures to replicate, though the journal also rejected submissions that claimed to support the Bem findings (Aldhous, 2011). While antipathy for null results may be generally true in the social sciences, and is likely to have had an impact on the published record as a whole by skewing it to the positive (see, for example, Schmidt, 2009), it is a surprising attribution to make in this case. The article seems unlikely to meet the journal's criteria that submissions will be evaluated on the basis of the statistical power of the study that is carried out, and the number and power of previous replications of the same finding. In this case, three low powered experiments have little prospect of providing an adequate refutation of the original studies. I conducted a power analysis to estimate the likelihood that a study with sample size 50 would produce an outcome that was significant at $p = .05$ (1-tailed) given an effect size d of .19 (as reported in Bem's experiment 8), and this produced a power estimate of .37. In other words, there is only a 37% chance that an individual study would successfully replicate the original significant outcome where the effect is real but small. A simple binomial analysis indicates that a collection of three such studies would all be nonsignificant about 25% of the time. However, if we use the much larger effect size d = .42 from Bem's experiment 9, then the power of each replication attempt increases markedly to 90% and the likelihood that none of the 3 is independently significant reduces to 0.1%. Nevertheless, the authors attracted a lot of media attention that was sympathetic to the claim that their initial publication difficulties were due to the mistreatment of failed replications, featuring for example in articles in *New Scientist* (Aldhous, 2011), *The Guardian* (French, 2012) and even in the *Stanford Encyclopedia of Philosophy*'s entry on 'Reproducibility of Scientific Results' (Fidler & Wilcox, 2018). The British Psychological Society's professional member magazine, *The Psychologist*, devoted an issue to concerns about replication that was opened by a summary of the Ritchie et al. replication failure (Ritchie, Wiseman & French, 2012b).

With respect to statistical power issues, Galak, LeBoef, Nelson and Simmons (2012) conducted a much more substantial replication attempt, comprising seven experiments and over 3,000 participants. This focused on Bem's facilitation of recall effect on the reasonable grounds that "the other findings reported in Bem (2011) hinge on nuanced affective responses" that can be "sensitive to subtle variation in the intensity and character of the stimuli" (p. 934). In contrast, with the selected experiment, participants are simply shown a list of words in the knowledge that they will subsequently be asked to recall as many as they can. This series of experiments adheres broadly to Bem's approach but does incorporate changes; for example, experiments 1, 2, 6 and 7 were conducted online, experiment 2 used (unspecified) different words and different categories, and experiment 6 included a 'standard' recall task. Participation pathways to the online experiment 7 - by far the largest study - included hyperlinks from an online report that described the original Bem study. It is not clear whether participants recruited by this method might have thereby been introduced to the set of test words used in the original study and (presumably) re-used here. Sample sizes for the seven experiments are very uneven at 112, 158, 124, 109, 211, 175 and 2,469, and this variation is not adequately explained.

Only one of the seven experiments - experiment 4 - showed a significant effect suggesting precognition (using a one-tailed p value), and the combined effect across all studies was very close to zero. Interestingly, the three experiments conducted in-person gave t values of +1.28, +1.77, and -0.71 (for comparison, Bem's original recall experiments gave t values of +1.92 and +2.96), whereas the online experiments gave t-values of -1.20, 0.00, -.33 and -.23. Considering just the in-person experiments gives a positive but non-significant effect size of 0.07 (Z = 0.940, p = 0.347).[1] It seems as if adopting an online protocol is not a valid variation. Online research clearly has a number of advantages, particularly with respect to generating large samples of participants and enabling people to participate at times that are convenient for them. However, there are marked disadvantages that result from participation not being monitored at any level by an experimenter: there are no checks that participants are attending to the task to the exclusion of all distractions; it is not possible to verify that participants are not cheating by writing down the words as they appear; and there is no facility to check whether participants are selectively withdrawing from the study (for example, if they discover that the words they have recalled are not among the words they subsequently have a chance to practise). To their credit, Galak et al. attempted to gauge participant attentiveness, but the approaches they incorporated (to ask people if they had been attentive, and to measure how long it took to complete the task) seem naïve and crude respectively. Until more effective methods have been built into their designs, data collected online is likely to remain of dubious validity.

Galak et al. (2012) additionally presented a meta-analysis of all replication attempts to date, including their own suite of experiments and the replication failures by Ritchie et al. (2012a). All studies in the database involved the facilitation of recall effect, and all were in-person tests apart from the four experiments by Galak et al. described above. The overall average effect size of .04 is considerably smaller than Bem's (2011) average effect size (.29) and is not statistically different from zero. This effect size is weighted by sample size and may have been disproportionately affected by Galak et al.'s experiment 7, which had 2,469 participants (over 60% of the total). This study was online and so suffers from the potential problems I have outlined; interestingly, a separate analysis by

[1] With thanks to Patrizio Tressoldi for calculating these statistics.

Galak et al. (2012) that excluded all online experiments gives a significant effect size of .09.

Bem, Tressoldi, Rabeyron and Duggan (2016) published a more comprehensive meta-analysis that encompassed all the 'feeling the future' protocols to date. They retrieved 69 attempted replications as well as 11 other experiments that "tested for the anomalous anticipation of future events in alternative ways". If Bem's original studies are included, the total sample comprises 90 experiments from 33 different laboratories located in 14 different countries, and involved 12,406 participants. The replications should resolve some of the controversy surrounding Bem's original work, since they were designed from the outset as confirmatory studies that were constrained to test for the specific effects described by Bem (2011) - 31 studies are described as "exact replications" and 38 as "modified replications". The overall effect size (Hedges' g) is 0.09, which is significant ($p = 1.2 \times 10^{-10}$) and is interpreted by the authors as "decisive evidence for the experimental hypothesis" (p. 7). When Bem's original experiments are removed from the analysis, the result remains highly significant. There were differences in outcome across experiment-types, with "fast-thinking protocols" which require quick judgements that do not allow time for reflection (such as the priming task) producing larger effects than the "slow-thinking protocols" (such as memorising and recalling words). It is interesting to note that the flurry of failures to replicate Bem's findings had all focused on this latter task type. Concerns about selective reporting are tested by comparing outcomes from peer reviewed publications with 'unpublished' studies (including conference proceedings); these did not differ in outcome, suggesting there was no overt publishing bias. It is possible to calculate the number of unpublished studies that average a null result which would be needed to cancel out the observed effect; in this case there would need to be more than 1,000 unpublished experiments, which is extremely unrealistic.

As a postscript I should note three unsuccessful priming experiments that have been reported since this second meta-analysis was published (Schlitz et al., 2021; Schlitz & Delorme, 2021). These experiments involved healthy sample sizes (N = 495, 564, and 246) and were conducted in-person rather than online, so it is unclear why there was no effect in the primary measure. Schlitz et al. (2021) recruited 32 experimenters who in turn recruited their own participants. As well as finding no overall priming effect, there was no effect of experimenter prior belief or expectancy. However, an exploratory analysis did find a priming effect in the English language version only, which seems to be related to sampling rather than language per se (the English language sample scored higher on 4 of 5 pre-specified predictor variables: practice of a mental discipline, belief in ESP, personal experience, and being easily bored). The second study involved participants reading a pro-psi or anti-psi statement before completing the trials. This study also failed to replicate the priming effect but did find significantly better performance from participants who received the pro-statement.

Conclusions

In summary, Bem's original proposal to adapt well-established psychology protocols so that they become a test for precognition is laudable. While it did not protect the work from methodological criticism, it has encouraged a range of researchers who would not normally get involved in parapsychological research to conduct replication attempts. Bem's stimulus paper has been widely criticised. Some of these criticisms are without merit, but others have legitimately drawn attention to inconsistencies and ambiguities in how the original studies were conducted and organised. Particular concerns around differentiating between exploratory and confirmatory studies are effectively resolved by the occurrence of independent replication attempts. Popular attention seems to have given a surprising amount of weight to three small but high-profile replication attempts. A more sophisticated understanding of the relationship between effect size and study power could have led to a more realistic understanding of the likelihood of achieving statistical significance where one is testing for a small but robust effect. An initial meta-analysis suggested that Bem's claimed effects could not be replicated, but these seem to have been compromised by the inclusion of online experiments with extremely large sample sizes that dominate that analysis. A more recent meta-analysis claims that effects can be replicated statistically and provides useful indicators for the next wave of replication attempts, particularly to map and explain the apparent advantage of fast-thinking protocols. While data from these second wave replications are encouraging, the effects remain small and precarious. Until we are able to identify necessary and sufficient conditions to produce a more robust and higher-yield effect it remains premature to speculate on the implications of these time-reversed effects for our understanding of time.

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VISUALISING TIME IN THE BRAIN: PERCEIVING THE PRESENT AND PREDICTING THE FUTURE

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Being able to accurately estimate the passage of time is an integral part of our everyday lives. For example, anticipating the moment at which a traffic light will turn green helps you to accelerate away more quicky. Alternatively, if the light turns amber just as you reach it, you must decide whether you have enough time to race through or whether you should hit the brakes. In these situations, time is being estimated implicitly to help guide motor behaviour. But it's also possible to make explicit perceptual judgments about duration - for instance, it's easy to judge whether a red traffic light typically lasts for a longer or shorter time than an amber one.

It might seem trivial, but it's crucial to note that to estimate how long an event lasts, we need to remember when it started. In other words, to estimate event duration we compare information at event offset with information at event onset. But the tricky thing about time is that at event offset, the information about event onset is no longer available in the environment. Therefore, in order to accurately judge event duration, we must access a memorised representation of information that is no longer physically there. As Gibson (1975) put it "Time is a ghost of the events of the world". Our sense of time is therefore constructed both from current sensory information and representations in working memory (WM). As the French philosopher Guyau (1890) said over 100 years ago "time can only be perceived … as representations rather than immediate sensations". And the fact that time is a cognitive construct makes it rather fragile and susceptible to interference or influence by other factors (Matthews and Meck, 2016). For instance, we've all experienced the sensation that time flies when we're having fun or that a watched pot never boils. In other words, the less we pay attention to the passage of time the shorter time appears, whereas the more we pay attention to it the

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longer it appears (Macar et al, 1994; Brown, 1997). Moreover, attention is not the only factor that influences our sense of time. For example, it's often been reported that time appears to slow during stressful events like car accidents. This phenomenon has been investigated experimentally in the laboratory and the duration of emotionally charged or stressful events, like angry faces (Droit-Volet et al, 2004) or bungee jumps (Stetson et al, 2007), are typically overestimated, which would correspond to a subjective slowing of the passage of time. Physical stimulus characteristics can also influence the perception of time. The duration of bigger or longer stimuli are overestimated compared to smaller or shorter ones (Xuan et al, 2006; Casasanto & Boroditsky, 2008), and the duration of stimuli presented on the right-hand side of a screen (Vicario et al, 2008), or even of stimuli that simply draw attention to the right of the screen (Droit-Volet and Coull, 2015), are overestimated compared to those on the left.

The cognitive mechanisms underlying the rather slippery sensation of time might be elucidated by identifying where it is represented in the brain. Around 25 years' worth of functional neuroimaging studies of duration perception have identified several timing-related regions of the brain, including the inferior prefrontal cortices, a region of dorsomedial frontal cortex called the Supplementary Motor Area (SMA), the basal ganglia, and the cerebellum (Wiener et al, 2010; Coull et al, 2011; Merchant et al, 2015; Teghil et al, 2019). Among these, the SMA is the region that is the most consistently implicated in duration processing (Nani et al, 2019), independently of WM and attentional task demands (Coull et al, 2015). As its name suggests, the SMA has traditionally been implicated in motor function, specifically motor preparation. But the SMA is activated even when participants are making purely perceptual judgements about stimulus duration (Coull et al, 2004; Wiener et al, 2010; Schwartze et al, 2012). So why would a region of the brain traditionally implicated in motor preparation be involved in perceiving time?

One possibility is that we build a notion of time in childhood from the duration of certain actions. For instance, when young children question how long a particular unit of time is, you might tell them that 10 minutes is the time it takes to walk to school or that one hour is the duration of their dance class. Indeed, experimental evidence suggests that young children represent time in terms of action. For example, Droit-Volet and Rattat (1999) asked children to press a button for however long they liked and then to squeeze a rubber ball for the same amount of time. The youngest children in the group (3-year-olds) had great difficulty with this task. Their perception of time was entirely defined by the action of the button press and did not exist independently of that action. However, by 5 years old, children were able to extract the temporal information from the button press action, transform it into an abstract mental representation of time, and then apply it to another, distinct action. In fact, action continues to improve and hone the sense of time even once an abstract representation of duration has been acquired in older children and adults. For instance, Monier et al (2019) showed children a rhythmic sequence of 33 dots that were presented consecutively at 800ms intervals. One group of children was asked to simply watch the sequence of dots while another group was asked to tap in time with the dots. They were then shown a single interval, bounded by two dots, and asked to estimate whether that interval was the same or different to the interval used in the rhythmic sequence. Children who had previously tapped in time to the dots had a more precise perception of the 800ms interval than children who had simply watched the sequence, indicating that action helped sharpen their representation of time. Action also helped relieve the memory burden of performing such timing tasks. Temporal precision in the group of children who had simply watched the sequence was strongly linked to their scores on neuropsychological tests of memory, confirming several previous findings (Droit-Volet et al, 2015; Zelanti and Droit-Volet, 2011, 2012). The better the memory capacity of the child, the better their performance on the timing task. By contrast, there was no link between timing performance and memory capacity in children who had tapped in time to the sequence, suggesting that action had provided an alternative functional framework that helped shape their representation of time.

So why do children find it so difficult to judge time? One possibility is that since performance on duration judgement tasks covaries with neuropsychological measures of memory, children's relatively poor memory function makes their judgements more variable (Droit-Volet and Hallez, 2019). However, the tight relationship between memory and duration judgement means that duration judgement tasks might not be entirely representative of children's timing ability. To test this, Droit-Volet and Coull (2016) compared children's performance on two comparable timing tasks: one that measured timing via explicit duration judgements and one that measured timing via implicit temporal learning. In the training phase of both tasks, children were trained on a standard 600ms interval by asking them to press a button upon presentation of the second of two auditory tones, which was always presented 600ms after the first. During the subsequent test phase of both tasks, the interval between the two tones was varied (from 240ms-960ms). However, the instructions for the two tasks differed. In the explicit duration judgement task, children were asked to decide whether the (variable) interval between two tones was the same, or not, as the trained (600ms) interval. In the implicit temporal learning task, we asked them simply to respond as quickly as possible to the presentation of the second tone. For the duration judgement task, confirming many previous findings (Droit-Volet, 2016), 5-year-olds were more likely to judge that an interval shorter or longer than 600ms was actually the same as the 600ms trained interval, meaning their temporal precision was significantly worse than that of older children or adults. By contrast, for the implicit temporal learning task, their temporal precision was as good as older children or adults: across all age groups, reaction times to the tone were fastest when the test interval was the expected 600ms and progressively slower when it was shorter or longer. If the 5-year-olds had failed to acquire the 600ms trained interval, their reaction times would have been no faster for 600ms test intervals than for shorter or longer ones. Therefore, it appears that children are capable of precisely representing time: they just find it difficult to translate that into an explicit duration judgement.

The U-shaped nature of the reaction time distribution in the implicit learning data indicate that the expectation for the 600ms trained interval is not a categorical on-off mechanism. Performance isn't fastest at 600ms and equally slow at all other intervals. Instead, there is a parametric slowing in response times as the test interval gets increasingly shorter or longer than 600ms. It's as though there's a spotlight of attention on the 600ms interval, that fades with increasing temporal distance from that interval. Although the idea of a spotlight of attention is usually discussed in spatial terms, with items in the spatial spotlight being processed better than those out of the spotlight, it appears that a spotlight of attention also exists in the temporal domain. This begs the question as to whether directing attention in time can optimize behaviour in the same way as directing attention in space?

Coull and Nobre (1998) attempted to answer this question by modifying the Posner spatial orienting of attention task (Posner, 1980). In the classic spatial version of the task, an arrow cue tells the participant whether a subsequent target is likely to appear on either the left or right side of the screen. If the target appears in the location predicted by the cue (a valid trial) RTs are faster than if it appears in the location not predicted by the cue (an invalid trial). In a temporal analogue of this task, cues predicted when (rather than where) the target was going to appear. Data showed that RTs were slower for invalid versus valid trials in both the spatial and the temporal versions of the task. In other words, there were RT costs then the target did not appear either where or when expected. Moreover, functional imaging data revealed a very neat hemispheric lateralisation for these two processes: while orienting attention in space activated right inferior parietal cortex, orienting attention in time activated left inferior parietal cortex. Preferential activation of left parietal cortex for temporal orienting of attention has been replicated several times in a variety of different contexts (Bolger et al, 2014; Cotti et al, 2011; Davranche et al, 2011; Coull et al, 2016).

It's important to note that left parietal cortex activation for temporal orienting is not incompatible with the SMA activation for duration perception mentioned earlier. These neuroanatomical differences merely reflect the fact that there are many functionally distinct forms of timing. SMA and left parietal cortex activation differentially represent the ability to judge how long an event lasts (duration perception) versus the ability to predict when an event will happen (temporal orienting). The functional and anatomical dichotomy between "how long" and "when" is particularly interesting given the fact that temporal order judgement tasks also activate left-lateralized parietal cortex (Davis et al, 2009; Binder, 2015; Mizayaki et al, 2016; Moser et al, 2009). In these tasks, participants typically judge which of two events appeared first, and so requires a judgement about "when" one event appears relative to another.

Left inferior parietal cortex might therefore be implicated more generally in the ability to temporally resolve and pinpoint the precise moment in time at which an event happens (Coull and Giersch, 2022).

In conclusion, action helps render the rather abstract concept of time more concrete. Children construct their notion of time through action, and action helps hone and sharpen the representation of time in adulthood. The association between time and action might therefore explain why the perception of time has come to be represented in motor structures of the brain.

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HOW WE EXPERIENCE THE PASSAGE OF TIME: THE BODY, FEELINGS, AND THE SELF

Marc Wittmann *

Through my contribution in this symposium on subjective time, I wish to bring attention to the body. The physiological processes of the body are a necessary prerequisite for understanding how we, as humans, perceive time on the scale of seconds to minutes. My talk will proceed as follows: (1) First I will introduce the standard cognitive model of time perception and I will speak about some empirical research that tested that model. (2) Then I will try to explain why, when it comes to investigating the perception of time, so many research models exist. To put it humorously, I like to say that when we gather five researchers who work on the topic of time, such as here at the BIAL symposium, we may very well end up listening to the presentation of six different models. (3) Then I will discuss my line of research on embodied time, i.e. arguing how the corporal processes govern our sense of time. I will present current and historical evidence that shows how body signals inform us about the passage of time. (4) Finally, I will talk about altered states of consciousness such as those induced through meditation, flotation-REST, and psychedelics. In such specific cases, the bodily self and subjective time are modulated in unison, in peak states of consciousness potentially culminating in timelessness and (body) selflessness. Research on altered states of consciousness can help us understand the nature of consciousness and, in particular, of time consciousness.

Cognitive models of time perception

There are two main areas of research on time perception. One area focuses on how temporal processes of the brain are involved in the timing of actions and in the sense of short duration. This area deals with event

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synchronization in the range of milliseconds to a few seconds, either as interpersonal coordination when two individuals communicate with each other through language or as movement synchronization when dancing or making music together. But time is also a key experience to understand cognitive processes and emotional states in the range of multiple seconds and minutes, such as in states of experienced flow during an activity or when bored while waiting.

When it comes to time perspectives, there is a crucial distinction to be made between prospective and retrospective time judgments (Zakay & Block, 1997). In prospective time judgments, as experienced at the present moment, an individual is aware of time while she is experiencing an event. Here the crucial moderator of subjective time is the 'attention' factor. When we pay attention to time, subjective duration expands, when we are distracted from time, subjective duration contracts. Typical situations when we pay attention to time - and feel that time passes slowly - involve waiting for something to happen. When we are caught up in pleasurable activities such as spending time with friends, and time is not in the focus of attention, we perceive time as passing quickly. In the retrospective time perspective, when looking back at an interval of time that has passed, it is the variety of experiences or amount of memory contents that defines duration. A larger variety of memory content, such as, for example, that of an eventful vacation, expands subjective duration. The same time spent in our everyday routine, which does not contain many memorable events, leads to the impression of a relatively shorter duration.

Utilized in psychological research, cognitive pacemaker-accumulator models postulate a timer whose regularly emitted pulses are accumulated in a counter (Treisman, 1963). The subjectively estimated duration results from the pulses accumulated in the counter. According to this model, more pulses accumulate in case of an objectively longer period of time, which is why the duration feels subjectively longer. The timing model incorporates two functional modulators (Zakay & Block, 1997). According to this model, the counter accumulates pulses only when attention is focused on time. More attention to time leads to relatively longer duration estimates. That is in agreement with the experience that time expands when we are waiting for something. Secondly, the model assumes that the frequency of emitted pulses increases in case of physiological (e.g., emotional) arousal. Stronger emotional arousal leads to a perceived stretching of the time flow because of an increased pulse rate.

The cognitive model of time perception was tested by my working group in three recent studies by means of an ecologically valid waiting time paradigm with uncertainty concerning the duration of waiting (Jokic et al., 2018; Witowska et al., 2020; Alvarez Igarzábal et al., 2021). Each participant was asked to wait alone in a functional waiting room for an experimenter and was told that the experimenter had to fix a technical issue on a computer next door first. No information was given about the duration of the waiting period. Beforehand, the subjects were asked to hand over their bags with personal belongings, including smartphones and watches. There was therefore no possibility of being distracted from the wait. After exactly 7.5 minutes, the experimenter came back and asked the subjects about the waiting time. The subjective impression of the duration of waiting deviated on average only slightly from the actual duration, but interpersonally the answers were very varied. There was a clear correlation between attention, emotional states, and the perception of time: the participants who focused more on time and those who were more negatively aroused while waiting (the two modulating factors of the pacemaker-accumulator model) estimated the waiting time to be longer and felt a slower passage of time.

Neural models of time perception

The described cognitive model of time perception is an excellent heuristic to explain every-day experience. However, when it comes to the questions of functional processing models or neural substrates of subjective time, there is no consensus on any given model. A list of processing models can be extracted from the 2009 special issue on time perception in the journal of *Philosophical Transactions of the Royal Society B* with a collection of 13 articles (Wittmann & van Wassenhove, 2009). The models are the following: the pacemaker-accumulator model, memory decay models, a model pertaining to the amount of energy expenditure when encoding time, a coincidence detection model related to neural oscillations, and a model on short-term synaptic plasticity in cell assemblies. When referring to dominant brain locations involved in temporal processing, the studies mentioned the striatum, the right frontal lobe, the right posterior parietal cortex, the cerebellum, and the anterior insula.

Why is it so difficult for researchers to find a consensus when it comes to processing models and neural substrates for the sense of duration? The reason is that too many different neurophysiological systems are implicated in time perception (Rubia & Smith, 2004; Wittmann, 2009). (1) There are several neurological patient populations that suffer from time perception impairments, among others, patients with lesions to cerebellum or with lesions to the cerebral right-hemisphere and patients with Parkinson's disease. (2) Different transmitter systems are involved, most importantly dopamine and serotonin systems with specific receptor subclasses (Wiener et al., 2011; Sysoeva et al., 2010). (3) Disruption of different brain areas accessible with Transcranial Magnetic Stimulation (TMS), such as the frontal cortex and the cerebellum, transiently impair the timing of duration in the millisecond and second time range (Koch et al., 2009). In neuroimaging studies there are always multiple parallel neural systems that are activated to process duration (Teghil et al., 2019; Nani et al., 2020). What is important to know is that 'impairment in timing', as temporarily induced or permanent in patients with neurological disorders, does not entail a break-down of timing performance. Individuals deviate in timing performance from control subjects, but time perception and motor timing are still possible, albeit less accurate or precise. These difficulties in finding the neurophysiological mechanisms clearly show that there is no sole area of the brain or a single transmitter system that regulates the perception of time. One way to explain the variance of time perception models is assuming the existence of different timing mechanisms for different time scales (Wittmann, 2009). There is evidence that modality-specific sense processes are responsible when it comes to perceiving durations of up to 300 to 500 ms, that sensorimotor processes are related to timing up to a few seconds, and that longer intervals of several seconds involve a different set of processes still. This categorization may be far too simplistic, but it could still serve as a starting point for a duration-dependent classification system.

The interoceptive model of time perception

In this talk I will present yet another idea on the neural basis of subjective time. At least in humans, insular cortex activity (as related to interoception, the sense of the internal states of the body) seems to be involved in the perception of multiple-second duration. My research at the University of California San Diego (2004-2009) in the lab of Martin Paulus enabled me to conduct a neuroimaging study with fMRI where individuals had to temporally reproduce tone durations of 3, 9, and 18 seconds. Study participants were first presented with a tone having one of the three durations (the encoding phase) which subsequently had to be reproduced in duration (the reproduction phase) (Wittmann et al., 2010). Ramp-like increases in fMRI activation was detected in the insular cortex, which corresponded to stimulus duration. This activity ended with the termination of the stimuli in both the encoding (dorsal posterior insula) and the reproduction period (anterior insula). The insula is the primary interoceptive cortex, the primary area to receive signals from all bodily organs, as it processes the physiological conditions of the body and enables the homeostatic regulation of physiological needs (thirst, hunger, temperature, pain, etc.). A comprehensive account regarding the relationship between awareness of bodily states, emotions, and the perception of time has been provided by Craig (2009), who proposed that the sense of time is related to emotional and visceral processes which share the common underlying interoceptive system encompassing the insular cortex.

Building on this conceptual and empirical work, one can conclude that the passage of time is not perceived in the outside world but through interoception, by the "material self". Subjective time is constituted through the existence of the bodily self across time as an enduring and embodied entity, an idea that was voiced by Merleau-Ponty (1945) in his phenomenological analysis: the physical self and subjective time are inseparable. The cognitive pacemaker-accumulator model, with its abstract 'pulses', can now be complemented with concrete entities. Still, the model is a heuristic approximation that does not directly mirror neural processes and substrates. The two modulators of subjective time (attention and arousal) can be understood as regulating inflow of signals from the body as they accumulate over time in the insular cortex. A subjective expansion of duration is achieved through an increase in sensing bodily states, either through more attention to the bodily self (such as during waiting) or through increased bodily arousal (in affective states).

Using the above fMRI duration reproduction task in a setting that allowed for psychophysiological measures, we intended to come closer to directly measuring body states and the perception of time. In this study (Meissner & Wittmann, 2011), participants took part in two tasks: a heartbeat-perception task conducted before the duration reproduction task (a measure of interoceptive sensitivity) and the auditory duration-reproduction task described above. In the classic heartbeat-perception task, subjects are asked to count their own heartbeats and report the number at the end of a designated interval. As a result, participants who had higher interoceptive awareness, i.e. they come closer to the actual number of heartbeats, performed more accurately in the duration-reproduction task. This can be interpreted as a sign that people who are more sensitive in detecting their own heart beats have a more accurate representation of time. The psychophysiological indices during the duration reproduction task - skin-conductance levels, cardiac period, and respiratory period - furthermore were indicative of the relationship between body and time. The cardiac periods increased (the heartrate slowed down) and skin-conductance levels as well as the breathing period decreased (a sign of relaxation) progressively and almost linearly during the encoding of the intervals. Even more specifically, the linear trend of the slowing-down of the heartbeats during the encoding intervals showed a positive linear trend that correlated with duration reproduction performance: the steeper the slope, the longer the reproduced duration.

Due to a widespread irreproducibility of results as discovered recently in experimental psychology and neuroscience, it is necessary to repeat studies, with some variations in content of course. Here are the results of our replication attempts. In a follow-up study where we studied inter-personal variations of impulsivity as a personality trait, we found the same fMRI-recorded increase of activation over time in the insular cortex for the encoding and reproduction intervals (Wittmann et al., 2011). In a replication of the psychophysiological study, we showed again the slowing down of heartbeats and a decrease in skin-conduction levels over time in an attempt to probe for influences of interpersonal variations in mindfulness (Otten et al., 2015). Importantly, these temporal signatures were also recorded in a task using visual stimuli, pointing to a supramodal processing of time. However, in this study we could not replicate the correlation between sensitivity in the heartbeat task and time perception accuracy, possibly due to methodological reasons (Otten et al., 2015; Garfinkel et al., 2022).

Of course, these findings need independent verification from other labs. The oldest psychophysiological study I was able to find was published in 1889 by Hugo Münsterberg, who managed one of the first psychophysiological laboratories in the world, in Freiburg. He used a duration reproduction task with intervals between 6 and 60 seconds which were marked by acoustic cues. Temporal reproductions were most accurate when the onset or offset of intervals coincided with the moment of breathing in. Münsterberg concluded that the sense of time relied on the sensation of tension in different organs which are caused by muscle contractions. 125 years later, Pollatos and colleagues (2014) measured the phase locking between the cardiac cycle and the onset and offsets of a duration reproduction task with intervals ranging between 2 and 40 seconds. There was significant synchronization between the heart cycle and the duration reproduction for durations up to 25 seconds. In a further study, the heart-rate evoked potential (HEP) as measured with the EEG was recorded during a 2-minute duration estimation task. An early negative component of the HEP amplitude was related to the accuracy in estimating the time interval (Richter & Ibáñez, 2021). Speaking more generally about the whole body system, a large amount of studies show how affective physical states are related to subjective time in the range of milliseconds and seconds (Mella et al., 2011; Droit-Volet et al., 2013). Two examples shall suffice: relatively higher psycho-physiologically arousal levels, as induced through threatening photos, which increase sympathetic activity, cause an overestimation of duration (Ogden et al., 2019a); relatively more relaxation as induced through a paced respiration exercise, which increases parasympathetic activity, leads to an underestimation of duration (Ogden et al., 2019b).

Recent work by a research group from Rome furthermore adds evidence to the involvement of interoceptive processes and the insular cortex in the processing of duration. In a behavioural study, researchers employed two types of duration reproduction tasks with intervals lasting between 8 and 18 seconds. The intervals, which started and ended with an acoustic cue, were filled with either regularly spaced or irregularly spaced visual numbers presented as a secondary task during the encoding and reproduction phase (Teghil et al., 2020a). Only timing accuracy of the timing task with irregularly presented numbers was predicted by interoceptive awareness assessed by a bodily self-awareness questionnaire. The individual ability to be aware of their own body states helped subjects to be more accurate in time perception when no regular external signals were available. In that case, subjects had to rely on the dynamics of their bodily self to judge duration. This is an important indication that various timing systems might come into play depending upon individual differences or upon the task. The finding that with fewer external cues available subjects on average have to rely more on body signals, is corroborated by a subsequent study by Teghil and coworkers (2020b) with the same duration reproduction tasks, where posterior insula connectivity, which was modulated by individual interoceptive awareness - measured with the bodily self-awareness questionnaire - correlated only with the irregular condition and not with the regular timing condition.

Also with shorter intervals than the ones employed in the studies above, the insular cortex proves an important neural hub for processing duration. In one fMRI duration reproduction task with acoustic and visual stimuli in the range of 500 to 1500 ms, activity in mid-insula was related to the encoding phase, while activity in the left anterior insula was related to the reproduction phase. The authors themselves speculated whether this activity in the insular cortex was related to the feeling of time passage (Bueti & Macaluso, 2011). What happens when patients with neurological damage to the insular cortex have to time their behaviour in this shorter time range? Using temporal intervals with duration between 300 ms and 1500 ms, 21 patients with a stroke either in the left hemisphere or right hemisphere extending into the insula were compared to healthy control subjects. Only patients with lesions to the right hemisphere were strongly impaired, while lesions to the left hemisphere did not affect patient performance (Mella et al., 2019).

Research by Teghil et al. (2020a, b) revealed that the sense of duration was processed in two different ways. Most likely, the processing of duration is distributed at multiple levels, local circuits and brain-wide circuits, depending upon stimulus features, contextual variables and the time scale (Buhusi et al., 2018). According to my conceptualization presented here, the involvement of the experienced-self during a given period of time will have a decisive impact. If self-awareness is rather low and the focus is strongly on happenings in the external world, such as during flow states when one is absorbed in what one is doing, time will pass relatively quickly. On the opposite end of the experience spectrum, when self-awareness is high and the focus is internal, like when we are bored or when we are mindful of what is happening to us, time will pass more slowly.

Many psychiatric and neurological syndromes are associated with distortions in emotional and bodily self-regulation as well as subjective time (Hartocollis, 1983). Patients with depression and anxiety report a subjective slowing down of time and of being stuck in time (Vogel et al., 2018; Wittmann et al., 2006). Although empirical evidence is inconsistent for experimental settings in the laboratory (Thönes & Oberfeld, 2015), patients with depression sometimes overestimate the duration of intervals in the minutes range (Bschor et al., 2004). Importantly, impulsivity as a symptom of many psychiatric and neurological syndromes is strongly tied to relative overestimation of duration, the feeling of not being able to wait through an interval of time being a strong indicator and symptom of everyday impulsiveness (Jokic et al., 2018; Wittmann & Paulus, 2008). A comprehensive review has linked time processing deficits in patients with psychiatric disorders to dysfunctions of the interoceptive system and insular cortex activity (Vicario et al., 2020).

In 1905 a psychiatrist at the Sainte-Anne psychiatric hospital in Paris described the symptoms of a female psychiatric patient named Alexandrine who might have suffered from a depersonalization syndrome (Revault d'Allonnes, 1905). Strikingly, Alexandrine had lost her sense of bodily urges, she did not feel any emotions, and she had lost her sense of time. What is remarkable about this case is the co-occurrence of these three conditions. Alexandrine did not feel hunger, satiety, thirst, nor the pressure to go to the toilet. Revault d'Allonnes conducted tests that showed that she was insensitive to ice water and needle pricks. She would show physiological reactions to emotions, like tearing up when she was sad, and she cognitively comprehended an emotional situation, but she reported not feeling anything. Although she exhibited cognitive control over the passage of time through newspapers, the changing daylight, and clocks, Alexandrine had lost her subjective sense of time. Tests revealed that she had an impaired perception of metronome speeds which she could not differentiate as being slower or faster. Revault d'Allonnes (1905) therefore concluded that conscious time is nothing less than visceral sensibility, that we have something resembling internal clocks made up of various physical rhythms, supplied by signals from our gut, bladder, lungs, arteries, and heart.

Altered states of consciousness and subjective time

What emerges from the studies discussed above is that (bodily) self-consciousness and time consciousness are modulated together. An intensified awareness of the self (the body, emotional feelings) correlates to an intensified awareness of time, while a weakened awareness of the self leads to a decreased awareness of time. As noted above, this can be easily observed empirically in the spectrum that ranges between the boredom we experience during waiting (intense feeling of self and time) to the states of flow that we experience when absorbed in an exciting activity (hardly noticing self and time). Triggered by various activities such as sports, work, music, or play (Csikszentmihalyi & Csikszentmihalyi, 1988), flow is a subjective state of enjoyment in which actions seem to happen fluently and automatically. In this highly focused yet effortless state people report a strong sense of control over the activity accompanied by a loss of self-awareness and time (Khoshnoud et al., 2020).

Whereas flow states can be achieved with any daily activity, altered states of consciousness are typically induced through a variety of psychological and pharmacological methods. In peak states during meditative contemplation, during physical exertion, or under the influence of certain drugs, a dissolution of self and time can happen (Wittmann, 2015; 2018). In the following paragraphs, I will refer to three induction methods for an altered sense of consciousness for which a reasonable amount of empirical evidence exists, namely, meditation, flotation-REST, and psychedelics.

Although there are many types of meditation practices, a common denominator for most of them is a focus on the body (Matko et al., 2021). Since body-centred techniques such as concentrating on breathing are of exceptional importance to most meditators, meditation practitioners typically experience a slowing of the subjective passage of time at the beginning of a session. The increased attention on the body is accompanied by increased insula activity and decreased cingulate activity (the Default Mode Network related to mind wandering), as demonstrated in an fMRI study with novices and mildly experienced meditators (Farb et al., 2007). For practiced meditators, however, the initial state of a slowed sense of time changes and meditators often report how the whole session felt much shorter than it actually lasted (Droit-Volet & Dambrun, 2019). An exceptionally experienced meditator, the Buddhist lama Tilmann Lhündrup Borghardt, talked about his peak states of "pure or non-dual consciousness" as a state of timelessness and selflessness (Costines et al., 2021, p. 5): "The timeless awareness during meditation is an awakening. It has no beginning and no end. This timeless time is an immersion into a being where no comparing happens. When we are comparing, there are always relations between a before and an after. It is timeless presence without the sense of an 'I', without observer. Perception and perceiver are one."

Floatation-REST (restricted environmental stimulation technique) is a practice of lying weightless in a floating cabin filled with body-warm salt water that supports the body. The cabin is completely dark and protected from all external sounds. While inside it, the boundaries of the body become blurred and only the inner sense of the body is present: one's own breathing, one's own muscles, and the activity inside one's own body come to the foreground. By increasing body awareness while eliminating external sensory input, the REST technique easily creates the conditions for a state of consciousness that can otherwise be attained only by very experienced meditators. That's why I like to call this method "instant meditation". After a floatation-REST session, people report a massive sense of relaxation and their time judgments range from a significant underestimation of the session duration to a complete lack of time orientation (Forgays & Belinson, 1986; Kjellgren et al., 2008). The existing studies on flotation-REST provide clear evidence of short-term downregulation of the pathologically increased emotional self by showing anxiolytic, antidepressant, and analgesic effects in various patient groups (Kjellgren et al., 2001; Jonsson & Kjellgren, 2017; Feinstein et al., 2018). An fMRI study with healthy subjects showed reduced connectivity within the default mode network as well as between the default mode network and many other cortical areas, including the posterior insula, after a floating session (Al Zoubi et al., 2021). The effects can be explained as a reduction in rumination in association with a relaxed body sensation, including forgetfulness of time.

When taking psychedelics such as psilocybin, LSD, or ayahuasca, manifold and tremendous changes in thinking, feeling, and experiencing occur. People can go through phases that can be interpreted as psychodynamic, causing changes in self-image as well as having spiritual dimensions (Nour & Carhart-Harris, 2017). The perception of time is strikingly altered during this process, as a systematic study on time estimation and temporal control of motor activity was able to reveal (Wittmann et al., 2007). As assessed with validated questionnaires, the changes in time perception are accompanied by a feeling of unity of the ego and the world (subject and object of experience becoming one) as well as a feeling of loss of the bodily self (Studerus et al., 2010). During different phases, different time experiences can occur, such as extreme time dilation. As a climax experience, timelessness and ego dissolution are reported: The self becomes one with the world; future, present, and past become one (Shanon, 2001).

Conclusion

Altered states of consciousness across different psychological and pharmacological induction methods are related to similar short-term phenomenal effects as well as neurophysiological correlates. Personal reports and systematic studies indicate that the senses of self and time are subject to change, with extreme experiences being described as the dissolution of time and ego (Wittmann, 2015; 2018). The relationship between subjective time and the bodily self in connection with insular cortex activity plays a fundamental role in understanding subjective time perception, such as the feeling of time passage and the estimation of duration (Wittmann, 2013). Personal experience is backed up by systematic research in the cognitive neurosciences: Results reveal that body processes create our immediate experience of time in each respective moment. The momentary perception of time passage is closely related to our experience of self and this explains the variability of subjective time as something that can move fast or slowly. It is about body time, emotional time, and processes in the insular cortex (Craig, 2009). The awareness of time and self are intimately related. Consciousness and the perceived present moment extend in time and can be described as a continuous flow of events. Any theory of consciousness must necessarily include time consciousness. Only then we might be able to explain how consciousness, the 1st person perspective, and the brain, the 3rd person perspective, are related (Kent & Wittmann, 2021).

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TIME AND THE WRITERS

TIME AND THE WRITERS: MODELS OF TIME IN LITERATURE, SCIENCE, AND BUSBY BERKELEY FILMS

Etzel Cardeña* * *(text) & Lauren Reid (videos)

(The text that follows is supplemented by 10 different film clips from Busby Berkeley films, found at https://lauren-reid.com/Time-and-the-Writers. The text gives examples from the world literature of 10 conceptions of time, illustrated in the videos).

My theory being that the actual event practically does not exist - nor time either.
Virginia Woolf, writer (in Bell, 1982, p. 118)

[D]ue to nonseparability, the said "Real" may in no sensible way be considered constituted of localized elements embedded in space-time…
Bernard d'Espagnat, physicist and philosopher (2006, p. 454)

In his play *Time and the Conways*, J. B. Priestley follows that family through three acts, from 1919 to 1937 and then back to 1919. A wrenching depiction of characters seeing their youthful illusions evaporate is not unusual, but the time twists are. Kay Conway has a disturbing vision in 1919 of their future failed lives, but her brother Alan promises that he will be able to tell her something in the future that will soothe her. In 1937 he reminds her of their previous interaction and reveals that our current sorrows are illusory because time is eternally present. Priestley, whose ideas about time were influenced by the ostensible precognitive dreams of the aeronautical engineer J. W. Dunne (1927/2001), is one of a number of writers who have had alternative views of time as a central motif in their works. *Contra* St. Augustine's statement about it in his *Confessions*, not only may time be difficult to define, but we are not even sure of its nature.

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Various sources can lead to questioning the linear account of time: writers' own personal experiences, theories from physics at the quantum and macro-levels, research on precognition and presentiment, mythical accounts of reality, and that timeless gadget called imagination.

Personal experiences. Not only have mystics like Meister Eckhart described their own experiences of a timeless/spaceless realm, but also ordinary individuals, whether exposed to a "near-death-experience," hallucinogenic drugs, or just spontaneously (Wulff, 2014). Many writers have conveyed the experience of timelessness in their writings (e. g. T. S. Eliot's *Burnt Norton,* "If all time is eternally present/All time is unredeemable"…"; see also Borges, 2010; Durr, 1970), or have depicted their own ostensible precognitive experience in their works, as in the case of García Lorca (Cardeña, et al., 2012). In contrast with an intensification of the present, authors who have had dissociative experiences, associated with being exposed to traumatic events (Cardeña & Classen, 2023) may have a discontinuous, jagged sense of time, with gaps in the immediate past or throughout one's life.

Physics theories of time. Einstein's theories and the ensuing experiments have demonstrated beyond doubt that objectively measured time and space are not absolute and depend on variables such as the position and speed of the observers and gravitation. Thus, for an observer traveling at near the speed of light, matters that are still in your future may have already been witnessed by him/her (Davies, 2002). This has given rise to alternative views of time, including a block model in which past, present, and future coexist simultaneously although our limited perception may engender the sense of sequentiality of moments. At the molecular level, experiments on quantum retrocausality suggest that subatomic events that occur later can retroactively determine those that occur earlier (Sheehan, 2011).

Controlled experiments on precognition and presentiment. Precognition is most often used to denote thoughts or images that seem to anticipate an event that could not have been predicted but has come to occur; presentiment denotes more vague hunches and/or (at times nonconscious) physiological changes that anticipate an unpredictable event (Cardeña et al., 2015). Cumulative evidence that individuals' conscious experience and their physiology can provide accurate, detailed information about future (or past) events that could not be otherwise inferred and more often than would be expected by chance has been obtained using different experimental paradigms (Cardeña, 2018; Honorton & Ferrari, 1989; Mossbridge et al., 2014).

Mythical accounts of time are not necessarily incongruous with some contemporary physics models. The historian of religions Mircea Eliade (1964) described how traditional cultures have juxtaposed the sequential *profane* time with a *sacred* one that can take different forms, including cyclical recreations of the universe or a timeless realm.

And then there is the unending spurt of literary *imagination.*

We describe below various conceptions of time found in the work of important writers, and illustrate them with edited sumptuously choreographed clips from Busby Berkeley's films, coupling the sacred and the profane. Our list of conceptions is not exhaustive (for instance, we do not cover *time travel* because it could be explained according to different models) and many more examples could be added to the ones we discuss.

Sequential Time

The common experience of time is that there is only a sliver of a moment, coming from a previous one and transforming into the next. Our sense of continuity, or "specious present," depends on the overlap in consciousness of the current and recent movements, along with an anticipation of immediate future ones (Wittmann, 2018). Every experience is transient and unrepeatable, with all conducing to the same end among living organisms, as the 15th century writer Jorge Manrique wrote in his *Coplas a la Muerte de su Padre* (Couplets for the Death of His Father) "*Nuestras vidas son los ríos/que van a dar en la mar,/qu'es el morir"* (Our lives are rivers, gliding free/ To that unfathomed, boundless sea, / The silent Grave! [Henry Wadsworth Longfellow, trans.]).

Taking a different approach, some authors have made their lines correspond to the ongoing dynamic sequence of flowing moments, as in James Joyce's sentence from *Finnegan's Wake* (1939), "Beside the rivering waters of, hitherandthithering waters," whereas others have sought to preserve the current moment by invoking its sensory presence repeatedly, trying to short-circuit associations or distractions. Gertrude Stein, who was also a student of psychologist/philosopher William James who coined the terms *stream of consciousness* and *specious present,* tried to arrest the passage of time and extend the present in a famous line from her poem *Sacred Emily, "Rose is a rose is a rose is a rose."*.

Disjointed Time

The experience of continuity, however, is far from absolute. Not only is it shattered in the case of brain damaged patients who may suddenly feel that they were completely unconscious until they regained consciousness a moment before (Restak, 1984), but it can happen to those with neurological or dissociative (i. e., psychogenically caused) amnesias, with lacunae for recent or distant memories they should remember (Cardeña, 1994). Even without any type of neurological or psychological condition, we all share disjointed time every day, both during dreams and when waking up. During non-lucid dreams, we may find ourselves suddenly in a situation without any sense of our preceding history, and after we wake up we have little to no recollection of our dreaming experiences.

In literature, a famous subversion of the typical sequence of a narrative account is Laurence Sterne's *The Life and Opinions of Tristram Shandy, Gentleman* (1759). The eponymous hero tries to chronicle his life, but is constantly frustrated by associations and distractions. Sterne also introduces other forms of discontinuity by interspersing blank pages, a page all in black, and even a couple of marble-patterned ones. August Strindberg's stunning *A Dream Play* (1902) brought into theatre the temporal disjunction of dreams, in which a year for a human character is described as a minute for the daughter of a God (Indra's daughter) and "The Officer" visibly ages while those around him do not, but returns at the end of the play to his initial age.

Suspended Time

Experienced time depends on our homocentric metric that disregards the modes of other living beings that hibernate or whose reproduction or even breathing might occur once every thousand years (Saey, 2016). The suspension of the passage of time for humans has been described in different ways. Before the advent of recent technologies, Edgar Allan Poe published in 1845 *The Facts in the Case of M. Valdemar,* in which a dying man is hypnotized and left in a "suspended hypnotic state" during which he dies but remains in limbo, unable to live or to fully die. He communicates from yonder the horrors of his pseudo existence but remains in that state for months until he is dehypnotized, and the months-long putrefaction of his body ensues instantaneously (there is a radio-theatre adaptation of this short story by Cardeña, available in Spanish at http://descargacultura.unam.mx/app1?sharedItem=500).

Moving from hypnosis to technology, Don DeLillo's novel *Zero K* (2016) occurs in a compound in which the dying (or those who want to join them) are frozen cryogenically and their death suspended until an uncertain future in which they may be revived. Earlier on, a horrifying view of suspended animation but with an experienced decaying sense of reality was offered in Philip K. Dick's novel *Ubik* (1969).

Another science fiction writer, Clark Ashton Smith, described the potential horror of a never changing landscape during space travel in his short story *Master of the Asteroid* (1932). In it, three astronauts are immersed in a space so vast that nothing seems to change. Their sense of being "perfectly stationary in a static void" makes an astronaut feel that he is sinking through a bottomless space, while another one goes on a murdering rampage. In a lighter variation of the theme of suspension, time does not stop for the main character but for everyone else in Nicholas Baker's *The Fermata* (1994), which describes the ribald adventures of Arno Strine after he learns how to pause time so he can become a voyeur.

Anticipated Time

There is no dearth of accounts in various mythological and religious traditions of individuals being able to foretell the future, either through mantic practices such as looking into the innards of a sacrificed animal, the induction of altered states (as with the Greek sybils; see Ustinova, 2017), and/or as a special gift from the divinity (as with Biblical prophets). The gift of prophecy may, however, come with a heavy price tag. In the myth of Cassandra (depicted, for instance, in *The Trojan Women,* by Euripides), daughter of the Kings of Troy, Apollo grants her the gift of foreseeing the future along with the curse of having no one believe what she says. In the novella *The Lifted Veil* (1859) by George Eliot (Mary Ann Evans), Latimer only reaps grief from his prophetic gift. In contrast, precognition comes as a relief in J. B. Priestley's *Time and the Conways*, mentioned earlier.

Circular Time

Guillaume Apollinaire has been the most influential practitioner of written and drawn poems in circular and other shapes, some which could be read *ad infinitum* (e.g., his 1918 *Miroir,* or *Mirror*, poem). In prose, Adolfo Bioy Casares offers a technological variation in his novella *La Invención de Morel* (*The Invention of Morel*) (1940), in which the eponymous character devises an invention that completely records everything (including conscious states) that transpires between him and his friends in an island for a few days. Those days are then replayed/re-experienced again and again, and will continue coming back as long as the projectors work, although the original actors are no longer around because the process of recording caused their premature death. And then we have the perfect circularity of Joyce's sophisticated romp *Finnegan's Wake,* in which the final sentence of the book is completed in its first one: "A way a lone a last a loved a long the/ riverrun, past Eve and Adan's, from swerve of shore to bend of bays..."

Reversed Time

Basic physics equations function the same forwards or backwards, but it has been proposed that because of the second law of thermodynamics (in a closed system entropy or "disorder" increases with time) time cannot be reversed (Sagan, 2013). The "time arrow" implied by this law is endorsed by the precocious Thomasina, in Tom Stoppard's theatrical masterpiece *Arcadia* (1993), who concludes that the universe cannot repeat itself but will eventually end.

In contrast, a reversed time model in literature shifts the sequence of past-present-future to future-present-past. *The Curious Case of Benjamin Button* (1922; made into a film with the same title), a short story by F. Scott Fitzgerald, chronicles the life of its hero, born as a speaking 70-year-old who in the course of the plot becomes a middle-aged man, a youngster and ends in kindergarten as the memory of his previous life fades away. A more ambitious work is Martin Amis's *Time's Arrow: or the Nature of the Offence* (1991), in which a Nazi doctor revisits his life in reverse, becoming a healer after having been a murderer in Treblinka and Auschwitz, while everything else also goes in reverse, with mosquitoes being invoked by a slap on the skin so they can give us blood to alleviate our pain and itching. In a lighter vein, Alejo Carpentier's *Viaje a la Semilla* (1944; Journey to the Seed) describes forward and reverse times, with a character noticing how, as he becomes younger, the furniture becomes larger and the teachers take away words and concepts from the minds of their pupils.

Alternate Times

Physicist Hugh Everett, III's, interpretation of the probabilistic nature of reality at the quantum level is that many alternate worlds are constantly being created from the realization of potential quantum probabilities (Joseph, 2014). An expanded presentation of Everett's 1957 doctoral thesis (DeWitt & Graham, 1973) contains two quotations, one by William James, the other a fragment of Borges's "El Jardin de los Senderos que se Bifurcan" (1941; The Garden of Forking Paths), which shows that Borges had anticipated Everett's idea, describing a labyrinth of multiple, forking worlds within a detective short story (Rojo, 2005). A somewhat related idea is presented in the "quantic" novel *Vidas Perpendiculares* (2008; Perpendicular Lives) by Álvaro Enrigue, in which Jerónimo relives simultaneously his various incarnations as a neglected Mexican boy growing up, a Greek maiden, and a prehistoric youngster, among others. This goes well beyond the seemingly accurate memories of some children who recall previous lives (Mills & Tucker, 2015) to the parallel re-experiencing of them. A whimsical example also occurs in Stoppard's *Arcadia,* in which characters from different times (1812 and "the present") coincide on stage simultaneously, and their interactions are appropriate not only for their time but also, in parallel, for the alternate time.

Closed Time Curves

This may be the most challenging view of time as it not only postulates that the future can affect the past but that an effect can be the cause of itself. The logician, mathematician, and philosopher Kurt Gödel postulated that, considering the curvature of space-time, someone travelling faster than the speed of light might go back into the past and cause itself (Joseph, 2014). In Carpentier's *El Camino de Santiago* (1958; The Way of St. James) Juan el Romero is lured into a disastrous journey to the new continent by a later version of himself, Juan el Indiano. A dizzying literary (in the visual arts one can think of Escher's *Drawing Hands*) example is Robert Heinlein's short story *All You Zombies* (1959) (filmed as *Predestination*), in which the main character is shown to have been, at different moments, a woman (with an additional set of male organs), the man who has come back from the future to impregnate her, and the baby that will become him/her.

Eternal Time/Space

The core of a mystical experience is a sense of unity with everything there is, along with an abeyance of the ordinary senses of time and space, sometimes described as an eternal present (Wulff, 2014). The religious writer Yvonne Lubbock (in Marshall, 2015, p. 49) described it as: "a feeling of timelessness, not only that time stood still, that duration had ceased, but that I was myself outside time altogether." The poet Jorgue Guillén wrote thus of his experience in *Las Doce en el Reloj*, "Centro en aquel instante/De tanto alrededor/Quien lo veía todo/Completo para un dios. Dije: Todo, completo" (Center in that moment/Of so much around/Observing everything/As full as a god/I said: Everything, complete [Etzel Cardeña, trans.]).

In his story *El Aleph* (1945), Borges as the character "Borges" encounters the mythical Aleph, a small iridescent sphere at the bottom of a basement stair. In its 2-3 cm diameter, everything happening in the cosmos from every perspective is simultaneously perceivable. "Borges" apologizes for having to use language, which is sequential and limited, to enumerate infinite perspectives on everything in the cosmos: a mirror seen from every conceivable perspective, the masses in America, snow, tobacco, the corpse of his beloved who had recently died, sunsets, dawn, and the more justified etc. in literature. This infinitude of the cosmos in a small apartment echoes the belief of some traditional cultures that in *profane* time there are openings through which *sacred* time can manifest (Eliade, 1964).

Some eminent quantum physicists have offered similar views. David Bohm (1980) postulated an *implicate order,* which precedes time-space differentiation and is foundational for the surface reality that we perceive as an *explicate order*, whereas Bernard d'Espagnat's (2006) described a unified *veiled reality*, inapprehensible by the mind.

End of Time

The end of time, as compared with the end of the human species, defies imagination. Whereas the latter has been presented in dystopic novels by Margaret Atwood, Cormac McCarthy, and others, the complete cessation of time cannot be encompassed by language. No literature can be made of that nothingness, and whatever attempts have been made take recourse of paradoxes. Likely the most famous account in the West is the *Apocalypse* or *The Revelation of St. John the Divine* (King James Version) in which the Almighty appears as "Alpha and Omega, the beginning and the ending... which is, and which was, and which is to come." Arthur C. Clarke presents a technological version of the Omega in his short story *The Nine Billion Names of God* (1953), in which a computer finishes its task of determining all the names of the divinity. At that point, one of the characters signals to the other as "Overhead, without any fuss, the stars were going out."

Finally, Borges, the explorer of time, now as a poet, has the last, very human, word of the end of times in his *Del Infierno y del Cielo* (1960):

"cuando el juicio retumbe en las trompetas / últimas y el planeta milenario / sea obliterado y bruscamente cesen / ¡oh Tiempo! tus efímeras pirámides, / los colores y líneas del pasado/ definirán en la tiniebla un rostro /durmiente, inmóvil, fiel, inalterable / (tal vez el de la amada, quizá el tuyo) / y la contemplación de ese inmediato / rostro incesante, intacto, incorruptible, / será para los réprobos, Infierno; / para los elegidos, Paraíso." (when Judgment Day sounds in the last trumpets/and planet and millenniums both/disintegrate, and all at once, O Time,/all your ephemeral pyramids cease to be,/the colors and the lines that trace the past/will in the semi-darkness form a face,/a sleeping face, faithful, still, unchangeable/(the face of the loved one, or, perhaps, your own)/and the sheer contemplation of that face-/never-changing, whole, beyond corruption-/will be, for the rejected, an Inferno,/and, for the elected, Paradise. [Alastair Reid, trans.]).

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Resumo do poster apresentado pela Fundação BIAL
Abstract of the poster presented by the BIAL Foundation

KEEPING UP WITH THE BIAL FOUNDATION PERFORMANCE: A BIBLIOMETRIC ASSESSMENT

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Background

Bibliometric indicators are a useful tool to assess the quality of several research outcomes. In 2014, we created an online database to gather the outcomes derived from projects supported by BIAL Foundation, thus enabling a more systematic and comprehensive evaluation of their research impact.

Aims

To analyze and monitor the productivity, and related outcomes, of the projects supported by the BIAL Foundation from 1994 until today.

Method

The productivity of projects was measured by counting the number of papers published in academic journals indexed on Web of Science (WoS) or Scopus. To examine the impact of publications we retrieved the number of citations per item from the WoS Core Collection in March 2022. The BIAL Foundation *h*-index was calculated by combining the total number of papers published (i.e., productivity) and the number of citations for each paper (i.e., impact). Moreover, for papers published between 2011 and 2021, the number of citations were compared with the expected number of citations for papers in the same research field and publication year, based on field baselines percentiles dataset of Essential Science Indicators (ESI), updated on January 13th, 2022. We also retrieved information regarding the Highly Cited Papers (those that

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ranked in the top 1% by citations for research field and publication year in WoS). Regarding journals' quality, it was assessed by the impact factor and, mainly, by the quartile score (i.e., Q1, Q2, Q3, and Q4), which was provided by Journal Citation Reports, to mitigate differences between research fields. It is noteworthy, that when a journal occupied different positions in the quartile ranking depending on the subject category with which it was associated, we chose the higher rank.

Results

Since 1994, there were 775 projects supported through the Grants Program for Scientific Research, in the areas of Psychophysiology (392 projects; 51%), Parapsychology (240 projects; 31%) and Interdisciplinary (i.e., a combination of Psychophysiology and Parapsychology; 143 projects; 18%). Moreover, the Foundation also supports four additional projects focused on specific topics of interest. Regarding projects' productivity, between 1994 and 2022, there were 2075 publications (article, book chapter, conference paper, conference proceedings, editorial material, journal, letter, and online paper), out of which 1606 were published in indexed journals. From those, 1361 were published in journals with an average impact factor of 4.016. We counted 35.146 citations, with 1430 publications being cited on average 23 times (M = 23,00), ranging from 0 to 538. Most of papers were published in journals of quartile 1 (n = 647; 48.24%) and quartile 2 (n = 378; 28.43%). The BIAL Foundation h-index was 83. Between 2011 and 2021, from the 1017 publications, 21% ranked in the top 10% by citations for field and publication year.

Conclusions

The use of up-to-date bibliometric indicators provides a basis for evaluating ongoing and to guide the strategy of future scientific projects supported by the BIAL Foundation. These results demonstrate the excellence of the research work under the scope of the Grants Program for Scientific Research supported by BIAL Foundation.

Keywords

BIAL Foundation grants, Indexed publications, Citations, Impact factor, Quartiles.

LISTA DE POSTERS
POSTERS

Posters com resultados finais apresentados pelos investigadores apoiados pela Fundação BIAL e/ou disponíveis em www.fundacaobial.com

Posters with final results presented by the BIAL Foundation grant holders and/or available at www.fundacaobial.com

Resumos dos posters disponíveis em / *Posters' abstracts available at* www. fundacaobial.com

2014

85/14 - "The clinical gut: Examining the cognitive processes and neural underpinnings of judgments, feelings of rightness and its impact on information seeking" - only abstract available
Researchers: Ana Sofia Bilreiro Jacinto Braga, Anne Krendl, Cara Charissa Lewis, Cilia Witteman, Elizabeth Collins, João Braga
Institution: Centro de Investigação e Intervenção Social (CIS-IUL), ISCTE - Instituto Universitário de Lisboa (Portugal); Department of Psychological and Brain Sciences - Indiana University Bloomington (USA)
Duration: 2015/05 - 2021/02

178/14 - "A study of the relationship between mindfulness, distraction and brain stimulation" - only abstract available
Researchers: Fabrice Parmentier, Javier Garcia-Campayo, Margalida Gili-Planas, Mauro García-Toro, Pilar Andrés
Institution: University of the Balearic Islands, Palma (Spain); Hospital Universitario Miguelñ Servet, Zaragoza (Spain)
Duration: 2015/06 - 2019/07

207/14 - "The role of astrocytes in complex cognitive processing"
Researchers: João Filipe Pedreira de Oliveira, Joana Correia, Luísa Pinto, Nuno Dias, Sónia Guerra Gomes, Vanessa Sardinha, Inês Caetano Campos
Institution: Life and Health Sciences Research Institute - ICVS/3B's - Government Associate Laboratory, Universidade do Minho, Braga (Portugal)
Duration: 2015/10 - 2019/11

211/14 - "Mind to mind: Brain dynamics of distant focused intention for consciousness expansion"
Researchers: Anabela Ventura Carraça, Carlos Miguel Loureiro Siopa, Hugo A. Ferreira, Carlos Moreira
Institution: LIMMIT - Laboratory of Mind-Matter Interaction with Therapeutic Intention, Faculdade de Medicina da Universidade de Lisboa (Portugal)
Duration: 2015/04 - 2019/04

242/14 - "The role of affective dimensions in the perception of facial expressions of emotion: Neuropsychophysiological, developmental, and neuroimaging examination of an affective predictive coding framework"
Researchers: Fernando Ricardo Ferreira Santos, Eva Inês Costa Martins, Francisco Sá Ferreira Loureiro Pipa, Manuel Fernando Santos Barbosa, Michelle de Haan, Pedro Manuel Rocha Almeida, Tiago de Oliveira Paiva, Torsten Baldeweg
Institution: Laboratory of Neuropsychophysiology - Faculty of Psychology and Educational Sciences of the University of Porto (Portugal)
Duration: 2015/10 - 2021/03

251/14 - "Signal or noise? Using a psychophysical approach to investigate the effects of attention and neurofeedback training on electrocortical predictive anticipatory activity (PAA) to true random stimuli"
Researchers: Michael Franklin, Jonathn Schooler, Stephen Baumgart
Institution: Department of Psychology and Brain Sciences, University of California at Santa Barbara (USA)
Estimated duration: 2015/04 - 2019/07

268/14 - "EEG localization and individual variability in response to emotional stimuli" - only abstract available
Researchers: William E. Bunney, Blynn G. Bunney, James Fallon, Joseph C. Wu, Julie Patterson, Richard Alan Stein
Institution: The Regents of the University of California, Irvine (USA)
Duration: 2017/03 - 2021/05

299/14 - "Neurofeedback-based adaptive audiovisual tutorial for enhancing multi-modal learning" - only abstract available
Researchers: Rainer Wilhelm Goebel, Gal Raz, Talma Hendler, Rick van Hoof
Institutions: Maastricht Brain Imaging Centre, Maastricht University (The Netherlands); The Medical Research Infrastructure and health services fund at the Tel Aviv Medical center (Israel)
Estimated duration: 2015/12 - 2020/01

304/14 - "The impact of music training on reading and mathematical abilities of normal and reading disabled children: a behavioral and neuroimaging longitudinal study"
Researchers: Maria de São Luís Vasconcelos da Fonseca e Castro Schöner, Christian Gaser, Daniela da Costa Coimbra, Marta Sofia Pinto Martins
Institutions: Faculty of Psychology and Educational Sciences at University of Porto, FPCEUP / Centre for Psychology at University of Porto (Portugal); Structural Brain Mapping Group/ Department of Psychiatry - Jena University Hospital (Germany)
Duration: 2015/10 - 2019/09

339/14 - "Neural mechanisms of social cognition in zebrafish" - only abstract available
Researcher: Ana Rita Silva Martins Nunes **-** only abstract available
Institution: Instituto Gulbenkian de Ciencia, Oeiras (Portugal)
Duration: 2015/05 - 2019/11

376/14 - "Lateralisation of cognitive functions in the brain: Typical vs. atypical patterns" - only abstract available
Researcher: Deborah J Serrien
Institution: School of Psychology, University of Nottingham (UK)
Duration: 2015/10 - 2018/11

427/14 - "Gliogenesis control of brain neuroplasticity, neurophysiology and cognitive function"
Researchers: Luísa Alexandra Meireles Pinto, Ana Rita Machado dos Santos, António Maria Restolho Mateus Pinheiro, Joana Sofia da Silva Correia, João Filipe Pedreira de Oliveira, João Miguel Bessa Peixoto, Nuno Dinis Alves, Vítor Manuel da Silva Pinto
Institution: Life and Health Sciences Research Institute - ICVS/3B's- Government Associate Laboratory, Universidade do Minho, Braga (Portugal); Center for Neuroscience and Cell Biology, University of Coimbra (Portugal)
Duration: 2015/09 - 2019/10

442/14 - "Neurochemical substrates of neurofeedback" - only abstract available
Researchers: Tomas Ros, Nathalie Ginovart
Institution: Interfacultary Center for Neuroscience, University of Geneva (Switzerland); Division of Nuclear Medicine, University Hospitals Geneva (Switzerland)
Duration: 2016/04 - 2020/09

528/14 - "Psi performance in attenuated electromagnetic fields" - only abstract available
Researchers: Michelle Fauver, Glenn Hartelius, Richard Knowles
Institution: California Institute of Integral Studies, Embodied Consciousness Research Group, San Francisco (USA)
Estimated duration: 2015/01 - 2018/07

2016

30/16 - "Exploring the neural basis of motivation"
Researchers: Ana João Rodrigues, Nivaldo Vasconcelos, Carina Cunha, Bárbara Coimbra, Laura Silva, Patrícia Monteiro, Sónia Borges, Pedro Morgado
Institution: Life and Health Sciences Research Institute - ICVS, School of Health Sciences, University of Minho, Braga (Portugal)
Duration: 2017/01 - 2020/03

32/16 - "Neural mechanisms of dream recall: Electrophysiological differences between young and older adults" - only abstract available
Researchers: Serena Scarpelli, Luigi De Gennaro, Anastasia Mangiaruga, Chiara Bartolacci
Institution: Department of Psychology, University of Rome "La Sapienza" (Italy)
Duration: 2017/04 - 2019/09

39/16 - "Considering voice hearing by psychic practitioners: A qualitative pluralistic investigation of mental health and well-being" - only abstract available
Researcher: Craig Murray
Institution: Division of Health Research, Lancaster University (UK)
Duration: 2017/05 - 2020/06

44/16 - "Inducing and measuring plasticity in response control mechanisms in the human brain"
Researchers: Alejandra Sel de Felipe, Matthew Rushworth
Institution: Department of Experimental Psychology, University of Oxford (UK)
Duration: 2017/10 - 2021/09

51/16 - "Cognitive plasticity: Modulation and monitoring through a neurophysiological approach" - only abstract available
Researchers: Carlo Miniussi, Romina Esposito
Institution: Centre for Mind/Brain Sciences - CIMeC, University of Trento, Rovereto (Italy)
Duration: 2017/03 - 2020/03

58/16 - "Psi, nonlocality and entangled photons" - only abstract available
Researchers: Dean Radin, Peter Bancel, Arnaud Delorme
Institution: Institute of Noetic Sciences, Petaluma, California (USA); Institute Metapsychique Internationale, Paris (France)
Duration: 2019/09 - 2021/11

62/16 - "Imagination and reactance in a psi task using the imagery cultivation model and a fuzzy set encoded target pool" - only abstract available
Researcher: Lance Storm
Institution: Brain and Cognition Research Centre, School of Psychology, University of Adelaide (Australia)
Duration: 2017/11 - 2019/04

66/16 - "Mindfulness meditation shapes synchronization of brain networks for effective perceptual decision making"
Researcher: Laura Marzetti
Institution: Department of Neurosciences, Imaging and Clinical Sciences, University "G. D'Annunzio" of Chieti - Pescara (Italy)
Duration: 2017/09 - 2019/09

69/16 - "Induced near-death-experiences in healthy volunteers: Phenomenology, psychophysiology and after effects. Illustration with two exceptional case studies"
Researchers: Mário Simões, Sofia Machado Ferreira, Ana Paula Farinha
Institution: Laboratory of Mind-Matter Interaction with Therapeutic Intention - LIMMIT, Faculdade de Medicina da Universidade de Lisboa (Portugal); Hospital de Santa Maria, Lisboa (Portugal)
Duration: 2018/05 - 2020/11

70/16 - "Understanding atypical metacognition and time perception in high hypnotic suggestibility"
Researcher: Devin Terhune
Institution: Department of Psychology, Goldsmiths, University of London (UK)
Estimated duration: 2017/11 - 2018/12

72/16 - "A physiological examination of full-trance channeling"
Researchers: Helané Wahbeh, Arnaud Delorme
Institution: Institute of Noetic Sciences, Petaluma, California (USA)
Duration: 2017/09 - 2019/03

75/16 - "The painful awareness of death: Influence of thoughts of death on behavioural and cerebral activity associated with painful nociceptive stimuli" - only abstract available
Researchers: Elia Valentini, Istvan Gyimes
Institution: Department of Psychology, Faculty of Science and Health, University of Essex, Colchester (UK)
Estimated duration: 2017/10 - 2020/09

88/16 - "The interoceptive self: Transcutaneous vagus nerve stimulation as a new tool to investigate heart-brain interactions"
Researchers: Ruben Azevedo, Emmanouil Tsakiris, Valerio Vallani
Institution: Department of Psychology, Royal Holloway, University of London (UK)
Duration: 2017/10 - 2019/10

93/16 - "Synchonizing brain and heart through decelerated respiration – An EEG-ECG study investigating the effects of paced breathing"
Researchers: Thilo Hinterberger, Teele Tamm
Institution: Research Section of Applied Consciousness Sciences, Department of Psychosomatic Medicine, University Medical Center Regensburg (Germany)
Duration: 2018/08 - 2020/06

100/16 - "Arousal effects on time perception and timed behaviour" - only abstract available
Researchers: Ruth Ogden, Michael Richter, Francis McGlone
Institution: School of Natural Sciences and Psychology, Liverpool John Moores University (UK)
Duration: 2017/09 - 2019/05

101/16 - "Implications of near-death experiences for the mind-brain relationship" - only abstract available
Researchers: Bruce Greyson, Surbhi Khanna, Lauren Moore, Lori Derr, Sue Ruddock
Institution: Division of Perceptual Studies, Department of Psychiatry and Neurobehavioral Sciences, University of Virginia, Charlottesville (USA)
Duration: 2017/07 - 2018/11

102/16 - "Using suggestion to influence attitudes and behaviour" - only abstract available
Researchers: Jeremy Olson, Thomas Strandberg, Amir Raz, Petter Johansson
Institutions: Raz Cognitive Neuroscience Lab, McGill University & Montreal Neurological Institute (Canada); Choice Blindness Laboratory, Lund University Cognitive Science (Sweden)
Duration: 2018/01 - 2020/01

111/16 - "A psychophysiological perspective of the transformative experience of pregnancy" - only abstract available
Researchers: Helena Rutherford, Linda Mayes, Catherine Monk, Elizabeth Meins, Brianna Francis
Institution: Child Study Center - CSC, Yale University School of Medicine, New Haven (USA)
Duration: 2017/03 - 2020/02

114/16 - "Effects of a mindfulness-based intervention for teachers: A study on teacher and student outcomes" - only abstract available
Researchers: Alexandra Marques-Pinto, Ana Pinheiro, Patricia Jennings, Mark Greenberg, Joana Sampaio de Carvalho
Institution: Centro de Investigação em Ciência Psicológica- CICPSI, Faculdade de Psicologia da Universidade de Lisboa (Portugal)
Duration: 2017/01 - 2020/03

117/16 - "Replication in parapsychology: The correlation matrix method" - only abstract available
Researchers: Caroline Watt, Ana Flores
Institution: Koestler Parapsychology Unit, University of Edinburgh, Scotland (UK)
Duration: 2017/01 - 2018/11

118/16 - "The experiences of participants in religious healing rituals in Lourdes: The role of noetic meaning and identity shift" - only abstract available
Researchers: Paul Dieppe, Sarah Goldingay, Sarah Warber, Emmylou Rahtz
Institution: Institute of Health Research, University of Exeter Medical School (UK); Centre for Research in Psychology, Behaviour and Achievement, University of Coventry (UK)
Estimated duration: 2017/07 - 2021/10

122/16 - "A fully transparent pre-registered replication study of precognitive detection of reinforcement using an expert consensus design" - only abstract available
Researchers: Zoltan Kekecs, Balazs Aczel, Bence Palfi, Aba Szollosi, Barnabas Szaszi
Institution: Decision Making Laboratory, Faculty of Education and Psychology, Eotvos Lorand University, Budapest (Hungary)
Estimated duration: 2017/05 - 2022/04

147/16 - "Metarepresentations of supernatural belief and the effect of context on physiological responses and cognitions"
Researchers: Malcolm Schofield, Ian Baker, David Sheffield, Paul Staples
Institution: Department of Psychology, College of Life and Natural Sciences, University of Derby (UK)
Estimated duration: 2018/02 - 2020/02

150/16 - "An investigation into the causal role of alpha oscillations in attention" - only abstract available
Researchers: Alexander Jones, Jonathan Silas, Lars Wicke
Institution: The Behavioural, Affective, and Cognitive Neuroscience research group - BACneuro, Middlesex University London (UK)
Estimated duration: 2017/03 - 2019/02

152/16 - "The role of the lateral occipital area in the visual processing of object size, shape, and orientation within and outside conscious awareness" - only abstract available
Researchers: Philippe Chouinard, Irene Sperandio, Robin Laycock
Institutions: La Trobe University, Melbourne (Australia); School of Psychology, University of East Anglia, Norwich (UK)
Duration: 2017/03 - 2019/09

157/16 - "Estranged from oneself, estranged from the others: Investigating the effect of depersonalisation on self-other mirroring"
Researchers: Anna Ciaunica, Harry Farmer, Ophelia Deroy, Vittorio Gallese
Institutions: Institute of Philosophy Porto, University of Porto (Portugal); Institute of Cognitive Neuroscience, University College London (UK)
Duration: 2017/05 - 2021/05

169/16 - "The potential effect of behavioral stimulation on social competence in dogs (via endogenous oxytocin release)" - only abstract available
Researchers: Anna Kis, József Topál, Alin Ciobica, Radu Lefter, Katinka Tóth
Institutions: Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Budapest (Hungary); Department of Animal Physiology and Behaviour "Alexandru Ioan Cuza" University, Iasi (Romania)
Duration: 2017/01 - 2021/11

176/16 - "Dissociating working memory and inhibition deficits as a result of healthy and unhealthy ageing" - only abstract available
Researchers: Stephen Badham, Mark Crook-Rumsey, David Connelly, Trevor Crawford, Christina Howard
Institutions: Division of Psychology, Nottingham Tent Univeristy (UK); Department of Psychology, Lancaster University (UK)
Duration: 2017/12 - 2021/05

183/16 - "Decoding the language of 'now': EEG microstates in experienced meditators, from letters to grammar"
Researchers: Elena Antonova, Chrystopher Nehaniv, Martin Holding
Institutions: Department of Psychology, Institute of Psychiatry, Psychology & Neuroscience, King's College London (UK); University of Hertfordshire, Hatfield (UK)
Estimated duration: 2017/09 - 2021/04

188/16 - "Accuracy and neural correlates of blinded mediumship compared to controls"
Researchers: Arnaud Delorme, Helane Wahbeh
Institution: Institute of Noetic Sciences, Petaluma, California (USA)
Duration: 2017/10 - 2020/10

189/16 - "Implicit beliefs in the study of experimenter effects in the replication of psi experiments: A global initiative"
Researchers: Marilyn Schlitz, Arnaud Delorme, Daryl Bem
Institution: Institute of Noetic Sciences, Petaluma, California (USA)
Duration: 2017/10 - 2021/04

190/16 - "Sleeping body, sentient mind? Searching for the neural bases of conscious experiences during sleep" - only abstract available
Researchers: Eus Van Someren, Yishul Wei
Institution: Department of Sleep and Cognition, Netherlands Institute for Neuroscience, Amsterdam (The Netherlands)
Duration: 2017/10 - 2019/05

191/16 - "Mind-matter entanglement correlation" - only abstract available
Researcher: Hartmut Grote
Institutions: Max-Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover (Germany)
Duration: 2017/03 - 2021/03

195/16 - "The sense of self: A neuroimaging study of interactions between intrinsic and extrinsic self networks" - only abstract available
Researchers: Sjoerd Ebisch, Mauro Gianni Perrucci
Institution: Department of Neurosciences, Imaging and Clinical Sciences, University "G. D'Annunzio" of Chieti - Pescara (Italy)
Duration: 2017/04 - 2019/10

203/16 - "Extraordinary experiences and performance on psi tasks during and after meditation classes and retreats" - only abstract available
Researchers: Jennifer Kim Penberthy, Cassandra Vieten, Lori Derr, Arnaud Delorme, Jenny Matthews, Loraine Walter
Institutions: Division of Perceptual Studies, Department of Psychiatry and Neurobehavioral Sciences, University of Virginia, Charlottesville (USA); Institute of Noetic Sciences, Petaluma, California (USA)
Duration: 2018/01 - 2020/01

207/16 - "The role of motion adaptation in bottom-up mechanisms of perceptual decision-making"
Researchers: Miguel Castelo-Branco, João Duarte, Ricardo Martins, Teresa Sousa, Gabriel Costa
Institution: Institute for Nuclear Sciences Applied to Health - ICNAS, University of Coimbra (Portugal)
Duration: 2017/11 - 2019/10

217/16 - "Physiological indices of the deleterious effects of unrealistic media images on body satisfaction: A cross-cultural investigation"
Researchers: Clédna Patrícia de Oliveira-Silva, Rachel Rodgers, Óscar Gonçalves, Pedro Dias, Rosana Magalhães, Eugénia Fernandes, Bárbara Machado, Joana Coutinho, Mike Marriott
Institutions: Centre for Studies in Human Development, Faculty of Education and Psychology, Universidade Católica Portuguesa, Porto (Portugal); Department of Applied Psychology, Northeastern University, Boston (USA); Nottingham Trent University (UK)
Estimated duration: 2018/06 - 2021/12

218/16 - "Virtual bodies, real empathy: Behavioural, bodily, and neural reactivity to the observation of pain and pleasure on self and others in immersive virtual reality"
Researchers: Gaetano Tieri, Martina Fusaro, Valentina Nicolardi, Salvatore Maria Aglioti
Institution: Unitelma Sapienza, Rome (Italy); Social Cognitive Neuroscience Laboratory, University of Rome "La Sapienza" (Italy)
Duration: 2017/05 - 2020/01

238/16 - "When prediction errs: Examining the brain dynamics of altered saliency in self-voice perception"
Researchers: Ana P. Pinheiro, Sonja Kotz, Michael Schwartze, Maria Amorim
Institutions: Faculdade de Psicologia da Universidade de Lisboa (Portugal); Faculty of Psychology and Neuroscience, University of Maastricht (The Netherlands)
Duration: 2017/03 - 2020/01

264/16 - "The influence of maternal bonding in neuroimmune synaptic sculpting"
Researchers: Ana Luísa Cardoso, João Peça, Joana Guedes, Ana Silvestre Cardoso, Ana Viegas, Elisabete Ferreiro
Institution: Center for Neuroscience and Cell Biology, University of Coimbra (Portugal)
Duration: 2017/01 - 2020/09

266/16 - "Early life stress and social hierarchies: The role of cortico-striatal circuits"
Researchers: João Peça, Joana Guedes, Ana Luísa Cardoso, Mohammed Hussien, Lara Franco, Mário Carvalho
Institution: Center for Neuroscience and Cell Biology, University of Coimbra (Portugal)
Duration: 2017/01 - 2021/01

281/16 - "Motor Imagery in speech processing"
Researchers: Patricia Martine Adank, Helen Nuttall, Gwijde Maegherman
Institution: Speech Hearing and Phonetic Sciences, Division of Psychology and Language, UCL, London (UK); Department of Psychology, University of Lancaster (UK)
Duration: 2018/01 - 2020/04

286/16 - "Getting the aging brain to train: A working memory and neurostimulation approach"
Researchers: Adriana Sampaio, Ana C. Teixeira Santos, Sandra Carvalho, Jorge Leite, Ana Raquel Mesquita, Felipe Fregni
Institutions: Psychology Research Center (CIPsi), School of Psychology, University of Minho, Braga (Portugal); Spaulding-Labuschange Neuromodulation Center, Spaulding Rehabilitation Hospital & Massachusetts General Hospital/Harvard Medical School, Charlestown (USA)
Estimated duration: 2017/06 - 2022/05

298/16 - "Empowering feedback connections in temporo-occipital network to boost visual perception of emotions" - only abstract available
Researchers: Sara Borgomaneri, Marco Zanon, Alessio Avenanti, Caterina Bertini
Institution: Center for studies and research in Cognitive Neuroscience, Department of Psychology, University of Bologna, Cesena (Italy)
Duration: 2017/09 - 2019/10

312/16 - "Mind-body interactions in writing (M-BW): Psychophysiological and linguistic synchronous correlates of expressive writing"
Researchers: Rui Alves, Teresa Limpo, Sara Costa, Ana Sousa, Mónica Moreira, José Leal, Teresa Jacques
Institution: Neurocognition and Language Research Group, Faculty of Psychology and Education Sciences of the University of Porto (Portugal); Faculty of Sciences of the University of Porto, (Portugal)
Duration: 2017/04 - 2020/09

329/16 - "Exploring the correlates and nature of subjective apparitional experiences"
Researchers: Christine Simmonds-Moore, Donadrian Rice, Chase O'Gwin
Institution: Psychology Department, University of West Georgia, Carrollton (USA)
Duration: 2018/04 - 2020/06

346/16 - "The mind possessed project: Mapping the varieties of possession experiences"
Researchers: Miguel Farias, Romara Delmonte
Institution: Centre for Research in Psychology, Behaviour and Achievement, Coventry University (UK)
Estimated duration: 2017/12 - 2021/04

2018

02/18 - "Neurobiological effects of Lourdes water: An fMRI study" - only abstract available
Researchers: Anne Schienle, Albert Wabnegger
Institution: Clinical Psychology, University of Graz (Austria)
Duration: 2019/01 - 2021/09

13/18 - "Biological bases of music cognition" - only abstract available
Researchers: Juan Manuel Toro, Paola Crespo-Bojorque, Alexandre Celma-Miralles, Carlota Pagés
Institution: Center for Brain and Cogntion, University Pompeu Fabra, Barcelona (Spain)
Duration: 2019/03 - 2021/10

16/18 - "The psychology and parapsychology of spiritual emergency" - only abstract available
Researchers: Lance Storm, Monika Goretzki
Institution: School of Psychology, University of Adelaide (Australia)
Duration: 2019/06 - 2021/09

29/18 - "Mind-matter practical applications" - only abstract available
Researchers: Patrizio Tressoldi, Luciano Pederzoli, Marco Bilucaglia
Institution: EvanLab, Firenze (Italy); Dipartimento di Psicologia Generale, Università di Padova (Italy)
Duration: 2019/01 - 2021/05

50/18 - "Changes in the temporal width of the present moment after meditation"
Researchers: Marc Wittmann, Stefan Schmidt, Karin Meissner, Damisela Linares Gutiérrez
Institutions: Institute for Frontier Areas of Psychology and Mental Health, Freiburg (Germany); University Clinic Freiburg (Germany); Coburg University of Applied Sciences (Germany)
Estimated duration: 2019/07 - 2021/08

72/18 - "Temperamental influences on social cognition under stress" - only abstract available
Researchers: Frederike Beyer, Ulrike Krämer
Institution: Psychology Department, School of Biological and Chemical Sciences, Queen Mary University of London (UK); Department of Neurology, University of Lubeck (Germany)
Duration: 2019/02 - 2021/09

82/18 - "Neuropsychological and cognitive-perceptual characteristics of mediums and psychics"
Researcher: Ken Drinkwater
Institution: Health, Psychology and Communities, Manchester Metropolitan University (UK)
Estimated duration: 2019/09 - 2021/09

93/18 - "Meditation-induced neuroplasticity of the embodied-self and its role in social processing" - only abstract available
Researcher: Aviva Berkovich-Ohana
Institution: The Edmond J. Safra Brain Research Center, University of Haifa (Israel); Gonda Multidisciplinary Brain Research Center, Bar-Ilan University (Israel)
Duration: 2019/02 - 2021/09

101/18 - "Hypnosis and cognition: Neural basis of hypnotic suggestion on executive functions and perceptual awareness" - only abstract available
Researcher: Rinaldo Livio Perri, Francesco Di Russo, Enrico Facco
Institution: Faculty of Psychology, University Niccolò Cusano, Rome (Italy); Cognitive Nueroscience o Action lab, University Foro Italico, Rome (Italy)
Duration: 2019/03 - 2021/09

106/18 - "How does consciousness work in real life?" - only abstract available
Researchers: Adrià Tauste Campo, Rodrigo Quian-Quiroga
Institution: Center for Brain and Cognition, University Pompeu Fabra, Barcelona (Spain)
Estimated duration: 2019/02 - 2021/05

113/18 - "Psi in everyday social interaction"
Researcher: Robin Wooffitt, Alicia Fuentes-Calle
Institution: Anomalous Experiences Research Unit, Department of Sociology, University of York (UK)
Duration: 2019/03 - 2021/04

117/18 - "The neuronal basis of biases" - only abstract available
Researchers: Rubén Moreno-Bote, Roozbeh Kiani
Institution: Center for Brain and Cognition, Department of Technologies of Information and Communications, Universitat Pompeu Fabra, Barcelona (Spain); Center for Neural Science, New York University (USA)
Duration: 2019/01 - 2021/04

138/18 - "The neural signatures of leadership: Two-brain directed synchronization during eye contact"
Researchers: Caroline Di Bernardi Luft, Isabelle Mareschal
Institution: School of Biological and Chemical Sciences, Queen Mary University of London (UK)
Estimated duration: 2019/07 - 2020/06

163/18 - "Effects of a short-term mindfulness intervention on hypnotisability and mental health" - only abstract available
Researchers: Zoltan Dienes, Peter Lush
Institution: School of Psychology, University of Sussex (UK)
Duration: 2019/04 - 2020/04

180/18 - "Exploring the effects of linguistic versus non-linguistic mentation in a remote viewing protocol, with coincident micropsychokinesis detection using a novel matrix REG" - only abstract available
Researchers: Paul Stevens, Ben Roberts
Institution: University of Derby (UK)
Estimated duration: 2019/05 - 2020/06

211/18 - "Correlating accurate intuition with learning styles and sensory modality preferences" - only abstract available
Researchers: Julie Beischel, Lisa Conboy
Institution: Windbridge Research Center, Tucson, Arizona (USA); Beth Israel Deaconess Medical Center at Harvard Medical School, Boston, Massachusetts (USA)
Duration: 2019/01 - 2021/10

228/18 - "Blurring the line between human and robot? Mapping and manipulating the socialness gradient in the brain" - only abstract available
Researchers: Ruud Hortensius, Emily Cross
Institution: Centre for Social, Cognitive and Affective Neuroscience - cSCAN, Institute of Neuroscience and Psychology, University of Glasgow (UK)
Duration: 2019/05 - 2021/09

230/18 - "Unraveling the mechanisms behind automatic and emotional control: Psychophysiological, cortical excitability and functional connectivity measures"
Researchers: Ignacio Obeso, Jose Ángel Pineda Pardo, Claudia Ammann, Lina Guida, Úrsula Alcañas, David Mata Marín
Institution: Centro Integral en Neurociencias A. C. - CINAC, Fundación Investigación HM Hospitales, Madrid (Spain)
Estimated duration: 2019/02 - 2021/12

261/18 - "Phenomenological experience and neurophysiological correlates of shamanic trance in healthy individuals"
Researchers: Olivia Gosseries, Nolween Marie
Institution: GIGA research center, GIGA-Consciousness, University of Liège (Belgium)
Duration: 2019/07 - 2021/11

284/18 - "Testing a neurophysiological model of inner speech processing"
Researcher: Bo Yao
Institution: Division of Neuroscience and Experimental Psychology, University of Manchester (UK)
Duration: 2019/09 - 2022/01

339/18 - "Analysis of brain activity in adolescents with different levels of emotional regulation" - only abstract available
Researchers: Jordi Solbes Matarredona, María Ángeles Gómez Climent, Samuel Hernández González, Carlos Caurín Alonso, Albert Clemente Soriano, Jose Luis Alba Robles, Rodrigo Zequeira Cotes
Institutions: Faculty of Education, University of Valencia (Spain); Faculty of Psychology, University of Valencia (Spain); Faculty of Psychology and Education, International University of Rioja, Logroño (Spain)
Estimated duration: 2019/02 - 2020/10

356/18 - "Neural mechanisms underlying unconscious working memory" - only abstract available
Researchers: Albert Compte, João Barbosa, Josep Valls-Sole
Institution: Institut d'investigacions Biomèdiques August Pi i Sunyer - IDIBAPS, Barcelona (Spain)
Duration: 2019/05 - 2021/09

PALESTRANTES E MODERADORES
SPEAKERS AND MODERATORS

ORPHEU BERTOLAMI Professor of Physics, Faculty of Sciences, University of Porto, Portugal. Scientific interests: astroparticle physics, cosmology, classical and quantum gravity, applied and fundamental physics in space, earth system physics.

MICHAEL BRECHT Professor of Systems Neuroscience, Humboldt University Berlin. Coordinator of the Bernstein Center for Computational Neuroscience Berlin, Germany. Scientific interests: memory formation, social touch, social neuroscience and biological approaches to brain function.

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JIMENA CANALES Writer and Professor at the Graduate College, University of Illinois, Urbana-Champaign, USA. Author of "A Tenth of a Second" and "The Physicist and the Philosopher: Einstein, Bergson, and the Debate That Changed Our Understanding of Time". Scientific interests: history of science.

ETZEL CARDEÑA Thorsen Professor of Psychology and Director of the Center for Research on Consciousness and Anomalous Psychology (CERCAP), Department of Psychology, Lund University, Sweden. Scientific interests: the psychology of anomalous experiences/non-ordinary mental expressions, including parapsychological phenomena; neurophenomenology of hypnosis, meditation and dissociation; stream of consciousness.

BERNARD CARR Professor of Mathematics and Astronomy, Queen Mary, University of London, UK. For his PhD he studied the first second of the Universe, working under Stephen Hawking. Former President of the Society for Psychical Research and current President of the Scientific and Medical Network. Scientific interests: cosmology and astrophysics - early universe, dark matter, black holes and the anthropic principle; the role of consciousness in physics - he is developing a new psycho-physical paradigm, linking matter and mind, which accommodates both normal and anomalous mental experiences.

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TERESA FIRMINO Graduated in Social Communication, NOVA University of Lisbon, Portugal. Science journalist at the Portuguese newspaper "Público", since 1992. In 2008/2009, she has studied science journalism with a Knight Science Journalism Fellowship at Massachusetts Institute of Technology (MIT), USA. Since 2012, she has been the science editor of "Público". She published three books of scientific dissemination. In 2008, she was awarded an honorary mention for "Scientific Journalism" by the Ilídio Pinho Foundation. In 2012, she received the "Journalism Award" of the Portuguese League Against Cancer and in 2017 the "Ciência Viva Montepio Media Award".

RAINER GOEBEL Professor of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands. Founding director of the Maastricht Brain Imaging Centre (M-BIC). Scientific interests: neuronal representations in the brain and how they are processed to enable specific perceptual and cognitive functions, neural correlates of visual awareness, clinical applications in brain computer interfaces (BCls) and neurofeedback studies.

JULIA MOSSBRIDGE Affiliate Professor, Department of Physics and Biophysics, University of San Diego, CA, and Fellow, Institute of Noetic Sciences, Petaluma, USA. 2014 recipient of the Charles Honorton Integrative Contributions Award from the Parapsychology Association. Scientific interests: the relationship between psychological and physical time, unconscious access to future events, training people to improve their future orientation.

CHRIS ROE Professor of Psychology, and Director of the Centre for Psychology & Sociology, University of Northampton, UK. Past-President of the Society for Psychical Research and Parapsychological Association, and past chair of the British Psychological Society Transpersonal Psychology Section. Scientific interests: understanding the nature of anomalous experiences, including experimental approaches to test claims for extrasensory perception and psychokinesis, particularly where they involve psychological factors.

STEFAN SCHMIDT Professor of Systemic Family Therapy and Head of the Academic Section of Systemic Health Research, Department of Psychosomatic Medicine and Psychotherapy, University Medical Centre, Freiburg, Germany. Director of the Institute for Frontier Areas in Psychology and Mental Health (IGPP), Freiburg, Germany. Scientific interests: systems approaches in health research, psychophysiology, consciousness research, mindfulness meditation, experimental parapsychology, exceptional experiences, placebo research and brain-computer interface.

ANIL SETH Professor of Cognitive and Computational Neuroscience, University of Sussex, and Founding Co-Director of the Sackler Centre for Consciousness Science, UK. Co-Director of the Canadian Institute for Advanced Research Azrieli Program in Brain, Mind, and Consciousness. Editor-in-Chief of the Neuroscience of Consciousness (Oxford University Press) and Wellcome Trust Engagement Fellow. Scientific interests: the understanding of the biological basis of consciousness by bringing together research across neuroscience, mathematics, artificial intelligence, computer science, psychology, philosophy and psychiatry.

DANIEL P. SHEEHAN Professor of Physics, University of San Diego, USA. Scientific interests: plasma physics, the foundations of thermodynamics, energy technology, nanotechnology, consciousness, and the physics of time and retrocausation.

MÁRIO SIMÕES Retired Professor of Psychiatry and Consciousness Sciences and Director of LIMMIT - Laboratory of Interaction Mind-Matter with Therapeutic Intention, Faculty of Medicine of Lisbon, Portugal. Scientific interests: psychology and psychophysiology of altered states of consciousness, ethnomedicine, human exceptional experiences and psychology and spirituality.

WOLF SINGER Professor, studied Medicine in Munich and Paris, obtained his MD and PhD in Munich. Director emeritus at the Max Planck Institute for Brain Research, Frankfurt, Germany. Founding Director both of the Frankfurt Institute for Advanced

Studies (FIAS) and of the Ernst Strüngmann Institute for Neuroscience (ESI) and Director of the Ernst Strüngmann Forum. Scientific interests: the neuronal substrate of higher cognitive functions.

JOSEPH S. TAKAHASHI Professor and Chair, Department of Neuroscience, Howard Hughes Medical Institute, University of Texas Southwestern Medical Center, Dallas, USA. Scientific interests: genetics and molecular neuroscience of circadian clocks in mammals, genetic basis of behaviour, healthy aging and longevity.

CAROLINE WATT Holder of the Koestler Chair of Parapsychology, and founder member of the Koestler Parapsychology Unit, Psychology Department, University of Edinburgh, Scotland. Scientific interests: replication and methodological issues in parapsychology.

MARC WITTMANN Research Fellow, Institute for Frontier Areas of Psychology and Mental Health, Freiburg, Germany. Scientific interests: the perception of time in everyday fluctuations of consciousness as well as during altered states of consciousness such as induced through meditation, ganzfeld, floating tank and hallucinogens; neurophysiological and psychological explorations of how subjective time is related to cognition, emotion and body states.

Posters com resultados finais apresentados pelos investigadores apoiados pela Fundação Bial
Posters with final results presented by the Bial Foundation grant holders

2014

85/14 - "The clinical gut: Examining the cognitive processes and neural underpinnings of judgements, feelings of rightness and its impact on information seeking" – only abstract available
Researchers: Ana Sofia Bilreiro Jacinto Braga, Anne Krendl, Cara Charissa Lewis, Cilia Witteman, Elizabeth Collins, João Braga
Institution: Centro de Investigação e Intervenção Social (CIS-IUL), ISCTE – Instituto Universitário de Lisboa (Portugal); Department of Psychological and Brain Sciences – Indiana University Bloomington (USA)
Duration: 2015/05 – 2021/02

Background: The psychotherapy session is a context in which it is difficult to decompose and analyse information in parts. Such non-decomposable contexts favor holistic intuitive judgments (Hammond et al., 1987) and constrain the interpretation of subsequent information according to the initially activated scheme (e.g., Gilbert, 1999; Eyal et al., 2011).

Aims: The present research explores confirmatory tendencies underlying clinical judgements. We hypothesize that holistic processing of information, when compared to sequential processing, favors confirmatory hypothesis testing strategies and primacy effects (Jacinto et al., 2018).

Method: Four experimental behavioral studies manipulated ease of decomposability. Participants listened to session recordings that elicited the diagnosis of depression, with (sequential processing) or without (holistic processing) interruptions. Participants then rated the likelihood of three diagnosis hypothesis. To further explore the neurocognitive processes of confirmatory tendencies, we adapted the behavioral paradigm to an EEG study. Specifically, we explored the N400 component in the integration of incongruent information, when participants were reading the session recordings; and explored the components N2 and P3 when participants were judging the likelihood of the elicited diagnosis.

Results: The behavioral studies indicate that sequential processing led to lower ratings of the elicited diagnosis of Depression, reducing confirmatory tendencies (study 1 and 2). Moreover, eliciting two alternative diagnoses that shared symptoms (Depression and Generalized Anxiety) did not reduce the confirmatory processing in the holistic condition (study 3), but eliciting two diagnosis that do not share symptoms (Depression and OCD) reduced the confirmatory tendencies of holistic processing (Study 4). EEG data show that the holistic condition led to higher sensitivity to incongruent information (enhanced N400) than sequential condition. Additionally, we found stronger processes of monitoring and updating responses (enhanced N2 and P3) in the holistic condition than in the sequential condition.

Conclusions: Confirmatory tendencies guide clinical judgments. Whether information is processed holistically or sequentially leads to rely more or less in the activated schema. This research has implications for psychotherapy training and practice and for mental illness stigma.

Keywords: Clinical decision making, Intuition, Confirmation bias, Holistic processing, ERPs N400/N2/P3

Publications:
**Jacinto, S., Lewis, C., Braga, J., Scott, K., (2018). A conceptual model for generating and validating in-session clinical judgments. *Psychotherapy Research,* 1, 91-105. doi: http://dx.doi.org/10.1080/10503307.2016.1169329
*Jacinto, S., Braga, J., Ferreira-Folgado, M., Collins, E., & Lewis, C. (in preparation) Decomposing the therapeutic process: Ease of task decomposability and confirmatory hypothesis testing in psychotherapy.
*Jacinto, S., Frade, S., Ferreira-Folgado, M., Krendl, A., C. (in preparation) Ease of task decomposability and confirmatory processing: An event related potentials study.
**Jacinto, S., Braga, J., Ferreira-Folgado, M., Krendl, A., Collins, E., & Lewis, C. (in preparation Psychological Disorder Diagnosis are no cure for trait inferences.
**Jacinto, S., Ferreira-Folgado, M., Braga, J., Krendl, A., & Collins, E., Body over Mind: Mental illness stigma and perceived competence to request euthanasia (to be submitted to *Psychological Science*).

*Publications stemming directly from research presented in the abstract.
** Publications stemming from the Grant 85/14.

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178/14 - "A study of the relationship between mindfulness, distraction and brain stimulation" – only abstract available

Researchers: Fabrice Parmentier, Javier Garcia-Campayo, Margalida Gili-Planas, Mauro García-Toro, Pilar Andrés

Institution: University of the Balearic Islands, Palma (Spain); Hospital Universitario Miguel Servet, Zaragoza (Spain)

Duration: 2015/06 – 2019/07

Background: Dispositional mindfulness is thought to be negatively associated to symptoms of depression and anxiety, and to reduce the incidence of intrusive thoughts. However, these have typically been studied separately.

Aims: The present study examined the effects of mindfulness on depression and anxiety, both direct and indirect through the mediation of four mechanisms of emotional regulation: worry, rumination, reappraisal and suppression.

Method: Path analysis was applied to data collected from an international and non-clinical sample of 1151 adults, including both meditators and non-meditators, who completed an online questionnaire battery.

Results: Our results show that mindfulness are related to lower levels of depression and anxiety both directly and indirectly. Suppression, reappraisal, worry and rumination all acted as significant mediators of the relationship between mindfulness and depression. A similar picture emerged for the relationship between mindfulness and anxiety, with the difference that suppression was not a mediator. Our data also revealed that the estimated number of hours of mindfulness meditation practice did not affect depression or anxiety directly but did reduce these indirectly by increasing mindfulness. Worry and rumination proved to be the most potent mediating variables.

Conclusions: Altogether, our results confirm that emotional regulation plays a significant mediating role between mindfulness and symptoms of depression and anxiety in the general population and suggest that meditation focusing on reducing worry and rumination may be especially useful in reducing the risk of developing clinical depression.

Keywords: Mindfulness, Depression, Anxiety, Emotional regulation

Publications:

Parmentier, F. B. R., Mauro-García, M., García-Campayo, J., Yañez, A. M., Andrés, P., & Gili-Planas, M. (2019). Mindfulness and symptoms of depression and anxiety in the general population: The mediating roles of worry, rumination, reappraisal and suppression. *Frontiers in Psychology*, 10:506. doi: 10.3389/fpsyg.2019.00506

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207/14 - "The role of astrocytes in complex cognitive processing"

Researchers: João Filipe Pedreira de Oliveira, Joana Correia, Luísa Pinto, Nuno Dias, Sónia Guerra Gomes, Vanessa Sardinha, Inês Caetano Campos
Institution: Life and Health Sciences Research Institute – ICVS/3B's – Government Associate
Duration: 2015/10 – 2019/11

Background: The importance of glial cells in the brain is rising due to emerging data supporting dynamic neuron-glia interactions, in which astrocyte signaling complements and modulates the communication between pre- and post-synaptic neurons.

Aims: The main research objective of this project was to assess how astrocyte signaling and calcium-dependent mechanisms underlying cognitive processing in the brain.

Method: We tested the dnSNARE model that lack astrocyte signaling via exocytosis and the IP3R2KO model that lacks calcium-dependent signaling in astrocytes. To assess the influence of these mechanisms to cognitive function, we used complementary state-of-the-art techniques such as in vivo electrophysiology, innovative behavior, structural and molecular analysis, to characterize, monitor and rescue cognitive functions.

Results: Our results show that neuronal synchrony between the dorsal hippocampus and the prefrontal cortex is dependent on astrocyte signaling. This synchrony supports correct cognitive computation and may be rescued by supplementation of D-serine, a known modulator of glutamatergic excitatory transmission, which is released by astrocytes. In turn, astrocytic calcium-dependent mechanisms are relevant for cognitive computation in different life stages.

Conclusions: This grant allowed us to explore the potential of astrocyte modulation in brain cells and circuits to allow correct cognitive computation. The results obtained in this project have widened our understanding of astrocyte-specific mechanisms that might mediate cognitive decline and/or enhancement.

Keywords: Astrocyte, Learning and memory, Hippocampus, Prefrontal cortex, Electrophysiology

Publications

Guerra-Gomes S, Viana JF, Correia JS, Caetano I, Sardinha VM, Sousa N, Pinto L, Oliveira JF (2018). The role of astrocytic calcium signaling in the aged prefrontal cortex. *Front. Cell. Neurosci*. 12.

Guerra-Gomes S, Sousa N, Pinto L, Oliveira JF (2018) Functional roles of astrocyte calcium elevations: from synapses to behavior. *Front Cell Neurosci* 11:427.

Sardinha VM, Guerra-Gomes S, Caetano I, Tavares G, Martins M, Reis JS, Correia JS, Teixeira-Castro A, Pinto L, Sousa N, Oliveira JF (2017) Astrocytic signaling supports hippocampal–prefrontal theta synchronization and cognitive function. *Glia* 65:1944–1960.

Tavares G, Martins M, Correia JS, Sardinha VM, Guerra-Gomes S, Neves SP das, Marques F, Sousa N, Oliveira JF. (2017) Employing an open-source tool to assess astrocyte tridimensional structure. *Brain Struct Funct*, 222:1989–1999.

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211/14 - "Mind to mind: Brain dynamics of distant focused intention for consciousness expansion"

Researchers: Anabela Ventura Carraça, Carlos Miguel Loureiro Siopa, Hugo A. Ferreira, Carlos Moreira
Institution: LIMMIT – Laboratory of Mind-Matter Interaction with Therapeutic Intention, Faculdade de Medicina da Universidade de Lisboa (Portugal)
Duration: 2015/04 – 2019/04

Background: In a distant Reiki treatment, the practitioner focuses his attention and intention on the receiver and "sends", by visualizing, a set of symbols associated with words with the intention of wellbeing towards the receiver. There is great interest in understanding the brain changes that occur in Reiki practitioners engaged in healing. Particularly, can they influence brain states of receivers?

Aims: This study explores whether intention from a distant Reiki healer directed to individual receivers affects the spectral signatures of the brain activity for the sender and/or the receivers. We also pose the question: is there any kind of brain synchrony between sender and receivers during a distant intention task?

Methods: A total of 13 participants (mean age = 23.9 ± 6, 6 female) were recruited as receivers, with 1 common intention sender (male, age 67), a Reiki practitioner with over 2 years of experience. Quantitative electroencephalography (EEG) was collected from sender and receivers for 13 sessions of distant healing (800 meters away) using a 19-channel cap. After initial baselines with eyes closed and open, the sender sent Reiki to the receivers during 20 minutes with the intention that they would have good performance in the cognitive tests. Receivers then performed a series of attention, memory and inductive reasoning tasks.

Results: Spectral analysis for the Cz channel showed a significant increase in alpha power during eyes closed baseline and intention task. While the sender showed a consistent alpha peak at 10 Hz for all session tasks, the receivers had greater variability in alpha, both in frequency and magnitude. Only 3 out of 13 receivers showed an increase in alpha power in the task vs baseline with eyes closed. Intersession spectral coherence for the sender was highest at 9 and 10 Hz during the intention task. However, no significant coherence between sender and receiver was found. Finally, Granger causality was tested between the task time series of sender and receivers (20 min., Cz channel). Using a 1% confidence level and a maximum lag of 0.1 seconds, for 7 out of 13 sessions the sender time series values provided statistically significant information about future values of the receiver.

Conclusion: The Reiki practitioner in this study showed a reliable alpha spectral signature at 10 Hz in the intention task. These preliminary results provide a promising insight into the measurable results of intention at a distance and the degree of causality between practitioner and receiver.

Keywords: EEG; Alpha waves; Coherence; Granger causality; Intention.

Publications

Ventura, A. C., Ferreira, H. A., & Simões, M. (submitted). *Cognitive Performance, Altered States of Consciousness and Intention.*

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242/14 - “The role of affective dimensions in the perception of facial expressions of emotion: Neuropsychophysiological, developmental, and neuroimaging examination of an affective predictive coding framework”

Researchers: Fernando Ricardo Ferreira Santos, Eva In~es Costa Martins, Francisco Sá Ferreira Loureiro Pipa, Manuel Fernando Santos Barbosa, Michelle de Haan, Pedro Manuel Rocha Almeida, Tiago de Oliveira Paiva, Torsten Baldeweg

Institution: Laboratory of Neuropsychophysiology – Faculty of Psychology and Educational Sciences of the University of Porto (Portugal)

Duration: 2015/10 – 2021/03

Background: There are long standing debates in theories of emotion between categorical models of basic emotions (e.g., fear) and models that propose more fundamental affective dimensions (arousal/valence) that may be combined in different ways to give rise to emotions. Neuroscientific research on Facial Expressions of Emotion (FEE) has typically favored basic emotions models, but recent evidence highlights that the affective properties of facial displays are relevant for understanding how the brain processes emotional facial stimuli.

Aims: The main goal of the project was to investigate the role of affective dimensions in the perception of and neural responses (EEG/ERP) to FEE, while retaining the concept of emotional categories as an important level of analysis. The Predictive Processing framework, that describes brain function in terms of predictions about the inputs that will be received according to existing prior representations, may provide a unifying model of emotional processing, combining categorical and dimensional aspects and overcoming some inconsistencies in the current literature, especially if considered in a developmental perspective.

Method: To fulfil this goal, there were several phases in this project. Over the course of the project, we developed novel theoretical accounts applying Predictive Processing models to Affective Neuroscience and Emotional Development. In terms of empirical studies, Phase 1 included three studies designed to assess how affective dimensions, such as arousal and valence, relate to (1) other facial features like the typicality of the face, (2) the presence of emotional or non-emotional content, and (3) emotional intensity. Phase 2 consisted of a cross-sectional study to assess the developmental evolution of FEE processing, covering over 100 children between 4 and 15 years old. We used self-reported affective ratings and event-related potentials (ERP) to examine the effects of emotional categories and affective properties of facial expressions.

Results: The general trend of the results across studies in Phase 1 suggested that the arousal/emotional intensity of facial displays is an important influence on electrophysiological responses in adults. This corroborates previous findings from our groups supporting that arousal, rather than emotional categories, drives early visual cortical responses to facial expressions. In Phase 2, the developmental results suggest that children are initially more sensitive to differences in the valence of facial expressions, while adolescents show a transitional pattern that resembles neither childhood nor adulthood.

Conclusions: The affective dimensions of valence and arousal of FEE appear to be crucial to understanding how the brain processes facial displays. Children, adolescents, and adults show different neurophysiological responses to these affective dimensions that seem to configure a developmental trajectory: children seem to be more sensitive to the valence of FEE while adults appear more responsive to the level of arousal of the expression, and adolescents seem to show an intermediate pattern of results. These findings are consistent with a Predictive Processing account, in which the accumulated experience across development gradually changes the neural systems subserving the perception of FEE.

Keywords: Facial expressions of emotion; Arousal; Valence; Development; Predictive processing; EEG/ERP

Publications:

Pereira, M. R., Barbosa, F., de Haan, M., & Ferreira-Santos, F. (2019). Understanding the development of face and emotion processing under a predictive processing framework. *Developmental Psychology*, 55(9), 1868-1881. doi: 10.1037/dev0000706

Ferreira-Santos, F. (2016). The role of arousal in predictive coding (Commentary). *Behavioral and Brain Sciences*, 39, e207. doi: 10.1017/S0140525X15001788

Ferreira-Santos, F. (2015). Facial emotion processing in the laboratory (and elsewhere): Tradeoffs between stimulus control and ecological validity. *AIMS Neuroscience*, 2(4), 236-239. doi: 10.3934/Neuroscience.2015.4.236

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251/14 - "Signal or noise? Using a psychophysical approach to investigate the effects of attention and neurofeedback training on electrocortical predictive anticipatory activity (PAA) to true random stimuli"

Researchers: Michael Franklin, Jonathn Schooler, Stephen Baumgart

Institution: Department of Psychology and Brain Sciences, University of California at Santa Barbara (USA)

Duration: 2015/04 – 2019/07

Background: Time-symmetries in fundamental physics have been used to model electromagnetism in the Feynman-Wheeler Absorption Theory and quantum mechanics in the Transactional Interpretation. More recently, it has been suggested by D. Bierman (2010) that physical time-symmetries might be used to model pre-stimulus physiological anticipation of non-inferential events in a model called "Consciousness Induced Restoration of Time-Symmetry (CIRTS)". Pre-stimulus physiological anticipation of non-inferential events has been alternatively called "presentiment" or "Physiological Anticipatory Activity (PAA)". Two published meta-analyses have indicated a weak but replicable effect.

Aims: The goal of this experiment was to create conditions conducive to creating a time-symmetric effect in EEG and test the CIRTS hypothesis.

Method: A large contrast between no-stimulus and stimulus conditions was created. Subjects sat in a shielded room in darkness and white noise and were instructed to attend to a sequence of auditory and sound stimuli events while electroencephalography (EEG) was recorded from the scalp. Three types of stimulus events were used in this experiment: 1) no stimulus (null), 2) light, and 3) sound. Each stimulus type was selected with equal probability using a quantum random number generator. For each participant there were four sessions, each with 20 stimulus events. Each event was separated by 28 to 32 seconds. The sound stimulus was generated by a buzzer whereas the light stimulus was generated by a monitor. The voltage across the buzzer relay and the voltage from a photovoltaic panel were measured to verify when the stimuli was active.

Results: Data were analysed in an exploratory fashion for Event Related Potentials (ERPs) and alpha wave power. The ERP analysis returned a null effect pre-stimulus while the alpha wave power showed a significant pre-stimulus effect.

Conclusion: The current results indicate that post-stimulus alpha suppression may be reflected in the pre-stimulus region of time. However, further confirmatory research is needed before conclusions can be reached.

Keywords: Presentiment, PAA, EEG, Time-symmetry, Alpha waves

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268/14 - “EEG localization and individual variability in response to emotional stimuli” – only abstract available

Researchers: William E. Bunney, Blynn G. Bunney, James Fallon, Joseph C. Wu, Julie Patterson, Richard Alan Stein

Institution: The Regents of the University of California, Irvine (USA)

Duration: 2017/03 – 2021/05

Background: A growing body of research is focused on whether physiological measures can differentiate pending unpredictable stimuli based on stimulus characteristics unknown to participants and experimenters, theorized as “predictive anticipatory activity (PAA)”.

Aims: The focus of this research was to determine if the pre-stimulus electroencephalographic (EEG) activity could differentiate between randomly pending pleasant, unpleasant,and emotionally neutral visual stimuli in the absence of sensory cues. A first group of participants were recruited to test this hypothesis and a second group to replicate the findings. A third exploratory analysis tested the same hypothesis on the larger sample.

Method: Prior to the presentation of each visual stimulus, participants and experimenters were blind to the pending stimulus type that was selected truly randomly. 64-channel EEG data of the pre-stimulus period were analyzed with robust methods including robust corrections for multiple testing.

Results: A significant difference was observed between the pleasant and neutral conditions from 1072 and 1024 ms pre-stimulus over occipito-parietal electrodes (corrected for multiple comparisons). However this effect was not confirmed by the second group examined. A third exploratory analsysis on both groups combined showed a similar significant difference (same conditions and areas; corrected for multiple comparisons) but occurring between 148 and 112 ms before stimulus presentation.

Conclusions: Findings suggest an anomalous pre-stimulus effect but an outright replication was not found. While caution should be taken regarding the interpretation of these findings, the robust methods employed in this study suggest they merit replication and further study to be better understood.

Keywords: Anticipation; Pre-stimulus; Electroencephalography; EEG; Emotion

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299/14 - “Neurofeedback-based adaptive audiovisual tutorial for enhancing multi-modal learning” – only abstract available

Researchers: Rainer Wilhem Goebel, Gal Raz, Talma Hendler, Rick van Hoof
Institution: Maastricht Brain Imaging Centre, Maastricht University (The Netherlands); The Medical Research Infrastructure and health services fund at the Tel Aviv Medical center (Israel)
Estimated duration: 2015/12 – 2020/01

Background: Our project aims to facilitate brain anatomy learning via an adaptive tutorial based on real-time brain-computer interface (BCI). Using high-field 7T fMRI, we pursue patterns of brain activity that reliably predict the learning of association between a visual pattern (animated brain structure) and a numerical identifier. The tutorial will adapt the frequency of presentation of the to-be-learned items depending on real-time processing of the fMRI data. Thus, if the presentation of a specific item does not elicit a neural pattern, which predicts successful long-term learning, the learner will have more opportunities to encode this item.

Aims:
1) Identifying fMRI patterns that reliably predict long-term learning;
2) Designing and validating an adaptive BCI tutorial.

Method: The tutorial included 6 learning runs with training and testing sessions. In each run, 8 short video clips were presented. A brightness detection task was used as an active baseline. The testing phase included the following conditions: Multiple-choice test, certainty level assessment, and correctness feedback. The participants completed a final examination of all 24 learned items outside of the scanner. An identical examination design was administered after 7 days. Neuroimaging data were collected during the learning phase using a 7T MRI scanner (Magnetom 7T Siemens, Erlangen, Germany) located at the Maastricht University. 32-channel head array coil (Nova Medical Inc.; Wilmington, MA, USA). Data were preprocessed using Brainvoyager QX version 20.4.0. We performed a support-vector machine analysis to predict the participant's answer. Voxelwise difference beta values for the contrast CLIP-BASELINE were used as features in this analysis. The model was trained on randomly selected data from 80% of the runs and tested on the left-out data (fixed effect).

Preliminary results: The accuracy of the participants' answers was above chance level (16.7%) in the final examination and the follow-up exam. On average, the participants correctly replied to 62.5±9.46, 57.5%±14.38%, and 52.2%±21% of the questions, respectively. The average certainly levels were 56.77%±7%, 48.75%±4.51%, and 42.28±9.16, respectively. The average accuracy of the prediction that was based on the fMRI models was 64.02%±6.93% and 71.41%±6.08% in the final and the follow-up, respectively.

Conclusions: Our preliminary findings indicate the feasibility of predicting learning. Therefore, we believe that BCI, which is based on the resulting models could improve long-term learning.

Keywords: Brain-computer interface, Learning, Machine learning, Neural decoding

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304/14 - "The impact of music training on reading and mathematical abilities of normal and reading disabled children: A behavioral and neuroimaging longitudinal study"

Researchers: Maria de São Luís Vasconcelos da Fonseca e Castro Schöner, Christian Gaser, Daniela da Costa Coimbra, Marta Sofia Pinto Martins

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Duration: 2015/10 – 2019/09

Background: Music training is a well-established model of brain plasticity. Most studies compare professional musicians with non-musicians or probe correlates of individual training in childhood, but neurocognitive effects of collective music training in regular school classrooms remain poorly examined.

Aims: To inspect brain/cognition links in music- and language-related abilities in children at the structural and connectivity levels, and to determine effects of a short collective music training as compared to analogous training in sports and to a passive control group.

Method: Longitudinal study with pre-test (T1), training, post-test (T2) and follow-up (T3), in three groups of 8-year-old children: music, basketball and no specific training. Children were matched on major cognitive and demographic variables and pseudorandomly assigned to one of the groups. Behavioral measures on cognitive and musical abilities, and on brain structural MRI and resting-state fMRI, were collected at T1, T2 and T3.

Results: Learning effects were significant in all groups. Resting-state connectivity revealed a link between sensorimotor systems and processing of emotional speech prosody. Behavioural benefits driven by music training were near transfer effects in the music domain and fine motor abilities; far transfer into simple arithmetics and phonological decoding were also found. Music training induced changes in gray-matter volume of the left cerebellum that correlated with gains in motor performance and with rhythm discrimination at T1, and to higher connectivity between the auditory and sensorimotor networks suggesting enhanced audiomotor coordination.

Conclusions: A resource-lean music training program was associated with near transfer behavioral benefits and with plastic changes in gray matter volume and functional neural connectivity.

Keywords: Children, Longitudinal, MRI, Connectivity, Music training

Publications:

Correia, A. I., Branco, P., Martins, M., Reis, A. M., Martins, N., Castro, S. L., & Lima, C. F. (2019). Resting-state connectivity reveals a role for sensorimotor systems in vocal emotional processing in children. *NeuroImage*, 201, 116052.

Martins, M., Neves, L., Rodrigues, P., Vasconcelos, O., & Castro, S. L. (2018). Orff-based music training enhances children's manual dexterity and bimanual coordination. *Frontiers in Psychology*, 9, 2616.

Martins, M., Silva, S., & Castro, S. L. (2019). Perceiving rhythmic repetition and change across development: Effects of concurrent pitch. *Empirical Studies of the Arts*. Advance online publication.

Forthcoming

Branco, P., Martins, M., Lima, C. F. & Castro, S. L. (2019). *Dynamic reorganization of functional connectivity after music and sports training: a longitudinal study*. Manuscript in preparation.

Martins, M., Castro, S. L., & Gaser, C. (2019). *A VBM study on the role of IQ and socioeconomic status in children's poor reading*. Manuscript in preparation.

Martins, M., Coimbra, D., Reis, A. M., Gaser, C, & Castro, S. L. (2019). *Orff-based music training fosters plasticity in the developing brain*. Manuscript in preparation.

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339/14 - "Neural mechanisms of social cognition in zebrafish" – only abstract available
Researchers: Ana Rita Silva Martins Nunes
Institution: Instituto Gulbenkian de Ciência, Oeiras (Portugal)
Duration: 2015/05 – 2019/11

Background: Visual recognition of individuals is crucial for social interactions and survival. Socially relevant visual information is extracted from the environment and proceessed in specific brain centers to guide social behaviors. However, little is still known about how visual cues contribute to social affiliation and which are the underlying mechanisms.

Aims: In this work we proposed to address the contribution of two mais social visual features in zebrafish: conspecific form and biological motion, on social affiliation. Furthermore, we addressed wether this contribution was mediated by oxytocin, a known neuromodulator of social behaviors across species, by using a genetic mutant zebrafish line with impaired oxytocin signaling.

Method: Using a videoplayback system, zebrafish was allowed to choose between two stimuli (videos) differing in conspecific shape, biological motion, or both. The time spent close to each stimulus was taken as a measure of preference.

Results: We demonstrated that each cue, conspecific form and biological motion, is sufficient to promote social attraction, and the combination of the two induces a robust preference towards a conspecific. The regulation of this visual processing mechanism is mediated by oxytocin, by regulating conspecific form and biological motion differently.

Conclusions: These findings support that visual cues are important for social affiliation in zebrafish and that oxytocin plays a role in very basic perceptual mechanisms underlying the recognition of conspecifics.

Keywords: Social affiliation, Perceptual mechanisms, Oxytocin

Publications:

Nunes A. R, Carreira L., Anbalagan S., Blechman J., Levkowitz G., Oliveira R. F., Perceptual mechanisms of social affiliation in zebrafish are modulated by oxytocin signaling (*in submission*).

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376/14 - “Lateralisation of cognitive functions in the brain: Typical vs. atypical patterns” – only abstract available

Researchers: Deborah J. Serrien
Institution: School of Psychology, University of Nottingham (UK)
Duration: 2015/10 – 2018/11

Background: Proneness to psychoses was widely investigated through self-report measures, showing moderate heritability in twin and family studies. It is unclear how life-events modulate it. In fact, distress is strongly associated to disorder onset.

Aims: In this behavioural study, we examine the balance between stability and flexibility of information processing in left- and right-handers. The work will offer new insights into individual differences in cognitive control and the relationship with handedness. It is argued that handedness influences hemispheric engagement, leading to variation of cognitive performance with left-handers showing increased flexibility for dealing with the task demands.

Method: We use computerised tasks that involve two types of decision-making, instructed (sensory cued) and voluntary (own choice), by means of distractor inhibition and hand/task switching.

Results: The data revealed that both groups showed opposite tendencies for instructed decision-making. Moreover, right-handers resisted distracting information more efficiently whereas left-handers showed superior switching abilities. When participants were involved in voluntary decision-making, no effects of handedness were noted, which suggests that free-choice processing alters the balance between stability and flexibility.

Conclusions: These data illustrate that handedness is an index of individual variation during instructed decision-making, biasing the proficiency of cognitive control towards stability and flexibility of information processing. These biases can however be overruled by top-down strategies that dominate during voluntary decision-making. Overall, the research underlines the antagonistic functions of stability and flexibility in decision-making, and offers an approach for examining cognitive control and the role of internal and external factors in balancing the stability-flexibility trade-off.

Keywords: Handedness, Laterality, Stability, Flexibility, Individual differences

Publications:

Serrien DJ, O'Regan L (2019). Stability and flexibility in cognitive control: Interindividual dynamics and task context processing. *PLoS One14*:e0219397.

O'Regan L, Serrien DJ (2018). Individual Differences and Hemispheric Asymmetries for Language and Spatial Attention. *Frontiers in Human Neuroscience*, *12*:380.

O'Regan L, Spapé MM, Serrien DJ (2017). Motor timing and covariation with time perception: Investigating the role of handedness. *Frontiers in Behavioral Neuroscience*, *11*:147.

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427/14 - "Gliogenesis control of brain neuroplasticity, neurophysiology and cognitive function"

Researchers: Luísa Alexandra Meireles Pinto, Ana Rita Machado dos Santos, António Maria Restolho Mateus Pinheiro, Joana Sofia da Silva Correia, João Filipe Pedreira de Oliveira, João Miguel Bessa Peixoto, Nuno Dinis Alves, Vítor Manuel da Silva Pinto

Institution: Life and Health Sciences Research Institute – ICVS/3B's – Government Associate Laboratory, Universidade do Minho, Braga (Portugal); Center for Neuroscience and Cell Biology, University of Coimbra (Portugal)

Duration: 2015/09 – 2019/10

Background: Although many advances have been made in understanding how cellular plasticity in the adult central nervous system (CNS) controls complex behaviors, the majority of evidence is focused on neuronal cells. Glial cells are increasingly recognized as fundamental partners of neurons in the maintenance of neurochemical and electrophysiological homeostasis. However, the real implication of glial cells, namely astrocytes and astrogliogenesis, for CNS neurophysiology and behavioral patterns in the healthy brain, is still largely unknown.

Aims: This project was designed to (i) explore how adult astrogliogenesis remodels neuro-glial networks in the adult CNS, (ii) determine how ablation of hippocampal adult-born astrocytes (ABAs) and pre-existing astrocytes (Pre-As) in the healthy brain impact on physiology and behavior.

Method: We designed and developed an innovative genetic tool to promote targeted cell-death of ABAs and Pre-As in the adult brain, while not affecting the neuronal lineage. We further explored the gliogenic control of brain neuroplasticity, neurophysiology and cognition, through an animal model which presents astrocytic dysfunctions, the IP3R2 Knockout mouse model.

Results: Constructs to ablate ABAs and Pre-As were developed and their specificity for astrocytes was proved in vitro. Moreover, our results show that astrocyte dysfunctions, including astrogliogenesis impairment, might be correlated with alterations in emotional and cognitive behavior in aged mice.

Conclusions: Our novel genetic tools and studies in vivo will allow to study how astrocytes and astrogliogenesis impacts on brain neuroplasticity, neurophysiology and cognitive function. We are confident that this study will greatly advance our knowledge on the importance of glial cells and cell cytogenesis processes for brain function.

Keywords: Astrogliogenesis, Astrocytes, Adult brain, Plasticity, Behavior

Publications:

Mateus-Pinheiro, A., Alves, N. D., Patricio, P., Machado-Santos, A. R., Campos, E., Silva, J., Sardinha, V., Reis, J., Schorle, H., Oliveira, J. F., Ninkovic, J., Sousa, N., & Pinto, L. (2017). AP2γ controls adult hippocampal neurogenesis and modulates cognitive, but not anxiety or depressive-like behavior. *Molecular Psychiatry, 22*(12), 1725-1734. doi: 10.1038/mp.2016.169

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Mateus-Pinheiro, A., Alves, N. D., Sousa, N., & Pinto, L. (2018). AP2y: A new player on adult hippocampal neurogenesis regulation. *Journal of Experimental Neuroscience, 12*: 1-4. doi: 10.1177/1179069518766897

Guerra-Gomes, S., Viana, J. F., Correia, J. S., Caetano, I., Sardinha, V. M., Sousa, N., Pinto, L., & Oliveira, J. F. (2018). The role of astrocytic calcium signaling in the aged prefrontal cortex. *Frontiers in Cellular Neuroscience, 12*: 379. doi: 10.3389/fncel.2018.00379

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442/14 - "Neurochemical substrates of neurofeedback" – only abstract available

Researchers: Tomas Ros, Nathalie Ginovart
Institution: Interfacultary Center for Neuroscience, University of Geneva (Switzerland), Division of Nuclear Medicine, University Hospitals Geneva (Switzerland)
Duration: 2016/04 – 2020/09

Background: Neurofeedback (NFB) is a brain-based training method that enables users to control their own cortical oscillations using real-time feedback from the electroencephalogram (EEG). Importantly, no investigations to date have directly explored the potential impact of NFB on the brain's key neuromodulatory systems.

Aims: Our study's objective was to assess the capacity of NFB to induce dopamine release as revealed by positron emission tomography (PET).

Method: Thirty-two healthy volunteers were randomized to either EEG-neurofeedback (NFB) or EEG-electromyography (EMG), and scanned while performing self-regulation during a single session of dynamic PET brain imaging using the high affinity D2/3 receptor radiotracer, [18F]Fallypride. NFB and EMG groups down-regulated cortical alpha power and facial muscle tone, respectively. Task-induced effects on endogenous dopamine release were estimated in the frontal cortex, anterior cingulate cortex, and thalamus, using the linearized simplified reference region model (LSRRM), which accounts for time-dependent changes in radiotracer binding following task initiation.

Results: Contrary to our hypothesis of a differential effect for NFB vs. EMG training, significant dopamine release was observed in both training groups in the frontal and anterior cingulate cortex, but not in thalamus. Interestingly, a significant negative correlation was observed between dopamine release in frontal cortex and pre-to-post NFB change in spontaneous alpha power, suggesting that intra-individual changes in brain state (i.e., alpha power) could partly result from changes in neuromodulatory tone.

Conclusions: Overall, our findings constitute the first direct investigation of neurofeedback's effect on the endogenous release of a key neuromodulator, demonstrating its feasibility and paving the way for future studies using this methodology

Keywords: Dopamine, Neurofeedback, Positron emissiontomography (PET), Electroencephalography (EEG)

Publications:
Ros, T., Kwiek, J., Andriot, T., Michela, A., Vuilleumier, P., Garibotto, V., & Ginovart, N. (2021). PET imaging of dopamine neurotransmission during EEG neurofeedback. *Frontiers in Physiology, 11*: 590503. doi: 10.3389/fphys.2020.590503

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528/14 - "Psi performance in attenuated electromagnetic fields" – only abstract available

Researchers: Michelle Fauver, Glenn Hartelius, Richard Knowles
Institution: California Institute of Integral Studies, Embodied Consciousness Research Group, San Francisco (USA)
Duration: 2015/01 – 2018/07

Background: Two major challenges facing researchers studying psychic (psi) phenomena include small effect sizes and inconsistent results. Previous research showed promising improvements in both through reducing exposure to electromagnetic (EM) fields. Little work has been done associating psychological traits with psi performance, with most psychometric studies having focused on psi beliefs.

Aims: This study sought to replicate previous EM research with a larger sample and more rigorous methods and study design. It also sought to test for the first time correlations between psi performance and measures of interoception (awareness of internal body processes), empathy, absorption, and transliminality.

Method: The within-subjects, triple-blind, randomized control design asked a convenience sample of 45 participants to perform a series of psi tests in four EM conditions. The psi test paired two participants in separate rooms. The sender randomly placed eight pictures on a board; the receiver attempted to place a matched set of pictures in the same arrangement. Scoring was based on the number of pictures in matching positions.
A Faraday cage tent substantially reduced exposure to environmental EM fields. Antennas reproduced outside EM fields inside the tent. Switches created three randomly ordered EM conditions inside the tent: 1) reduced EM field, tent grounded; 2) reduced EM field, tent ungrounded; and 3) environmental EM field reproduced, tent grounded. The receiving participant performed four trials: A baseline trial outside the tent then three trials inside the tent, one in each condition.

Results: There was no significant difference in psi performance between any of the four EM conditions, Kruskal-Wallis ANOVA H (3, N= 540) =.17, p = .98.
Of the 14 psychological dimensions measured, all showed correlations in the predicted direction, with 6 statistically significant at the $p < 0.05$ level. Higher psi performance correlated positively with increased openness to absorbing experiences, increased access to subconscious or unconscious material, one dimension of empathy, and the interoceptive dimensions of emotional awareness, self regulation, and experiencing the body as trustworthy.

Conclusions: The study found no evidence that reducing exposure to EM fields increases psi performance, countering previous research. Increased psi performance was found to be strongly correlated with heightened interoceptive awareness, absorption, and transliminality.

Keywords: Electromagnetic fields, Psychometrics, Faraday cage, Psi

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2016

30/16 - “Exploring the neural basis of motivation”

Researchers: Ana João Rodrigues, Nivaldo Vasconcelos, Carina Cunha, Bárbara Coimbra, Laura Silva, Patrícia Monteiro, Sónia Borges, Pedro Morgado
Institution: Life and Health Sciences Research Institute – ICVS, School of Health Sciences, University of Minho, Braga (Portugal)
Duration: 2017/01 – 2020/03

Background: Optimal decision-making is highly dependent on the value attributed to the outcome but also individual motivational status. Evidence has highlighted the nucleus accumbens (NAc) as a core brain region in the neural circuitry underlying motivation. Major inputs to the NAc includes the canonical dopaminergic projections from the ventral tegmental area (VTA), which in turn is tightly controlled by the laterodorsal tegmentum (LDT). Interestingly, LDT also directly projects to the NAc, though the nature and biological role of such connections remains completely unknown.

Aims: Characterize LDT-(VTA)-NAc circuit, and identify the role of these inputs in motivation in control animals and in a model of prenatal exposure to glucocorticoids (iuGC model) that presents motivational deficits.

Methods: Neuroanatomical characterization of the rodent circuit using viral transynaptic markers. This neuroanatomic study was complemented by an electrophysiological characterization of LDT-NAc projections *in vivo* in control and iuGC animals. We also optogenetically modulated LDT-VTA-NAc projections in order to evaluate their impact in motivation in rodents.

Results: We showed that LDT-VTA projections are altered in iuGC model, and these changes underlie its motivational deficits[2]. Next, we showed that optogenetic activation of LDT-NAc projections have a pro-motivation and rewarding effect in rats[1]. Moreover, we demonstrate that optogenetic activation of LDT-NAc cholinergic projections is sufficient to recapitulate this behavioral effect. Optogenetic activation of LDT-NAc glutamatergic projections also enhanced motivation but to a lesser extent, whereas activation of GABAergic inputs decreased motivational drive[1].We have also shown that optical activation of D2 neurons in the NAc enhances motivation and requires dopamine release from VTA dopaminergic terminals that then act on dopamine receptor D1 and D2[3]. Additionally, we found that activation of either NAc D1 or D2 neurons can drive reward or aversion, depending on the pattern of stimulation[4].

Conclusions: LDT-VTA-NAc projections play an important role in motivation in rodents, and iuGC exposure impacts this circuitry.

Keywords: Motivation, Reward, Nucleus accumbens, Neuronal circuit

Publications:

Soares-Cunha, C., Vasconcelos, N., Coimbra, B., Domingues, A. V., Silva, J. M., Loureiro-Campos, E., ... Rodrigues, A. J. (2020). Nucleus accumbens medium spiny neurons subtypes signal both reward and aversion. *Molecular Psychiatry, 25*(12), 3241-3255. doi: 10.1038/s41380-019-0484-3

Coimbra, B., Soares-Cunha, C., Vasconcelos, N. A. P., Domingues, A. V., Borges, S., Sousa, N., & Rodrigues, A. J. (2019). Role of laterodorsal tegmentum projections to nucleus accumbens in reward-related behaviors. *Nature Communications, 10*: 4138. doi: doi: 10.1038/s41467-019-11557-3

Soares-Cunha, C., Coimbra, B., Domingues, A. V., Vasconcelos, N., Sousa, N., & Rodrigues, A. J. (2018). Nucleus accumbens microcircuit underlying D2-MSN-driven increase in motivation. *eNeuro, 5*(2), e0386-18. doi: 10.1523/ENEURO.0386-18.2018

Coimbra, B., Soares-Cunha, C., Borges, S., Vasconcelos, N. A., Sousa, N., & Rodrigues, A. J. (2017). Impairments in laterodorsal tegmentum to VTA projections underlie glucocorticoid-triggered reward deficits. *eLife, 6*: e25843. doi: 10.7554/eLife.25843

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32/16 - "Neural mechanisms of dream recall: Electrophysiological differences between young and older adults" – only abstract available

Researchers: Serena Scarpelli, Luigi De Gennaro, Anastasi Mangiaruga, Chiara Bartolacci
Institution: Department of Psychology, University of Rome "La Sapienza" (Italy)
Duration: 2017/04 – 2019/09

Background: Neural correlates of dream recall (DR) in elderly people are still largely unknown. Previous studies in older adults found a general decrease in DR and with the notable exception of Chellappa et al. (2009) no investigations have been carried out on EEG correlates of DR in aging.

Aims: Our study aimed to investigate whether specific EEG patterns during sleep in elderly predict a subsequent DR.

Method: 40 healthy older and 40 young adults were recorded with polysomnography: 21 older subjects were awakened from REM sleep and 19 older subjects from stage 2 NREM sleep; 20 young subjects were awakened from REM sleep and 20 young subjects from stage 2. DRs were collected upon morning awakening from both stages. EEG power spectra of the total sleep and of the last 5 min were calculated by Fast Fourier Transform (FFT). The algorithm to detect oscillatory activity was applied on the last 5 min of sleep.

Results: The two-way ANOVAs Recall X Age performed on the EEG power bands showed no main effect of Recall neither significant interaction for REM sleep as well as NREM sleep. Only a significant main effect of Age was observed both for total sleep and the last 5 min, during REM and NREM sleep. The analysis of oscillatory activity revealed that frontal theta oscillations during the last 5 min of REM sleep are related to DR, without any age-effect.

Conclusions: Our results partly replicated the previous evidence in young individuals and it is completely new for older individuals, showing that the theta oscillations play a pivotal role in the retrieval of dreaming also in this population. The findings are in line with the "Continuity Hypothesis" between waking and sleep mental functioning from a neurobiological viewpoint. Moreover, our results did not confirm a greater presence of the theta activity in healthy aging. Differently, we found a greater amount of rhythmic theta and alpha activity in young than older subjects. We underline that the theta oscillations detected are related to cognitive functioning and that the oscillatory theta should be distinguished from the non-rhythmic theta activity found in relation to other phenomena such as (a) sleepiness and hypoarousal conditions during wakefulness and (b) cortical slowing, an EEG alteration in clinical conditions.

Keywords: Dream recall, Dreaming, Sleep, Older adults, Theta

Publications:

Full papers

Mangiaruga A., Scarpelli S., Bartolacci C., De Gennaro L. (2018). Spotlight on dream recall: the ages of dreams. *Nature and Science of Sleep, 10*:1-12. doi: 10.2147/NSS.S135762

Scarpelli S., D'Atri A., Bartolacci C., Mangiaruga A., Gorgoni M., De Gennaro L. (2019). Oscillatory EEG activity during REM sleep in elderly people predicts subsequent dream recall after awakening. *Frontiers in Neurology, 10*:985. doi:10.3389/fneur.2019.00985

Proceedings

Scarpelli S., D'Atri A., Gorgoni M., Mangiaruga A., Lauri G., Truglia I., Bartolacci C., Ferrara M., De Gennaro L. Aging and dreaming: EEG oscillations predict dream recall. Sleep Medicine 2017; 40: e294, World Sleep Congress, October 7-11 2017. doi:10.1016/j.sleep.2017.11.862

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39/16 - “Considering voice hearing by psychic practioners: A qualitative pluralistic investigation of mental health and well-being” – only abstract available

Researchers: Craig Murray

Institution: Division of Health Research, Lancaster University (UK)

Duration: 2017/05 – 2020/06

Background: This research is a qualitative pluralistic project concerned with clairaudience experienced by psychic practitioners. A key aspect of the research is to use different methods of qualitative analysis to analyse the same data. The different emphases of these approches are expected to provide complimentary insights into the target phenomenon. The study builds on previous research with mediums, to identify and explore clairaudience in a sample of psychic practitioners who do not have religious or professional affiliations that provide explanatory frameworks for these lived experiences.

Aims: The aim of the research is to identify what factors protect against distress (as found in clinical samples of voice hearers) for people who hear voices but do not require service support. This will enable a test of how robust these findings are in non-clinical voice hearers or how such a sample might display a different pattern of relationships.

Method: Fourteen psychic practioners have been interviewed for the study. To date, we have applied interpretative phenomenological analysis to the data set (Wilde et al., 2019). In this study, we aimed to gain an understanding of how mediums experience their mental health in relation to their mediumistic practice and how they recognise and respond to psychological difficulties experienced by their clients.

Results: Four themes were identified: from past traumas to mediumistic identity; spirit makes sense, mental illness is chaos; being resilient but vulnerable; and ethical mediumistic practice.

Conclusions: The research highlights the value of not dismissing or attempting to change appraisals of valued aspects of mediums’ anomalous experiences. However, the findings do indicate that support for exposure to clients’ difficulties might be helpful.

Keywords: Voice-hearing, Hearing-voices, Mediums, Psychics

Publications:

Wilde, D.J., Murray, J., Doherty, P., & Murray, C.D. (2019). Mental health and mediumship: an interpretative phenomenological analysis, *Mental Health, Religion & Culture*, *22(3)*, 261-278, doi: 10.1080/13674676.2019.1606186.

Valavanis, S., Thompson, C., & Murray, C.D. (2019). Positive aspects of voice-hearing: a qualitative metasynthesis, *Mental Health, Religion & Culture*, *22(2)*, 208-225, doi: 10.1080/13674676.2019.1601171.

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44/16 - "Inducing and measuring plasticity in response control mechanisms in the human brain"
Researchers: Alejandra Sel de Felipe, Matthew Rushworth
Institution: Department of Experimental Psychology, University of Oxford (UK)
Duration: 2017/10 – 2021/09

Background: Among human prefrontal cortex regions, the ventral pre-motor cortex (PMv) and adjacent premotor areas plays a pre-eminent and crucial role in action selection and inhibition.

Aims:
a) Characterise the causal relationship between PMv and the primary motor cortex (M1) in action control and inhibition by means of transcranial magnetic stimulation (TMS)
b) Examine the possibility of potentiating the effects of PMv over M1 during action control as measured by electroencephalography (EEG), and to explore bidirectional relationships between M1 and rPMv.

Method: Participants performed a go/no-go task in two task blocks while measuring the cortical excitabiltiy of M1 with electromiography (EMG – studies 1 and 2), and neural responses with EEG (study 3). Between the two task blocks we manipulated and entrained the PMv-M1 corticocortical pathway by delivering noninvasive repetitive paired associative transcranial stimulation (rPAS) near PMv and M1. We then measured the effect of the cortico-cortical entrainment in M1 cortical excitability (study 1 and 2) as well as motor oscillatory dynamics (study 3).

Results: The entraining of PMv-M1 cortical connectivity leads to a state-dependent modulation of the causal influence of prefrontal over motor cortex, as reflected in (a) increased M1 cortical excitability in Go trials, and (b) enhanced beta and theta rhythms in Go and No-Go trials, respectively. Additionally, the plasticity effect was dependent on stimulation order. rPAS of PMv before M1 led to augmented beta and theta oscillations reflecting an enhanced top-down influence of PMv on M1, whereas the opposite results were observed after the reversed M1-PMv stimulation.

Conclusions: These results show that PMv excerts a state-dependent effect over M1, and that PMv-M1 cortico-cortical connectivity can be artificially manipulated leading to functional changes in the spectral fingerprints of the motor circuit

Keywords: Action control, Ventral premotor cortex, EEG, rPAS, Cortico-cortical plasticity

Publications:
Directly related to the grant
Sel, Angerer, David, Klein-Flüge, Verhagen, Rushworth. Entraining and measuring corticocortical plasticity in action control and inhibition (ready for submission to *Current biology*).
Sel, Shepherd. Inhibitory control and self-control (book chapter – accepted for publication).

Other publications
Gentsch, Sel, Marshall, Schütz-Bosbach (2018) Affective interoceptive inference: evidence from heart-beat evoked brain potentials. *Human Brain Mapping*.
Sel, A., Sui, J., Sheppard, J. and Humphreys, G., Self-Association and Attentional Processing Regarding Perceptually Salient Items. *Review of Philosophy and Psychology*.

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51/16 - "Cognitive plasticity: Modulation and monitoring through a neurophysiological approach" – only abstract available
Researchers: Carlo Miniussi, Romina Esposito
Institution: Centre for Mind/Brain Sciences – CIMeC, University of Trento, Rovereto (Italy)
Duration: 2017/03 – 2020/03

Background: Acquired visuo-spatial relationships between objects in a visual scene can produce more accurate and faster responses in the identification of a target. This process is thought to be mediated by the activity of frontal and parietal cortical regions through a memory-mediated guidance of visuo-spatial attention.

Aims: In the present project we used transcranial electrical stimulation (tES) to investigate whether visuo-spatial contextual learning (VSCL) could be reliably modulated by an external stimulation and what are the neural mechanisms subtending its formation.

Method: In the first part of the project, we tested the effects produced by different tES protocols on behavioral measures of VSCL. In the second part, we used electroencephalogram (EEG) to investigate the neural markers subtending tES-mediated modification of VSCL measures.

Results: In our first work, we showed that anodal transcranial direct current stimulation (AtDCS) applied over the posterior parietal cortex (PPC) produced a significant decrease in VSCL [1] and this result was also confirmed by behavioral data obtained in our second work [2]. EEG measures revealed a significant increase in the early N1 component in response to repeated contexts presentation in both the Real- and the Sham-tDCS group, together with an increase of the P2 component in the group receiving Real-tDCS.

Conclusions: The AtDCS-induced reduction of VSCL could have been produced by homeostatic regulatory mechanisms put in place by the system to control from an excessive increase of PPC activity. Interestingly, EEG measures revealed that VSCL reduction was not associated with changes in early attentional mechanisms but could rather reflect cortical modulation within a later processing stage. The reported tDCS-induced increase in the amplitude of P2 component could represent the electrophysiological marker of a stimulation dependent reduction of perceived saliency associated with the presentation of the visual search arrays, a phenomenon that could have hindered the acquisition of visuo-spatial regularities associated with contexts repetition.

Keywords: Cognitive plasticity, Visuo-spatial learning, Transcranial electrical stimulation

Publications:
Grasso P. A., Tonolli E. & Miniussi C. (2020). Effects of different transcranial direct current stimulation protocols on visuo-spatial contextual learning formation: evidence of homeostatic regulatory mechanisms. *Scientific Reports*, *10*(1), 1-14
Grasso P. A., Tonolli E., Bortoletto M. & Miniussi C. (2021) tDCS over posterior parietal cortex increases cortical excitability but decreases learning: an ERP and TMS-EEG study. *Brain Research*, *1753*, 147227

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58/16 - "Psi, nonlocality and entangled photons" – only abstract available
Researchers: Dean Radin, Peter Bancel, Arnaud Delorme
Institution: Institute of Noetic Sciences, Petaluma, California (USA); Institute Metapsychique Internationale, Paris (France)
Duration: 2019/09 – 2021/11

Background: The experiment funded by this grant tested the hypothesis that quantum theory is a special case of a more comprehensive theory that would include aspects of consciousness. To our knowledge, this mind-matter interaction study was the first to investigate possible psychophysical interactions between nonlocal mind and nonlocal matter, the latter in the form of quantum entanglement.

Aims: The first aim was to see if focused attention and intention could modulate the strength of entanglement between photons. The second aim was to see if entanglement could be pushed above the Tsirelson Bound, the theoretical upper limit to entanglement strength based on orthodox quantum theory.

Method: A commercial optical system was used to generate about 1,000 entangled photons per second. Using this apparatus, three experiments were conducted at the Institute of Noetic Sciences (IONS) laboratory and one experiment in France. IONS also ran an online version of the experiment. The experimental task asked participants, in an alternating fashion, to focus their attention toward a line graph that showed the real time strength of quantum entanglement in pairs of photons, with intention to increase the line. Or they were asked to withdraw their attention and intention. A differential metric compared entanglement strength between these two conditions.

Results: The results of the experiments in the IONS lab were highly significant ($p = 0.0002$); the test conducted in France was not significant. Control runs in both locations, which used the same equipment but without anyone watching the apparatus, were uniformly nonsignificant. The online experiment also showed a modestly significant result ($p < 0.05$) in a high-quality subset of entanglement data.

Conclusions: The results suggest that human attention and intention can modulate the strength of quantum entanglement, but none of our experiments were able to push entanglement strength beyond the Tsirelson Bound. Based on these results, we do not know if exceeding this boundary is simply not possible, or if the apparatus we used was simply not capable of achieving that level of entanglement fidelity.

Keywords: Mind-matter interaction; Entangled photons; Quantum theory

Publications:
Radin, D., Bancel, P., Delorme, A. (2021) Psychophysical interactions with entangled photons: Five exploratory experiments. *Journal of Anomalous Experience and Cognition.* 1 (1-2), 9-54.

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62/16 - "Imagination and reactance in a psi task using the imagery cultivation model and a fuzzy set encoded target pool" – only abstract available

Researchers: Lance Storm
Institution: Brain and Cognition Research Centre, School of Psychology, University of Adelaide (Australia)
Duration: 2017/11 – 2019/04

Background: A psi-conducive altered state of consciousness can be induced through a shamanic-like journeying protocol in accordance with the Imagery Cultivation (IC) model proposed by Storm and Rock (2009 a;b). Alternatively, individuals who do *not* believe in psi ('goats') are prone to reactance (Brehm, 1966), which can be psi-inhibitive (Storm, Ertel, & Rock, 2013; Storm & Rock, 2014). Reactance is a motivational state aimed at restoring one's sense of freedom when one feels threatened (Silvia 2005). A reactance treatment in the form of an opinionated communication (perceived as a threat to freedom) can raise reactance, which remains high if no outlet is provided. This induced effect can result in a noncompliant attitude and response, purely as a knee-jerk reaction to the threat.

Aims: Hypotheses: (1) that a shamanic-like journeying protocol *cultivates* psi-related mental *imagery*; (2) higher noncompliant behavior (e.g., psi-missing) can be induced in goats.

Method: IC and Reactance principles were used to manipulate psi in positive and negative directions. Four groups were formed: (i) IC/Reactance, (ii) IC/No-Reactance; (iii) No-IC/Reactance, and (iv) No-IC/No-Reactance.

Results: The IC treatment produced a non-significant higher psi effect than the control condition. Reactance had a stronger effect on goats than sheep, indicated by a significantly greater discrepancy in goats over the opinionated communication. Reactance effects were not found, but effects were in the directions expected, with reversals of effects probably due to goats and 'indecisives' (mid-range psi belief scorers) in the No-IC/Reactance group. A sheep-goat effect was found.

Conclusions: Replication attempts would be worthwhile that include refinements to the various IC conditions, and a less persuasive (more challenging) reactance communication.

Keywords: Imagery cultivation, Paranormal belief, Reactance, Psi, Sheep-goat effect

Publications:

Storm, L. (2019). Imagination and reactance in a psi task using the imagery cultivation model and a fuzzy set encoded target pool. *Journal of Scientific Exploration*, *33*(2), 193-212.

Storm, L., & Goretzki, M. (in press). Spiritual emergency and psi: Testing the psychic opening hypothesis. *Journal of Transpersonal Psychology*.

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66/16 - “Mindfulness meditation shapes synchronization of brain networks for effective perceptual decision making”

Researchers: Laura Marzetti
Institution: Department of Neurosciences, Imaging and Clinical Sciences, University “G. D’Annunzio” of Chieti – Pescara (Italy)
Duration: 2017/09 – 2019/09

Background: Meditation is as an awareness training resulting in alterations in attention, perception and cognition. Theoretical and empirical papers show effects of meditation on focused and sustained attention. Conceivably, improved attention skills also impact on perceptual sensitivity and decision-making performance although scarce evidence exists.

Aims: We aim at understanding whether and how mindfulness meditation training affects attention, perception and decision making and the rhythmic interplay between brain networks involved in these processes.

Method: We designed a visual perceptual decision-making task (study1) in meditators and non-meditators. Subjects monitor incoherently moving dots for periods of coherent motion. Additionally, we used in-house multivariate connectivity to detect behaviorally relevant long-range synchronization in a cued visual attention paradigm in non-meditators (study2). MEG data were acquired in both studies. In study 1, modulations of power were analyzed in response to coherent motion. In study 2, modulations of connectivity were analyzed in response to cue presentation.

Results: In study 1, in non-meditators a sustained decrease of alpha power is observed in occipital and parietal areas after coherent motion, the strength of which varies with the task difficulty. Such a decrease is not observed in meditators. In study 2, an increase in alpha connectivity between occipital and parietal areas in response to the cue presentation is found.

Conclusions: In both studies a role for alpha in enhancing or reducing inhibition of parietal and occipital regions is observed. A Brain Theory of Meditation has also been put forward providing theoretical support for the role of power and connectivity modulations.

Keywords: Mindfulness meditation, Phase synchrony, Magnetoencephalography, Brain Rhythms

Publications:

D'Andrea, A., Chella, F., Marshall, T.R., Pizzella, V., Romani, G.L., Jensen, O., & Marzetti, L. (2019). Alpha and alpha-beta phase synchronization mediate the recruitment of the visuospatial attention network through the Superior Longitudinal Fasciculus. *Neuroimage*, *188*, 722–732. doi: 10.1016/j.neuroimage.2018.03.004.

Raffone, A., Marzetti, L., Del Gratta, C., Perrucci, M.G., Romani, G.L., & Pizzella, V. (2019). Toward a brain theory of meditation. *Progress in Brain Research*. *244*, 207-232. doi: 10.1016/bs.pbr.2018.10.028.

Croce, P., Zappasodi, F., Marzetti, L., Merla, A., Pizzella, V., & Chiarelli, A.M. (2019). Deep Convolutional Neural Networks for Feature-Less Automatic Classification of Independent Components in Multi-Channel Electrophysiological Brain Recordings. *IEEE Transactions on Biomedical Engineering*, *66* (8), art. no. 8587223, 2372-2380. doi: 10.1109/TBME.2018.2889512

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69/16 - "Induced near-death-experiences in healthy volunteers: Phenomenology, psychophysiology and after effects. Illustration with two exceptional case studies"

Researchers: Mário Simões, Sofia Machado Ferreira, Ana Paula Farinha
Institution: Laboratory of Mind-Matter Interaction with Therapeutic Intention – LIMMIT, Faculdade de Medicina da Universidade de Lisboa (Portugal); Hospital de Santa Maria, Lisboa (Portugal)
Duration: 2018/05 – 2020/11

Background: The core features of a Near-Death Experience (NDE) include leaving the body, going through a tunnel towards a divine light, interacting with dead relatives or spiritual figures and having a life-review. Often, after an episode, a psychological transformation occurs and a new life purpose is sometimes found. Few scientific studies yet exist on the possible therapeutic applications of hypnotically induced NDEs.

Aims: To explore the influence of a hypnotically induced NDE in producing the same phenomenology and after-effects and assess changes in psycho-physiological indicators.

Method: A quasi-experimental method approved by the University of Northampton's Ethics Committee, was used with a convenience sample of a single group of 19 participants, whose vulnerability to emotionally charged situations was screened. Their level of hypnotic trance relied on clinical indicators. Two saliva samples were collected before and after the hypnosis session, for cortisol and melatonin measurements. The BSI-18 (Derogatis,2001), SHALOM (Gomez & Fischer, 2003) and DAP-R (Wong, Reker & Gesser, 1994) and open-ended questionnaires were used in pre and post-test phases. After the session, the NDE Scale (Greyson, 1983) was filled. Thematic Analysis (TA) was used for the exploration of the questionnaires, as well as for in-depth interviews conducted with two volunteers who had exceptional experiences.

Results: In all subjects the occurrence of a NDE-like episode was observed, by scoring above the NDE Scale cut-off point. The BSI-18, SHALOM, DAP-R and overall physiological results were not statistically significant. However, the qualitative outcome showed that an induced NDE positively affected spirituality measures, reduced death fear and increased its acceptance. The in-depth interviews conducted with two spiritually mature participants filled Pahnke's (1969) criteria for a mystical experience and their cortisol and melatonin levels showed a significant increase after the session.

Conclusions: The adequacy of a hypnosis protocol to induce an event phenomenologically equivalent to a spontaneous NDE was confirmed. The qualitative results revealed that an induced NDE could positively affect spirituality and death attitude measures. With two exceptional participants, who reported full mystical experiences, a remarkable increase in their cortisol and melatonin levels was also observed.

Keywords: Hypnosis, Near-Death-Experience, Mystical Experience

Publications:
a) HYPNOTICALLY INDUCED NEAR-DEATH-LIKE EXPERIENCES: An Exploratory Study of Phenomenological Similarities. Brief Report submitted to the Journal of Near-Death Experiences in March 2021.
b) LORNA VISITS HER DEAD GRANDPARENTS: A modern ghost story in the frontier where science meets paranormality. Chapter submitted to Is There Life After Death? Vol. 2: Case Studies (June 2021) Edited by Dr Leo Ruickbie and Robert McLuhan for the Society for Psychical Research

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70/16 - "Understanding atypical metacognition and time perception in high hypnotic suggestibility"
Researchers: Devin Terhune
Institution: Department of Psychology, Goldsmiths, University of London (UK)
Estimated duration: 2017/11 – 2018/12

Background: A subset of the population is capable of experienced pronounced changes in behaviour and perception in response to suggestions. The neurocognitive and psychiatric profiles of these individuals are poorly understood.

Aims: This project sought to strengthen current understanding of the cognitive, neurophysiological, and psychiatric characteristics of highly suggestible individuals and clarify the extent to which hypnosis parallels other seemingly germane phenomena.

Method: Highly suggestible (or dissociative) individuals underwent resting state magnetoencephalography and completed psychophysical measures of intention awareness, interval timing, and metacognition of interval timing. A systematic review was undertaken to identify similarities and differences in timing in hypnosis, meditation, psychedelics, and state dissociation. A psychometric-behavioural study aimed to discriminate between models of dissociation and a meta-analysis was undertaken to estimate suggestiblity in dissociative and functional neurological disorders.

Results: Highly suggestible were characterized by reduced functional connectivity between a medial prefrontal and a right frontal-parietal network, suggesting reduced frontal communication. Hypnotic suggestibility was negatively associated with precision of intention awareness signifying aberrant metacognition in highly suggestible individuals. Hypnosis, psychedelics, and dissociative states were characterized by similar timing distortions with a dissimilar pattern to meditation. Suggestibility was associated with dissociation in individuals exposed to trauma, thereby corroborating the diathesis-stress model that suggestibility predisposes individuals to psychopathology. This hypothesis was further corroborated by meta-analyses showing that dissociative and functional neurological disorder patients exhibit high hypnotic suggestibility.

Conclusions: These results expand upon previous research and suggest that highly suggestible individuals are characterized by impaired intention awareness, reduced medial-lateral prefrontal communication, and a stress-mediated predisposition to dissociative psychopathology.

Keywords: Default mode network, Dissociation, Functional neurological disorder, Hypnosis, Metacognition

Publications:
Lemercier, C. & Terhune, D. B. (2018). Psychedelics and hypnosis: Commonalities and therapeutic implications. *Journal of Psychopharmacology, 32*, 732-740.
Wieder, R., & Terhune, D. B. (2019). Dissociation and anxious attachment influence the relationship between trauma and suggestibility: A moderated-moderation analysis. *Cognitive Neuropsychiatry*, *24*, 191-207.

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72/16 - "A physiological examination of full-trance channeling"
Researchers: Helané Wahbeh, Arnaud Delorme
Institution: Institute of Noetic Sciences, Petaluma, California (USA)
Duration: 2017/09 – 2019/03

Background: Numerous world cultures believe channeling provides genuine information, and channeling rituals in various forms are regularly conducted in both religious and non-religious contexts. Little is known about the physiological correlates of the subjective experience of channeling.

Aims: The overall goal of this project was to assess neurophysiological correlates associated with the process of channeling. With a prospective within-participant design, the study's objective was to evaluate neurophysiological measures in trance channels before, during and after channeling sessions to characterize correlates involved in the process of going from a baseline state to a channeling state and back again.

Method: We conducted a prospective within-subject design study with 13 healthy adult trance channels. Participants alternated between 5-minute blocks of channeling and no-channeling three times while electroencephalography (EEG), electrocardiography (ECG), galvanic skin response (GSR), and respiration were collected on two separate days. Voice recordings of the same story read in channeling and no-channeling states were also analyzed.

Results: The pre-laboratory survey data about demographics, perception of the source, purpose and utility of channeled information reflected previous reports. Most participants were aware of their experience (rather than in a full trance) and had varying levels of perceived incorporation (i.e. control of their body). Voice analysis showed an increase in voice arousal and power (dB/Hz) differences in the 125 Hz bins between 0 and 625 Hz, and 3625 and 3875 Hz when reading during the channeling state versus control. Despite subjective perceptions of distinctly different states, no substantive differences were seen in EEG frequency power, ECG measures, GSR and respiration.

Conclusions: Voice parameters were different between channeling and no-channeling states using rigorous controlled methods, but other physiology measure collected were not. Considering the subjective and phenomenological differences observed, future studies should include other measures such as EEG connectivity analyses, fMRI and biomarkers.

Keywords: Trance channeling, Mediumship, Anomalous information reception, Electroencephalography, Electrocardiography, Galvanic skin response, Voice analysis, Spirit possession

Publications:
Wahbeh, H., & Bethany B. (2019). Characteristics of English-Speaking Trance Channelers. *Explore*, *16*(5), 304–309. https://doi.org/10.1016/j.explore.2020.02.002
Sagher, A., Butzer, B., Wahbeh, H., (2019). The characteristics of exceptional human experiences. *Journal of Consciousness Studies*, 26(11–12), 203–237.
Wahbeh, H., Cannard, C., Okonsky, J., & Delorme, A. (2019). A physiological examination of perceived incorporation during trance [version 2; peer review: 2 approved]. *F1000Research*, *8*(67). https://doi.org/10.12688/f1000research.17157.

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75/16 - “The painful awareness of death: Influence of thoughts of death on behavioural and cerebral activity associated with painful nociceptive stimuli” – only abstract available

Researchers: Elia Valentini, Istvan Gyimes

Institution: Department of Psychology, Faculty of Science and Healthy, University of Essex, Colchester (UK)

Estimated duration: 2017/10 – 2020/09

Background: There is overwhelming evidence that reminding people of their own death triggers a unique anxiety mechanism, which differs from any other symbolic threats, and affects social behaviour. Previous research into the neuronal mechanisms of this phenomenon seems to provide supporting evidence. However, no research has questioned the neural substrates associated with the idea of our close ones' death nor there is sufficient information on what factors could down-regulate the anxiety mechanism.

Aims: Here we tested the two hypotheses that 1) the effects of thinking about a romantic partner's death would modulate perception and brain activity, and 2) the meditation practice (as well as of the mindfulness personality trait) would buffer the effects of death-related anxiety, thus shielding the self from existential threat.

Method: We measured electroencephalography (EEG) in the context of a classical mortality salience (MS) manipulation whereby participants were exposed to reminders of mortality in a single reflective induction event. Before and after the induction they were submitted to electrical painful stimuli on the dorsum of their left hand. These were suggested being more or less safer for the skin on the basis of their waveform. Yet, in reality the stimuli were all having the same physical features. Such psychological manipulation, in interaction with the MS induction, was expected to increase the chance of perceiving a somatosensory stimulus as more painful as well as increasing the magnitude of brain responses when compared to a negative control mind-set. In turn, these effects were expected to be dampened by the cognitive and emotional regulation exerted by meditation in expert practitioners as well as by the individual's mindfulness trait.

Results: We provide evidence that both ratings of pain and EEG responses to somatosensory painful stimulation are affected by reminders of death. We found that the thought of one's romantic partner death is associated with a modulation of perceived painfulness of the electrical stimuli as well as of the EEG responses to somatosensory stimuli. This finding is less robust in participants exposed to the thought of their own death. Finally, we also detected a buffering effect of meditation expertise and mindfulness trait on MS effects.

Conclusions: Together these results lay out the neural correlates of reminders of a significant other's death. Moreover, for the first time, they outline how the effects associated with reminders of death are buffered by meditation practice and mindfulness trait.

Keywords: Electroencephalography, Meditation, Mindfulness, Mortality salience, Pain

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88/16 - "The interoceptive self: Transcutaneous vagus nerve stimulation as a new tool to investigate heart-brain interactions"

Researchers: Ruben Azevedo, Emmanouil Tsakiris, Valerio Vallani
Institution: Department of Psychology, Royal Holloway, University of London (UK)
Duration: 2017/10 – 2019/10

Background: Interoception is the body-to-brain axis of sensations originating from the internal body organs signalling their physiological state. Neurally, these visceral signals are mainly conveyed through the vagus nerve to the Nucleus Tractus Solitarius in the brainstem from where they are relayed to regions such as the locus-coerelous and the amygdala and, through thalamocortical projections, to higher order structures such as the insula. However, despite the recognized importance of the vagus nerve in the conduction and regulation of autonomic signals, experimental evidence of its role in bringing these signals into consciousness and in emotional processing is still lacking.

Aims: Explore the potential of non-invasive transcutaneous auricular vagus nerve stimulation (taVNS) in the modulation of interoceptive processing and in the appraisal of emotional stimuli.

Method: In a series of studies, we used single-blind within-subjects designs to compare perfomance during active and sham taVNS stimuation: i) in a task assessing the ability to consciously perceive heartbeats (Study 1); ii) in an experimental paradigm designed to measure the impact of cardiac afferent signals in emotional processing (Study 2); in an auditory oodball task, known to rely on the locus coeruleus-noradrenaline system, to show the effectiveness of a novel rapid event-related stimulation protocol (Study 3).

Results: In Study 1, we found improved interoceptive accuracy during active taVNS compared to sham stimulation. Study 2 showed that tVNS modulates the impact of afferent cardiac signals in the processing threat cues. In Study 3, taVNS modulated performance and pupil dilation during an auditory oddball task, providing a proof-of-principle on the effectiveness of a novel rapid event-related stimulation protocol.

Conclusions: Together, these findings enhance our understanding of the mechanisms underlying interoceptive and salience processing, and demonstrate the potential of taVNS as an important tool to investigate brain-body interactions.

Keywords: Transcutaneous vagus nerve stimulation, Interoception, Emotion, Noradrenaline

Publications:

Villani, V., Tsakiris, M., Azevedo, R.T., (2019) Transcutaneous vagus nerve stimulation improves interoceptive accuracy, *Neuropsychologia*. doi: 10.1016/j.neuropsychologia.2019.107201

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93/16 - "Synchronizing brain and heart through decelerated respiration – An EEG-ECG study investigating the effects of paced breathing"
Researchers: Thilo Hinterberger, Teele Tamm
Institution: Research Section of Applied Consciosness Sciences, Department of Psychosomatic Medicine, University Medical Center Regensburg (Germany)
Duration: 2018/08 – 2020/06

Background: Numerous methods for enhancing consciousness and well-being emphasize the role of breathing. Since neural correlates of breathing were only studied within standard EEG frequencies and imaging methods, the link between body rhythms and slow cortical brain dynamics during paced breathing remained unexplored.

Aims: We hypothesize that with a decelerated breathing rhythm of about 10 seconds/cycle the baroreceptor activity will synchronize with the respiration which leads to an increased heart rate variability and also a synchronization with the slow cortical potentials and other brain rhythms.

Methods: Physiological data from 37 participants are presented, who conducted paced breathing sessions with respiration rates from 6 to 14 seconds/cycle for 7 min each task. Measures of respiration, heart rate variability (HRV), and 64 channels EEG as well as subjective ratings were recorded and compared with each other.

Results: Both, the respiratory sinus arrhythmia of the HRV and the slow cortical potentials (SCPs) of the EEG correlated with the respiration cycle. Other EEG frequencies were only weakly influenced. The SCPs demonstrated the highest correlations at a respiration rate of 10 seconds/cycle. Here, a strong positive voltage deflection during inhalation is followed by a negative variation during exhalation (20µV pp). This decelerated breathing rhythm matches the frequency of the baroreceptor sensitivity, leading to synchronization between breath, HRV, baroreceptors and the brain. Subjectively, participants rated this respiration as the most relaxing one.

Conclusions: This study demonstrates the importance of the speed of breathing and its strong dependency with slow cortical potentials (SCPs) of the brain. In this study, we show for the first time, that decelerated breathing at a rate of 6 cycles/minute results in a great synchronicity. We were able to show that central and frontal SCPs only synchronize at slower respiration rates and already develop during the first minute of a paced breathing task. This mechanism may explain the beneficial effect ascribed to decelerated breathing in various mind-body practices. An influential effect of stress level and psychosomatic impairment on correlations of breathing rhythms in the brain could not have been validated here. Generally, more research is needed to uncover the impact of this synchrony to mental and physical health as well as on the functions of consciousness.

Keywords: Paced breathing, Heart rate variability (HRV), Slow cortical potentials (SCP), Synchronicity

Publications:

Peer reviewed journal article

Hinterberger, T., Walter, N., Doliwa, C., Loew, T., (2019). The brain's resonance of breathing – decelerated breathing synchronizes heart rate and slow cortical potentials. *Journal of Breath Research, 13*, 046003. https://doi.org/10.1088/1752-7163/ab20b2

Conference presentations

Hinterberger, T.: "Breathing and the brain – decelerated breathing synchronizes brain and body rhythms". DGPPN Conference (German Association for Psychiatry, Psychotherapy and Psychosomatics) "Focusing on the Future", 28 November – 1 December 2018, Berlin, Germany

Hinterberger, T.: "Breathing and the brain – decelerated breathing synchronizes brain and body rhythms" Abstract and oral presentation at TSC Conference "Towards a Science of Consciousness", 26-28 June 2019, Interlaken, Switzerland

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100/16 - "Arousal effects on time perception and timed behaviour" – only abstract available
Researchers: Ruth Ogden, Michael Richter, Francis McGlone
Institution: School of Natural Sciences and Psychology, Liverpool John Moores University (UK)
Duration: 2017/09 – 2019/05

Background: Previous research shows that our perception of duration is distorted by emotion. Typically, negatively valenced events last for subjectively longer than neutral events whereas positively valenced events last for subjectively less time than neutral valenced ones. These distortions are theorized to be caused by changes in physiological arousal.

Aims: To test the theory that changes in physiological arousal are predictive of emotional distortions to time.

Method: Experiment 1: Participants completed a time estimation task in which they judged the duration of high and low arousal positively, negatively and neutrally valenced images. Experiment 2: Participants completed a time estimation task in which they judged the duration of negatively and neutrally valenced images flowing a period of normal breathing or a period of paced breathing designed to increase PSNS activity. In both experiments, HF-HRV, to index parasympathetic nervous system activity (PSNS), and PEP, to index sympathetic nervous system activity (SNS), were recorded throughout. The relationship between changes in SNS and PSNS activity and perceptions of duration in each condition were established.

Results: Experiment 1: SNS reactivity was predicative of perceived duration, but only for high arousal negatively valenced stimuli, with decreases in PEP being associated with longer duration estimates. SNS and PSNS activity was not predictive of perceived duration for the low arousal negative stimuli or the low and high arousal positive stimuli. Experiment 2**:** Paced breathing increased PSNS activity and reduced the perceived duration of the negative and neutrally valenced stimuli relative to normal breathing. PSNS activity was not however predictive of these reductions in perceived duration.

Conclusions: Physiological arousal is only predictive of distortions to the perceived duration of highly arousing negative stimuli. We therefore propose a new model suggesting that emotional distortions to time result from a combination of bottom-up (physiological arousal) and top-down (threat detection) factors.

Keywords: Time perception, Arousal, Emotion.

Publications:

Ogden, R. S., Henderson, J., McGlone, F., & Richter, M. (2019). Time distortion under threat: Sympathetic arousal predicts time distortion only in the context of negative, highly arousing stimuli. *PloS one*, *14*(5).

Ogden, R. S., Henderson, J., Slade, K., McGlone, F., & Richter, M. (2019). The effect of increased parasympathetic activity on perceived duration. *Consciousness and cognition*, *76*, 102829.

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101/16 - "Implications of near-death experiences for the mind-brain relationship" – only abstract available

Researchers: Bruce Greyson, Surbhi Khanna, Lauren Moore, Lori Derr, Sue Ruddock
Institution: Division of Perceptual Studies, Department of Psychiatry and Neurobehavioral Sciences, University of Virginia, Charlottesville (USA)
Duration: 2017/07 – 2018/11

Background: Most neuroscientists believe that brain generates consciousness. An alternative view is that mind operates independent of its associated brain but is dependent on the brain for expression. The idea that brain generates consciousness is challenged by near-death experiences (NDEs), complex experiences that can occur when the brain is severely disabled. Exploration of brain activity during NDEs may shed light on the mind-brain relationship.

Aims: We reviewed the medical record of a detailed NDE during deep coma, focusing on the severity of condition and neurophysiology, in order to assess the implications of such NDEs for the mind-brain relationship.

Method: Three physicians separately reviewed the medical record of an 8-day coma during which the patient experienced a vivid NDE.

Results: The patient had an NDE with vivid perceptions, intense emotions, and clear memory, including accurate memories of events around his body during the period of deepest coma. Medical records document that he was not expected to survive and that his brain function was severely impaired and unlikely to generate consciousness at the time of the NDE.

Conclusions: The patient was comatose and unresponsive, but nonetheless had a vivid NDE including complex perceptions, cognitions, emotions, and memory. This NDE during documented deep coma is incompatible with consciousness being produced by brain, but is compatible with consciousness being filtered by brain. We encourage other clinical investigators to report examples of NDEs in patients with severely compromised brain function in order to explore further the brain mechanisms associated with complex consciousness and the relationship between consciousness and brain function.

Keywords: Near-death experience, Mind-body relationship, Meningitis, Encephalitis, Coma

Publications:

Khanna, Surbhi, Moore, Lauren, & Greyson, Bruce. (2018). Full neurological recovery from E. coli meningitis associated with near-death experience. *Journal of Nervous and Mental Disease, 206*(9), 744-747. doi: 10.1097/NMD.0000000000000874

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102/16 - "Using suggestion to influence attitudes and behaviour" – only abstract available
Researchers: Jeremy Olson, Thomas Strandberg, Amir Raz, Petter Johansson
Institution: Raz Cognitive Neuroscience Lab, McGill University & Montreal Neurological Institute (Canada); Choice Blindness Laboratory, Lund University Cognitive Science (Sweden)
Duration: 2018/01 – 2020/01

Background: American politics is becoming increasingly polarized, which biases decision-making and reduces open-minded debate.

Aims: In two experiments, we demonstrate that despite this polarization, a simple manipulation based on suggestion and false feedback can make people express and endorse less polarized views about competing political candidates.

Method: In Study 1, we approached 136 participants at the first 2016 presidential debate and on the streets of New York City. Participants completed a survey evaluating Hillary Clinton and Donald Trump on various personality traits; 71% gave responses favoring a single candidate. We then covertly manipulated their surveys so that the majority of their responses became moderate instead.

Results: Participants only noticed and corrected a few of these manipulations. When asked to explain their responses, 93% accepted the manipulated responses as their own and rationalized this neutral position accordingly — even though they reported more polarized views moments earlier. In Study 2, we replicated the experiment online with a more politically diverse sample of 498 participants. Both Clinton and Trump supporters showed nearly identical rates of acceptance and rationalization of their ostensibly neutral positions.

Conclusions: These studies demonstrate how suggestion and false feedback can powerfully shape the expression of political views. More generally, our findings reveal the potential for open-minded discussion even in a fundamentally divided political climate.

Keywords: Depolarization, Choice blindness, Suggestion, Presidential candidates, Attitudes

Publications:

Strandberg, T., Olson, J. A., Woods, A., Hall, L., & Johansson, P. (in revision). Depolarizing American minds: False beliefs can induce depolarized expressions about presidential candidates. *PLOS One*.

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111/16 - "A psychophysiological perspective of the transformative experience of pregnancy" – only abstract available

Researchers: Helena Rutherford, Linda Mayes, Catherine Monk, Elizabeth Meins, Brianna Francis
Institution: Child Study Center – CSC; Yale University School of Medicine, New Haven (USA)
Duration: 2017/03 – 2020/02

Background: Pregnancy may be conceptualized as a period of neurophysiological and psychological reorganization to facilitate later caregiving. Although primarily studied in women, the impact of pregnancy on men, and indeed the role of fathers in parenting research more broadly, is receiving increasing attention. In understanding the perinatal origins of parenting, studies have begun to examine parental, specifically maternal, neural responsiveness to infant affective cues during pregnancy, and their potential implications for caregiving postpartum. However, while relations between psychological measures of parenting and caregiving postpartum have been examined, the associations between neural and psychological measures of parenting in pregnancy are yet to be established. Further, the relative strength of and differences in observed relations for expectant mothers and fathers is unknown.

Aims: In expectant mothers and fathers, our aims were to examine (1) the P300 elicited by photographs of distress and neutral infant faces; (2) levels of prenatal mind-mindedness as a psychological construct important for later parenting; and (3) whether the P300 would be associated with our measures of prenatal mind-mindedness.

Method: Expectant mothers (n=38, M_{age}=29) and fathers (n=30, M_{age}=32) during the third trimester of pregnancy viewed infant distress and neutral faces while electroencephalography was recorded. Following pre-processing, the P300 amplitude was measured for each participant. Parents also completed an assessment of prenatal mind-mindedness towards their unborn child.

Results: Expectant fathers evidenced a greater P300 response to infant faces as compared to expectant mothers, specifically for infant distress, $F(1,66) = 8.34$, $p = .004$. P300 reactivity to infant distress, relative to neutral, faces was associated with prenatal mind-mindedness in expectant fathers, $r = .38$, $p = .045$, but not expectant mothers, $r = .10$, $p = .559$.

Conclusions: Although extension and replication of these findings are warranted, they raise important insight into sex differences in the experience of pregnancy. They also speak to the neural and psychological preparedness of expectant fathers, which has not previously been considered. Critically, our findings indicate that expectant parents can take the perspective of their future child and suggest an important interplay between neural and psychological factors in the preparation for parenthood in expectant mothers and fathers.

Keywords: Expectant parents, Parental brain, Mind-mindedness

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114/16 - "Effects of a mindfulness-based intervention for teachers: A study on teacher and student outcomes" – only abstract available

Researchers: Alexandra Marques-Pinto, Ana Pinheiro, Patricia Jennings, Mark Greenberg, Joana Sampaio de Carvalho

Institution: Centro de Investigação em Ciência Psicológica – CICPSI, Faculdade de Psicologia da Universidade de Lisboa (Portugal)

Duration: 2017/01 – 2020/03

Background: Due to the difficult demands of their work, teachers feel increasingly stressed, and their stress and burnout can affect their health, well-being and professional performance (i.e., the quality of teaching and classroom management) and, as a result, negatively interfere with students' learning and engagement.

Aims: This study aims to evaluate the proximal and distal effects of *Atentamente*, a mindfulness-based program specially developed to promote teachers' social and emotional competences (SEC), across a variety of teachers, classroom climate and student outcomes.

Method: The study followed a randomized trial design, and included three data collection points: pretest, posttest, and follow-up. Participants in the Experimental Group (EG) included 112 elementary school teachers (six groups of around 20 teachers each) from state schools, their 1500 students and this students' parents, while the Control Group (CG) comprised 93 elementary school teachers, their 1500 students and respective parents. A mixed data collection strategy was used that included teachers and students' self-report data, observational ratings of teachers' classroom behaviors and parents' reports on students.

Results: After the intervention, EG teachers, compared to CG teachers, reported a significant increase in mindfulness and emotional regulation skills, self-efficacy beliefs and general and social well-being level, and a decrease in burnout symptoms. Similarly, a significant improvement was found on EG teachers classroom behaviors related to students' socio-emotional support, attention and responsiveness to their needs, and classroom management. Finally, significant improvements were also found in EG students' perceptions of the quality of their teachers' involvement in classroom relationships, self- reported emotions and social competencies perceived by their parents.

Conclusions: These findings further the knowledge on the role played by mindfulness- based interventions in reducing teachers' burnout symptoms and cultivating their SEC and well-being, in promoting a nurturing classroom climate and also in promoting the SEC and well-being of students. This knowledge, in turn, may inform future teacher training policies and intervention practices and thus contribute to both teachers and students' well-being.

Keywords: Mindfulness, Social and emotional competencies, Teachers, Classroom climate, Students

Publications:

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117/16 - “Replication in parapsychology: The correlation matrix method” – only abstract available
Researchers: Caroline Watt, Ana Flores
Institution: Koestler Parapsychology Unit, University of Edinburgh, Scotland (UK)
Duration: 2017/01 – 2018/11

Background: The Correlation Matrix Method (CMM) is theoretically supported by the Model of Pragmatic Information (MPI) (von Lucadou, 1995) and the Generalised Quantum theory (GQT) (Atmanspacher et al. 2012). CMM argues to measure non-local correlations produced by generalised entanglement as an explanation to parapsychological phenomena.

Aims: The aim of the project was to study and contribute to the progress of the Correlation Matrix Method (CMM), by conducting a software validation and three new independent pre-registered CMM replication experiments. A Psychokinesis task was given to participants to test that more significant correlations were produced under the mental influence of participants against the control system.

Method: The studies were pre-registered, ethics were obtained from University of Edinburgh committee and consent from participants. A laptop with windows XP and a random number generator (RNG) was used to collect data. A fractal Mandelbrot image was shown on the laptop screen and participants were asked to mentally influence the movement of the fractal. The movement of the fractal was created by the RNG and participants had to press a keyboard key for a new RNG movement to be shown on the screen.
Variables produced by the participants and by the RNG were recorded for analysis. Each study is composed by 200 sessions, each session has 720 trials or participant key presses.
Two methods of analysis were performed, the original method used by Lucadou, and the permutation method that was introduced as an improvement to the analysis.

Results: The hypothesis tested whether a greater number of significant correlations would be produced when participants were trying to mentally influence the fractal, than when there was no participant and the system ran alone or against the permutation method. The three studies were exact replications between them. For study 1 a successful result obtained a p value 0.0005, study 2 achieved a p=0.0003 and study 3 shown a p= 0.001.

Conclusions: The significant results of the three studies show that participants impact on the creation of randomness. According to the results, the RNG has different behaviour when participants mentally try to interact with it than when it runs alone without participants or against a random permutation. As such, psychokinesis should be further investigated.

Keywords: Psychokinesis, Consciousness, Correlation matrix, Quantum measurement, Observer effect

Publications:

Flores, A., & Walach, H. (2017) *An Emerging New Paradigm for* Complementary Medicine: Generalised Entanglement and New Experimental Support. Paper submitted to 36th SSE Conference, 14-17, Yale University, New Haven, Connecticut.

Flores, A., Watt, C., & Tierney, I. (2017) Replication and Extension of a New Paradigm For Psychokinesis: Mind-Matter Interaction through Non-Local Entangled Correlations? 41st International SPR Conference; De Vere Horsley Estate, East Horsley, KT24 6DT.

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Flores, A. (2018) Edinburgh Software Validation Test for Researchers in Psychology. *Open Science Journal of Psychology*, *5*, 68-72.

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118/16 - "The experiences of participants in religious healing rituals in Lourdes: The role of noetic meaning and identity shift" – only abstract available

Researchers: Paul Dieppe, Sarah Goldingay, Sarah Warber, Emmylou Rahtz
Institution: Institute of Health Research, University of Exeter Medical School (UK); Centre for Research in Psychology, Behaviour and Achievement, University of Coventry (UK)
Estimated duration: 2017/07 – 2021/10

Background: The Catholic pilgrimage site of Lourdes, in South West France, is best known for reports of miraculous cures of physical disease resulting from pilgrims' visits. Following our previous visits to Lourdes, the authors hypothesised that more common positive outcomes for pilgrims might be improvements in health and wellbeing, facilitated by transcendent (spiritual or noetic) experiences.

Aims: We wished to ascertain whether visitors to Lourdes who take part in religious healing rituals would have transcendent experiences, and whether they described positive changes in physical, mental or spiritual health.

Method: During a 10-day visit to Lourdes 5 researchers embedded themselves in the culture of Lourdes, taking part in the rituals there, and working closely with three specific pilgrimage groups. We collected data through interviews, pictures, and ethnographic observation. Interviews were recorded and transcribed. The data was subjected to thematic analysis.

Results: We obtained recorded interviews from 67 visitors, many of whom were sick and who had come in the hope of a cure (ages 15-87, 72% female). Of these 26 described some sort of transcendent, spiritual or noetic experience whilst there - most commonly when alone in the grotto rather than during a religious ritual. These experiences were often intense, resulting in feelings of immense joy, love, peace or a sense of connection with something outside of the self. Some described lasting benefits. The other big theme to emerge from the data was 'positive change': respondents describing a wide variety of personal changes in their physical, mental or spiritual health, and in their identity, facilitated by nourishing exchanges with others in Lourdes.

Conclusions: Visits to Lourdes can result in powerful personal 'out-of-the-ordinary' experiences, and changes in health status and identity. How and why this occurs requires further research. We believe that these phenomena are the 'true miracle of Lourdes' rather than the rare cures of physical disease that have attracted most attention and research there.

Keywords: Lourdes, Transcendent experiences, Identity change, Healing rituals

Publications:

Dieppe, P., et al. (2021). Many miracles take place each day, in the spirit and in the heart. *Bulletin De L'Association Medicale Internationale de Notre-Dame De Lourdes, 352*, 42-51.

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122/16 - "A fully transparent pre-registered replication study of precognitive detection of reinforcement using an expert consensus design" – only abstract available
Researchers: Zoltan Kekecs, Balazs Aczel, Bence Palfi, Aba Szollosi, Barnabas Szaszi
Institution: Decision Making Laboratory, Faculty of Education and Psychology, Eotvos Lorand University, Budapest (Hungary)
Estimated duration: 2017/05 – 2022/04

Background: Growing evidence for a systematic positive bias in the published research reports is often interpreted as a 'confidence crisis' in psychological science. Studies testing controversial hypotheses suffer even more of the burden of the confidence crisis, because the lack of objective indicators to distinguish between reliable and unreliable results promotes risk-averse and the maintenance of the status quo.

Aims: This project aims to develop methodological tools that facilitate highly credible and rigorous research. Furthermore, we aim to conduct a multi-site, fully transparent replication of Bem's (2011) Experiment 1 using these credibility-enhancing methodologies. We also seek to disseminate our output in the scientific community via publications, talks, and seminars.

Methods: The project will culminate in conducting a multi-site, fully transparent replication of Bem's (2011) Experiment 1. We have developed a study protocol for this replication effort via a Consensus Design Process. During this process more than twenty experts on the field (both proponents and opponents of the original hypothesis) contributed to finalizing the protocol. The protocol includes a comprehensive toolkit of safeguards against researcher biases and mistakes that are often thought of as the primary cause for the abundance of non-reproducible findings in psychology and biomedicine. The safeguards include radical transparency about the whole research pipeline via Born Open Data, Direct Data Deposition, Real-time Research Reports, automation, trusted third party oversight, tamper evident seals on data and software, documented training, and lab logs.

Preliminary Results: We have conducted a pilot study involving two research sites and one hundred eighty-four participants. This pilot study demonstrated the feasibility of our approach, and the adequacy of the consensus-derived study protocol. During this pilot investigation we observed 49.49% successful guesses within 3308 trials (99.5% CI = 47%, 51.9%; posterior mode = 50.6%, posterior 90% HDI = 49.4%, 51.7%). It is important to note though that the aim of the pilot study was to assess the feasibility and acceptability of the study protocol and research materials, and not hypothesis testing, this dataset should not be used for hypothesis testing, since the research materials were not yet finalized. The registered report of the main replication study is currently under review. After in principle acceptance from the journal, we will carry out the research protocol involving 2,102 - 7,560 participants using a sequential analysis plan.

Conclusions: We are in the second (final) stage of our project execution. Seeing the favourable reviews of the registered report submission and we are now actively recruiting laboratories who are interested in joining the replication effort. Those interested in joining should fill out the application form at http://tiny.cc/tpp-signup, or contact the lead PI directly via zoltan.kekecs@psy.lu.se. For more details visit: https://osf.io/jk2zf/

Keywords: Transparency, Research credibility, Consensus methodology, Parapsychology

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147/16 - “Metarepresentations of supernatural belief and the effect of context on physiological responses and cognitions”

Researchers: Malcolm Schofield, Ian Baker, David Sheffield, Paul Staples
Institution: Department of Psychology, College of Life and Natural Sciences, University of Derby (UK)
Estimated duration: 2018/02 – 2020/02

Background: This project will build on the model of supernatural belief, cognition and personality proposed by Schofield et al. (2021) by introducing physiological measures. Implicit belief and context will be manipulated to further study the belief and cognition interaction. The interplay between cognitive processes and implicit belief may manifest itself as a physiological response in the form of somatic markers, i.e. changes in the autonomic nervous system.

Aims: Examine implicit belief and its effect on explicit belief by examining the evidence for implicit belief using context and physiological measures.

Methods: Study one recruited 172 participants and used three religious, paranormal and neutral contexts as primes. Implicit association was measured using a modified Brief Implicit Association Test that looked at paranormal and religious belief. This and the subsequent study also measured explicit supernatural belief, cognitive reflection, unhelpful metacognitions, and confidence. Study two recruited 44 participants and showed them cognitively complex and cognitively simple tasks while taking physiological measures of heart rate, blood pressure and skin conductance.

Results: For study one, a hierarchical multiple regression revealed that a lower belief in the supernatural (apart from psychokinesis), a religious prime and high confidence predicts reflective thinking. Common paranormal perceptions, religious prime and confidence were significant predictors in the model. For study two, a Path Analysis found that the change in skin conductance between cognitively complex and cognitively simple tasks was positively predicted by belief in mental and psychic phenomena, psychokinesis, and common paranormal perceptions. Belief in psychokinesis was also negatively predicted by lack of cognitive confidence and positively predicted by negative beliefs about uncontrollability and danger. Belief in supernatural entities is positively predicted by the need to control thoughts. Study two findings are preliminary and more data is to be collected.

Conclusions: Study one suggests that the religious prime influenced participants to be more analytical. Furthermore, study two indicates that skin conductance is a biomarker for analytical tasks in paranormal believers, which is not present in religious believers. This points to stress and threat response's role in a belief polarisation paradigm and an implicit role for belief.

Keywords: Supernatural, Cognition, Priming, Psychophysiology, Somatic Markers Hypothesis

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150/16 - "An investigation into the causal role of alpha oscillations in attention" – only abstract available

Researchers: Alexander Jones, Jonathan Silas, Lars Wicke
Institution: The Behavioural, Affective, and Cognitive Neuroscience research group – BACneuro, Middlesex University London (UK)
Estimated duration: 2017/03 – 2019/02

Background: Using Electroencephalography (EEG) an event-related change in alpha activity has been observed over primary sensory cortices during the allocation of spatial attention. This is most prominent during top-down, or endogenous, attention, and nearly absent in bottom-up, or exogenous orienting. These changes are highly lateralised, such that an increase in alpha power is seen ipsilateral to the attended region of space and a decrease is seen contralaterally. It is unknown whether peak alpha differs across these tasks and whether changes in alpha oscillatory activity are causally related to attentional resources.

Aims: This grant had two aims: 1. To test for differences in peak alpha amplitude and frequency during tactile attention and perception tasks. 2. To test the causal role of alpha in tactile attention.

Methods: We explored individualized alpha in EEG during three well established tactile attention and perception tasks. In these experiments, participants completed a tactile endogenous and exogenous attention tasks and a perceptual task while EEG was recorded. We implemented a novel approach to exploring the data to look for differences in individual alpha frequencies and alpha amplitude. To explore the causal role of alpha in tactile attention we are conducting a study that is still ongoing. Specifically, we are using transcranial Alternating Current Stimulation (tACS) to modulate alpha activity in the somatosensory cortex whilst measuring performance on tactile attention paradigms. All participants complete an endogenous and exogenous tactile attention task in three stimulation conditions; alpha, sham and beta. During experimentation alpha tACS stimulation is administered at individualised alpha frequency.

Results: For the EEG study on individualized alpha we used a data driven approach to compare alpha changes and we show that alpha decreases differ only between exogenous and endogenous attention tasks for only a short time window, 500–600 ms after cue onset. Findings for the tACS experiment have been pre-registered in Cortex but data collection is not yet completed.

Conclusions: On the basis of our EEG study we suggest that alpha amplitude modulations play a specific role in both in voluntary orientating and stimulus predictability. Furthermore, we demonstrate that there are no key differences in peak alpha frequencies compared across different tactile attentional tasks.

Keywords: Alpha, Attention, tACS, EEG, Somatosensory

Publications:

Jones, A., Yarrow, K. & Silas, J. (2018). Are alpha oscillations generated by the somatosensory cortex involved in tactile attention? A registered report using transcranial Alternating Current Stimulation (tACS). *Cortex,* Registered report: In Principle Accepted. doi: 10.17605/OSF.IO/P7AME

Silas J. and Jones A. (2018): Individual peak alpha frequency in touch – cognitive and methodological implications. Presentation at *British Association for Cognitive Neuroscience (BACN)*, Glasgow

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152/16 - "The role of the lateral occipital area in the visual processing of object size, shape, and orientation within and outside conscious awareness" – only abstract available

Researchers: Philippe Chouinard, Irene Sperandio, Robin Laycock
Institution: La Trobe University, Melbourne (Australia); School of Psychology, University of East Anglia, Norwich (UK)
Duration: 2017/03 – 2019/09

Background: What is and is not processed outside of conscious awareness is currently being increasingly investigated as the field begins to appreciate and understand more the involvement of different visual pathways in the brain.

Aims: Our project aimed to determine the degree to which different object characteristics and types of objects are processed subconsciously relative to when they are processed consciously and to determine the contribution of the lateral occipital complex (LOC) in some of these processes.

Method: Several behavioural experiments were carried out. The experiments used continuous flash suppression and more traditional visual masking paradigms to examine if the form, size, and orientation of objects, as well as words and emotionally salient stimuli, could be processed outside of conscious awareness. We also used functional magnetic resonance imaging (fMRI) to examine the contribution of different subdivisions of LOC in processing the form, size, and orientation of objects using an adaptation paradigm.

Results: The behavioural experiments revealed that words and emotionally salient stimuli are processed outside of conscious awareness but not the most basic features of objects, including their form, size and orientation, at least within the context of visual perception. Our fMRI experiment further revealed how different subdivisions in LOC contribute to the processing of form, size and orientation of objects during conscious awareness.

Conclusions: Taken together, our findings indicate that consciousness awareness is required for processing the basic features of objects, such as their form, size, and orientation, for perceptual purposes.

Keywords: Object features, Vision, Consciousness, Psychophysics, Functional magnetic resonance imaging.

Publications:

Cox, E. J., Sperandio, I., Laycock, R., & Chouinard, P. A. (2018). Conscious awareness is required for the perceptual discrimination of threatening animal stimuli: A visual masking and continuous flash suppression study. *Conscious Cogn, 65*, 280-292. doi:10.1016/j.concog.2018.09.008

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Peel, H. J., Sperandio, I., Laycock, R., & Chouinard, P. A. (2018). Perceptual Discrimination of Basic Object Features Is Not Facilitated When Priming Stimuli Are Prevented from Reaching Awareness by Means of Visual Masking. *Front Integr Neurosci, 12,* 13. doi:10.3389/fnint.2018.00013

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157/16 - "Estranged from oneself, estranged from the others: Investigating the effect of depersonalization on self-other mirroring"

Researchers: Anna Ciaunica, Harry Farmer, Ophelia Deroy, Vittorio Gallese
Institution: Institute of Philosophy Porto, University of Porto (Portugal); Institute of Cognitive Neuroscience, University College London (UK)
Duration: 2017/05 – 2021/05

Background: The sense of self lies at the heart of conscious experience, anchoring our disparate perceptions, emotions, thoughts and actions into a unitary whole. There is a growing consensus that sensory information about the body plays a central role in structuring this basic sense of self. Depersonalisation (DP) is an intriguing form of altered subjective experience in which people report feelings of unreality and detachment from their sense of self.

Aims: Our project brings together interdisciplinary resources from philosophy, cognitive neuroscience and psychophysiology in order to explore the relationship between the experience of DP and sensorimotor processing of self and other.

Method: The current study used the Visual Remapping of Touch (VRT) paradigm to explore self-bias in visual tactile integration in non-clinical participants reporting high and low levels of depersonalisation experiences. 63 participants (17 male) with a mean age of 24 ± 4 participated in this study.

Results: Due to the alterations in self-experience that characterise DP, we predicted that participants in our high DP group would show a reduced overall VRT effect regardless of the observed face (H1) and fail to show the self-bias VRT effect previously reported in other studies (H2). Our results offered support for H2 by showing that amount of anomalous body experiences reported by participants was negatively correlated with the size of their VRT self-bias. However contrary to H1 we found evidence for increased overall VRT effect in the high DP group compared to the low DP group.

Conclusions: Our findings revealed that participants high in DP showed an increased overall VRT effect but a no self-face bias, instead showing a greater VRT effect when observing the face of another person. In addition, across all participants, self-bias was negatively predicted by score on the anomalous body experiences subscale suggesting that this effect was specifically linked to disruptions in the perception of the bodily self. These results provide evidence for disrupted integration of tactile and visual representations of the bodily self in those experiencing DP and provide a greater understanding of how disruptions in sensory perception of the self may underlie the phenomenology of depersonalisation.

Keywords: Depersonalisation, Self, Visual remapping of touch, Touch, Social cognition

Publications:

Farmer et al. (under review). The Detached Self: Investigating the Effect of Depersonalisation on Self-Bias in the Visual Remapping of Touch.

Ciaunica, A., Charlton, J., Farmer, H. (forthcoming). When the Window Cracks – Transparency and the Loss of the Sense of Self in Depersonalisation and Meditation, *Frontiers in Theoretical Psychology*.

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169/16 - "The potential effect of behavioral stimulation on social competence in dogs (via endogenous oxytocin release)" – only abstract available

Researchers: Anna Kis, József Topál, Alin Ciobica, Radu Lefter, Katinka Tóth

Institution: Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Budapest (Hungary); Department of Animal Physiology and Behaviour "Alexandru Ioan Cuza" University, Iasi (Romania)

Duration: 2017/05 – 2021/11

Background: Family dogs *(Canis familiaris)* are increasingly recognised as translational models of human social behaviour. The current project focuses on determining to what extent the oxytocin sytsem regulates such human-like behaviours in dogs.

Aims: In two relating studies we first aimed to confirm the effect of social interaction on dogs' peripheral (plasma) oxytocin. Then we aimed to test how increased oxytocin levels influence behaviour.

Methods: A conceptual replication of canine serum oxytocin increase following positive dog-human interaction was carried out on $N = 6$ dogs. In an independent study dogs ($N = 33$) were treated with either oxytocin or placebo nasal spray and exposed to a contagious yawning situation.

Result: Positive social interaction (petting, playing, talking) was found to increase serum oxytocin levels ($t_{(5)} =$ 4.846, $p = 0.005$). It was found that oxytocin pre-treatment significantly decreased the number of yawns, especially during the test phase (pre-treatment × phase: $F_{(1,121)} = 4.499$, p=0.036; pre-treatment main effect: $F_{(1,121)} = 4.459$, $p = 0.037$). In addition the number of yawns was strongly related to the number of mouth licks, especially during the post phase (mouth licks × phase: $F_{(1,121)} = 8.234$, $p = 0.005$; mouth licks main effects: $F_{(1,121)} = 14.100$, $p < 0.001$; Fig. 2).

Conclusions: We have validated and described both an immunoassay method to measure oxytocin as well as a social interaction that reliably increases oxytocin levels. Testing for the effect of intranasal oxytocin on an empathy-related measure (contagious yawning) we have found, that contrary to expectations oxytocin decreased the number of yawns in dogs. This suggests that contagious yawning is not a valid measure of empathy in dogs, as our results indicate that a stress behaviour (mouth licking) is strongly related.

Keywords: Dog, Oxytocin, Social behaviour

Publications:

Hritcu, L. D., Horhogea, C., Ciobica, A., Spataru, M. C., Spataru, C., & Kis, A. (2019). Conceptual Replication of Canine Serum Oxytocin Increase Following a Positive Dog-human Interaction. *REVISTA DE CHIMIE*, 70(5), 1579-1581.

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176/16 - "Dissociating working memory and inhibition deficits as a result of healthy and unhealty ageing" – only abstract available

Researchers: Stephen Badham, Mark Crook-Rumsey, David Connelly, Trevor Crawford, Christina Howard
Institution: Devision of Psychology, Nottingham Tent University (UK); Department of Psychology, Lancaster University (UK)
Duration: 2017/12 – 2021/05

Background: Prior research has focused on EEG differences across age or EEG differences across cognitive tasks/eye tracking. There are few studies linking age differences in EEG to age differences in behavioural performance which is necessary to establish how neuroactivity corresponds to successful and impaired ageing.

Aims: To understand neuropsychological mechanisms that underpin age-related cognitive decline using electroencephalography (EEG) and eye-tracking. This is the first study to our knowledge that combines EEG and eye tracking data in the context of ageing.

Method: The current study investigated EEG predictors of inhibition and working memory in typically-aging older adults(n=44) and young adults (n=31). General mental state was assessed with the Geriatric Depression Scale, Mini Mental State Exam and Alzheimer's Disease Assessment Scale. General cognitive functioning was assessed using tests for verbal learning (Hopkins test), task switching (Trails a and b) and verbal IQ (National Adult Reading Test). In addition, participants completed tests of working memory (forwards and backwards digit and spatial span) and inhibition (day-night task). Inhibition was further investigated using eye tracking (saccades, antisaccades, and a Go-No-Go paradigm). Resting state EEG was assessed at 128 electrodes during eyes-open and eyes-closed conditions.

Results: Age deficits in cognition were aligned with the literature, showing working memory and inhibitory deficits along with an older adult advantage in vocabulary. Older adults showed poorer eye movement accuracy and response times, but we did not replicate literature showing a greater age deficit for antisaccades than for prosaccades. We replicated EEG literature showing lower alpha peak frequency in older adults but not literature showing lower alpha power. Older adults also showed higher beta power and less parietal alpha power asymmetry than young adults. Interaction effects showed that better prosaccade performance was related to lower beta power in young adults but not in older adults. Performance at the trail making test part B (measuring task switching and inhibition) was improved for older adults with higher resting state delta power but did not depend on delta power for young adults.

Conclusions: It is argued that individuals with higher slow-wave resting EEG may be more resilient to age deficits in tasks that utilise cross-cortical processing.

Keywords: EEG, Eye tracking, Working memory, Inhibition

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183/16 - "Decoding the language of 'now': EEG microstates in experienced meditators, from letters to grammar"

Researchers: Elena Antonova, Chrystopher Nehaniv, Martin Holding
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Estimated duration: 2017/09 – 2021/04

Background: The analysis of the EEG into microstates representing a distinct topographical organization of the power of the EEG signal over the skull is an established method, but the test-retest reliability of the EEG microstates and their functional interpretation remain unclear.

Aims: To investigate the functional significance of the EEG microstates classes and their pair-wise transitions, as well as to establish their within-session test-retest reliability.

Method: We recorded 30-channel EEGs in 20 healthy volunteers during three eyes-closed conditions: mind-wandering, silent verbalization (repeating the word 'square' every 2 sec), and visualization (visualizing a square). Each condition lasted three minutes and the sequence of three conditions was repeated four times (two runs of two repetitions). The participants' alertness and their sense of effort and focus during each condition was rated using visual-analogue scales. The EEG data were 2-20 Hz bandpass-filtered and analyzed into four canonical micro-state classes: A, B, C, and D.

Results: EEG microstate lasses C and D were persistently more dominant than classes A and B in all conditions. Of the classical micro-state parameters, the average micro-state duration was the most reliable one. The duration of micro-state class D was longer in the mind-wandering condition (106.8 ms) than during verbalization (102.2 ms) or visualization (99.8 ms), with a concomitantly higher coverage (36.4 % vs. 34.7 % and 35.2 %), but otherwise it was difficult to associate the four micro-state classes to particular mental states. As for the transitions from one microstate to another, only the transitions between classes C and D (and in particular those from C to D) were significantly higher than what would be expected from the respective states' occurrences. The transition probabilities, however, did not distinguish between conditions, and their test-retest reliability was overall lower than that of the first-order parameters such as duration and coverage. The test-retest reliability was higher at the beginning of each run.

Conclusions: Further studies are needed to establish the functional significance of the canonical EEG microstates. This might be more fruitfully achieved by looking at their complex syntax beyond pair-wise transitions using methods as previously proposed (Nehaniv and Antonova, 2017). To ensure greater test-retest reliability experimental designs should allow for shorter epochs with regular breaks.

Keywords: EEG microstates, Resting state EEG, Resting-state networks, Neuroimaging, Biomarkers

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188/16 - "Accuracy and neural correlates of blinded mediumship compared to controls"
Researchers: Arnaud Delorme, Helané Wahbeh
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Duration: 2017/10 – 2020/10

Background: Anomalous psychological phenomena, in which individuals claim to have access to information not available through conventional means, have been reported since antiquity. Despite tremendous popular interest, few studies have tested these claims rigorously.

Aims: The current study aimed to fill this gap. We asked volunteers to look at facial photographs of deceased people and guess one of three choices for the cause of death, while simultaneously collecting electroencephalogram (EEG) data.

Method: The volunteers were 13 professional "psychic mediums" and 13 controls who claimed no special ability. There were three possible choices for cause of death: "heart attack", "death by firearm", or "car accident." The facial photographs were a balanced pool of 201 black and white photographs, where the cause of death was known in each case. The participants did not see any of these photographs before the experiment.

Results: Pooled data from all participants showed accurate guesses for the cause of death (partial η^2=0.13; p=0.003). Control subjects were primarily responsible for this effect (partial η^2=0.15; p=0.001). EEG activity differences were found between talented participants and controls in event related potentials (ERP) following the presentation of the photographs. The controls had larger amplitude ERP components than the talented participants between 80 and 110 ms and between 200 and 350 ms, which could be interpreted as reflecting greater attention and less response inhibition by controls as compared to the mediums.

Conclusions: To conclude, we found EEG differences in EEG between mediums and controls in regards to how face photographs are processed. We also found that as a whole, participants were capable of categorizing the type of death above chance expectation. We recommend that others try to investigate these effects in other participant pools. The images and presentation scripts used in our study are available upon request. To help minimize performance anxiety, we also recommend that future studies investigate mediums under conditions that more closely match what they do as part of their professional work.

Keywords: Intuition, Mediumship, Electroencephalography, Behavior, Machine-learning

Publications:
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189/16 - “Implicit beliefs in the study of experimenter effects in the replication of psi experiments: A global initiative”
Researchers: Marilyn Schlitz, Arnaud Delorme, Daryl Bem
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Duration: 2017/10 – 2021/04

Background: Three experiments examined the effects of psi beliefs on a "time-reversed" priming task (Bem, 2011).

Aims: Assess relations between experimenters'/participants' psi beliefs to reaction times (RTs) on congruent/incongruent prime/picture pairs. A congruent pair is when both the priming word and the picture are both positive or both negative. An incongruent pair is when one is positive and the other is negative. The psi hypothesis is that RT's to congruent pairs will be shorter than RT's to incongruent pairs.

Method: *Study 1* examined the relationship of psi beliefs to RTs to congruent/incongruent word/picture pairs. *Study 2* attempted to influence expectancies of success by pre-exposing participants' to pro or anti-psi statements. Study 3 assessed unconscious expectations of success using the Implicit Association Task (IAT).

Results: *Study 1:* A significant psi effect did not emerge in the preplanned analysis, but did when trials were used as the unit of analysis. There was no correlation between experimenter expectancy and the psi effect. *Study 2* showed no significant effects. *Study 3* showed a significant reversal of the hypothesis and a significant negative correlation between participants’ IATs and their overt beliefs in psi.

Conclusions: Results showed no effect of participants' or experimenter's beliefs on psi but do support using trials as the unit of analysis.

Keywords: Priming, Expectancy effect, Experimenter effect, Retrocausation

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190/16 - "Sleeping body, sentient mind? Searching for the neural bases of conscious experiences during sleep" – only abstract available

Researchers: Eus Van Someren, Yishul Wei
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Duration: 2017/10 – 2019/05

Background: Insomnia Disorder (ID) is a prevalent and persistent condition, yet its neural substrate is not well understood. The cognitive, emotional, and behavioral characteristics of ID suggest that vulnerability involves distributed brain networks rather than a single brain area or connection.

Aims: The present study utilized tractography to compare the whole-brain structural connectivity networks of people with ID and those of matched controls without sleep complaints.

Method: Diffusion-weighted images and T1-weighed images were acquired in 51 people diagnosed with ID (21–69 years of age, 37 female) and 48 matched controls without sleep complaints (22–70 years of age, 31 female). Probabilistic tractography was used to construct the whole-brain structural connectivity network of each participant. Case–control differences in connectivity strength and graph efficiency were evaluated with permutation tests.

Results: People with ID showed structural hyperconnectivity within a subnetwork that spread over frontal, parietal, temporal, and subcortical regions and was anchored at the right angular gyrus. The result was robust across different edge-weighting strategies. Moreover, converging support was given by the finding of heightened right angular gyrus nodal efficiency (harmonic centrality) across varying graph density in people with ID. Follow-up correlation analyses revealed that subnetwork connectivity was associated with self-reported reactive hyperarousal.

Conclusions: The findings demonstrate that the right angular gyrus is a hub of stronger structural connectivity in ID. Hyperconnectivity within the identified subnetwork may contribute to increased reactivity to stimuli and may signify vulnerability to ID.

Keywords: Insomnia, Sleep, Tractography, Brain structural connectivity, White matter, Connectome, Network, Hub, Hyperarousal

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191/16 - "Mind-matter entanglement correlation" – only abstract available
Researchers: Hartmut Grote
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Duration: 2017/03 – 2021/03

Background: Mind-matter correlations are a long-standing, but also controversial and difficult to research topic of investigation.

Aims: This experiment tested the hypothesis of mind-matter correlations between human intention and a physical random number generator.

Method: The experiment was a conceptual replication of the so-called correlation matrix method as proposed by W. von Lucadou. A strict blind analysis protocol was used to prevent any biased analysis. Part 1 of this analysis was performed live on the PA convention in Paris 2019.

Results: The main outcome of the blind analysis is not significant under a null hypothesis of no mind-matter correlations. However, some astonishing phenomena were observed as an 'aside' of this investigation, which had not been predicted by the main analysis.

Conclusion: This experiment and its outcomes is a prime example of the difficulty conducting experiments of this kind. Purported 'effects' of mind-matter correlations, if they exist, seems to systematically escape dedicated experiments, in strong support of experiments (-psi) effects.

Keywords: PK-experiment, Mind-matter interaction, Correlation-matrix, Experimenter effects

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195/16 - "The sense of self: A neuroimaging study of interactions between intrinsic and extrinsic self networks" - only abstract available

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Duration: 2017/04 – 2019/10

Background: Self concepts have been studied extensively in neuroscience and psychology to understand mind and consciousness as well as altered self-awareness phenomena. How different self concepts constitute a multidimensional sense of self is poorly understood. The intrinsic self concerns the experience of mental activity and environmental information as intrinsically related to one's own person and real-life personal context ("identity"). The extrinsic self emerges from sensorimotor interactions with the external world, like the awareness of being the source of one's own actions and consequences thereof ("agency"). Clinically, both concepts play a key role in self-experience disturbances linked with psychosis.

Aims: To test the hypothesis in a non-clinical sample that multidimensional self processing (and individual differences in its alteration) depends on the functional interactions between brain networks related to the intrinsic and extrinsic self, including the default mode network and sensorimotor networks.

Method: Functional magnetic resonance imaging (fMRI) was performed in 39 healthy adult volunteers during rest and task conditions differentiating between "self-agency" and "other-agency" (agency factor) of action consequences in "self-identity" and "other-identity" contexts (identity factor). Statistical analyses assessed: (i) Modulation of fMRI data by the identity and agency factors, particularly brain functional connectivity and neuronal network organization; (ii) Associations of behavioral/psychometric data (e.g., psychotic/schizotypal traits, sense of agency measures) with the fMRI data.

Results: Graph theoretical measures of functional connectivity patterns showed that brain modules became fragmented when self-relatedness was totally missing (in other-identity, other-agency conditions), while they formed coherent modules when at least one component of the action consequences was self-related. Moreover, individual differences in psychosis-relevant traits were associated with decreased inter-network interactions in contexts of diverging intrinsic and extrinsic self-related information.

Conclusions: The findings provide evidence that the sense of self is a multidimensional phenomenon based on integrative brain functioning through cross-network information propagation. Interactions between networks that support the maintenance of a coherent self-experience in ambiguous contexts could be diminished in individuals with high psychosis-relevant traits.

Keywords: Intrinsic self, Extrinsic self, Agency, Identity, Psychosis

Publications:

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203/16 - "Extraordinary experiences and performance on psi tasks during and after mediatation classes and retreats" – only abstract available

Researchers: Jennifer Kim Penberthy, Cassandra Vieten, Lori Derr, Arnaud Delorme, Jenny Matthews, Loraine Walter

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Duration: 2018/01 – 2020/01

Background: Anecdotal reports and some research indicate that meditation increases mindfulness and paranormal experiences of precognition, telepathy, clairvoyance, and synchronicities. There is limited knowledge about the prevalence or impact of these experiences in people who meditate and the general population. We conducted a prospective trial to collect data about these experiences and abilities from individuals who either voluntarily enlisted in a meditation course or those who did not. We collected pre and post data and explored the impact of experiences.

Aims: Aims of the study were to assess frequency and impact of self-reported mindfulness, paranormal experiences and performance on psi tasks in two groups and over time.

Method: We collected data on mystical, transcendent, or transformative experiences during or related to meditation practice and anomalous physical phenomena related to meditation, extended human capacities and difficult states of meditation practice. We collected data from tasks administered online to evaluate psi abilities. We explored the impact of such experiences or abilities upon the individuals experiencing them. We collected data securely online with IRB approval and used mixed-ANOVA to compare groups across time, and independent samples t-tests to examine post-test data.

Results: 118 completed the study (meditation intervention = 78; control = 40). Overall, those who engaged in a meditation practice (and scored higher on the mindfulness variables) endorsed higher levels of paranormal experiences. The meditation group reported higher levels of paranormal experiences (M = 1.48, SD = .18) than the control group (M = 1.81, SD = .15), p < .001 and the meditation group reported higher levels of meaning attributed to those experiences (M = 78.10, SD = 17.04) than the control group (M = 64.89, SD = 25.40), p = .002 at the end of the study.

Conclusions: The nonrandomly selected meditation group demonstrated increased mindfulness scores over time and mindfulness levels were positively associated with higher levels of reported paranormal experiences both before and after the intervention, when compared to the control group. Performance on psi tasks did not improve in either group over time and these tasks may not be sensitive enough to detect significant changes.

Keywords: Meditation, Mindfulness, Parapsychology, Psi

Publications:

Penberthy, J. P., Hodge, A. S., Hook, J. N., Delorme, A., Pehlivanova, M., & Vieten, C. (2020). Meditators and nonmeditators: a descriptive analysis over time with a focus on unusual and extraordinary experiences. *J Yoga Physiother*, *8*(3), 555744.

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207/16 - “The role of motion adaptation in bottom-up mechanisms of perceptual decision making”
Researchers: Miguel Castelo-Branco, João Duarte, Ricardo Martins, Teresa Sousa, Gabriel Costa
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Duration: 2017/11 – 2019/10

Background: Studying the human brain response to shifts in perception provides an insight on the neuronal processes which underlie perceptual decision. Visual ambiguous stimuli are a powerful tool to investigate such processes, since perception varies over time despite the physically unchanging properties of stimuli.
A classic example of an ambiguous visual stimulus is when two moving gratings are superimposed to form a plaid. The perception of a moving plaid switches back and forth between two interpretations: it can be perceived as a single surface with coherent motion or as two surfaces sliding one over the other (incoherent motion).

Aims: Our goal was to test whether that perceptual multistability arises from competition between opposing percepts, which might be influenced by mechanisms such as neuronal adaptation, inhibition, and memory. Current perceptual stability models consider bistable perception as a result of the interaction between these mechanisms, but the relative contribution of each one is still under debate.

Method - Here, using fMRI, EEG and behavioral approaches, we explore how each of these contributes to perceptual decision during bistable visual perception of moving plaids, taking into account the possible interaction between them. We hypothesized that the crucial role of adaptation in perceptual bistability arises from its influence on other mechanisms, such as perceptual persistence (a special form of short term visual memory) and inhibition.
Based on a set of three experiments, we first tested for distinct levels of adaptation during visual motion perceptual bistability. Then, we investigated how such adaptation competes with persistence to influence perceptual experience. Finally, we tested whether cross-inhibitory effects occur between bistable percepts of a moving plaid, elicited by adaptation.

Results: We found that adaptation can contribute to regulating percept duration during visual bistability, with distinct weights, depending on the type of percept. Our results provide further evidence for continuous competition between adaptation and persistence, the first leading to negative and the second to positive hysteresis, with a relevant role for perceptual experience. Finally, we demonstrated, both at the behavioral and neuronal level, that inhibition across neural populations plays a key role in the disambiguation of moving plaids.

Conclusions: Taken together, our findings add to the understanding of how the visual system achieves perceptual decisions based on interactions between low and high-level neuronal mechanisms, one based on adaptation and the second on short-term visual memory (persistence).

Keywords: Adaptation, Short-term memory, Ambiguous visual motion, Perceptual bistability, Perceptual decision, Visual motion integration, fMRI

Publication:
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217/16 - “Physiological indices of the deleterious effects of unrealistic media images on body satisfaction: A cross-cultural investigation”

Researchers: Clédna Patrícia de Oliveira-Silva, Rachel Rodgers, Óscar Gonçalves, Pedro Dias, Rosana Magalhães, Eugénia Fernandes, Bárbara Machado, Joana Coutinho, Mike Marriott
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Estimated duration: 2018/06 – 2021/12

Background: A recent initiative to improve the media environment, repeatedly criticized for conveying unrealistic appearance ideals (especially for women), is the addition of disclaimer labels on fashion images indicating that the image has some degree of digital manipulation to correct perceived physical flaws. To our knowledge, no previous studies have explored the emotional impact of short-term exposure to labeled media indexed by more objective and reliable tools such as psychophysiological measures.

Aims: This study aimed to [i] Explore the impact of two strategies aiming to decrease the deleterious effects of media on body image through psychophysiological measures across two cultures (Portugal and England); and [ii] Determine the relationship between psychophysiological reactivity and self-report on body dissatisfaction (BD).

Method: For this study, 162 Portuguese (PT) and 159 British (BR) women (18-35 years old) were randomly assigned to one of the 3 experimental conditions: (1) average-sized models without stamp; (2) average-sized models with “retouch free” stamp; and (3) thin-ideal models.

Results: The PT group presented higher levels of BD, a higher skin conductance level for the condition with average-sized models, a higher level of preference for thin-ideal models portrayed in social media (58%), and less social media consumption compared to the BR sample. The PT group also revealed not trusting the “retouch free” stamp used in media more often than the BR group. Diminished heart rate responses were found in the BR sample when participants were observing average-sized models with “retouch free” stamp, but not in PT sample.

Conclusions: Our findings showed that BD was not associated with media consumption in the PT group since Portuguese women showed higher levels of BD but lower levels of media consumption than the BR group. However, the overrepresentation of thin bodies in social media, compared to average-models, seems to be more acceptable or even desirable among the Portuguese women than the British women, as shown by self-report and the psychophysiological data. Considering that BD is a risk factor of eating disorders, especially in young women, psychophysiological approaches can help to understand better the impact of some efforts to mitigate the effects of potential deleterious media practices on women’s BD. Also, we believe our study shows that disclaimers may not moderate the deleterious effect of continuous exposure to thin body images.

Keywords: Body dissatisfaction, social media, disclaimer labels, heart rate, electrodermal.

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218/16 - "Virtual bodies, real empathy: Behavioural, bodily, and neural reactivity to the observation of pain and pleasure on self and others in immersive virtual reality"

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Duration: 2017/05 – 2020/01

Background: Empathy is the social ability that allows one to share the emotions and feelings of other individuals. It consists in a variety of components ranging from the self-centred reactivity that maps on the self what we see in others to the other-oriented stance that allows us to understand others through cognition or emotion. However, a clear comprehension of the beahvioural, physiological and the neural mechanisms underlying the observation of others' pain and pleasure is incomplete. Moreover, information about role played by the physical and congnitive perspective in affecting these mechanisms is largely unavailable.

Aims: We capitalize on the power of Virtual Reality (VR) to create a specific empathogenic scenario in order to investigate behavioural (VAS ratings), physiological (SCR, Study 1), sensorimotor (MEP, Study 2) and neural (EEG, Study 3) reactivity elicited by observation of pain and pleasure on self and others.

Method: In three different studies, participants were immersed in a virtual reality scenario and observed a virtual: needle penetrating (pain), caress (pleasure), or ball touching (neutral) the hand of an avatar seen from a first (1PP)- or a third (3PP)-person perspective.

Results: In all the studies we found: i) the observation of a virtual body in 1PP always induced a strong illusory sensation that the virtual body belongs to the observe; ii) the observation of virtual stimuli representing Pain and Pleasure induced unpleasant and pleasant sensations, respectively, that parallel with stronger sensation's intensity respect to neutral stimuli; iii) the observation of Pain resulted in increased physiological reactivity and wider amplitude of motor evoked potentials compared to observation of Neutral stimuli. This effect was found in both 1PP and 3PP conditions suggesting that similar neural networks are recruited; iv) the observation of Pain and Pleasure affected the early stage of the cortical processing resulting in a greater negative amplitude of the visual evoked potentials.

Conclusions: Overall, our paradigm opens novel ways to investigate the vicarious experience of virtual stimuli and shed new light on the body and brain reactivity to empathic mapping of pain and pleasure.

Keywords: Virtual Reality, Empathy for pain and pleasure, Transcranial magnetic stimulation (TMS), Electroencephalography (EEG), Illusory body ownership

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238/16 - "When prediction errs: Examining the brain dynamics of altered saliency in self-voice perception"

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Duration: 2017/03 – 2020/01

Background: In the last decades, a growing body of evidence has demonstrated that self-generated sensations are perceived differently from externally generated sensory input. Suppression of sensory cortical responses to self-generated stimuli allows for the "tagging" of sensations as self-generated, so that they are not confused with sensations produced by something or someone in the external environment. Critically, when we speak, we also have to monitor the emotional content of our voice. Therefore, investigating what happens when the sensory consequences of a speech act that do not match the prediction differ in emotional value is critical. However, existing studies fail to account for the effects of emotional salience in speech and how it affects prediction and prediction errors when what we hear is not what we intended.

Aims: The current study aimed to investigate the effect of change in self-voice quality on sensory feedback to self-generated and externally generated self-vocalizations.

Method: Twenty-six healthy young adults participated in the experiment. First, participants were instructed to repeatedly vocalize the syllable "ah" with neutral, angry, and pleasure intonation, imagining themselves in scenarios eliciting anger, pleasure, or no emotion. Voice samples were processed to remove background noise before morphing. These vocalizations were morphed to generate neutral-to-angry and neutral-to-pleasure continua using STRAIGHT software. This continua consisted of five stimuli ranging from fully neutral to fully emotional: 100% neutral, 60-40% neutral-emotional, 50-50% neutral-emotional and 40-60% neutral-emotional and 100% emotional. Second, they performed a standardized motor-to-auditory task to generate self-vocalizations step wise changing from fully neutral to fully emotional in quality. During the experimental task, EEG data were recorded using a 128 channel actiCHAMP active system at a digitization/sampling rate of 1000 Hz.

Results: N1 suppression was enhanced in response to changes in the self-voice that corresponded to an increase in emotional content (60/40 neutral-emotional, 50/50 neutral-emotional, 40/60 neutral-emotional).

Conclusions: These results suggest that sensory suppression varies as a function of the perceived salience of the auditory feedback that does not match the prediction. They further substantiate the intricate link between emotion and sensory prediction.

Keywords: Sensory prediction, Voice, Emotion, Event-related potentials, N1

Publications:

Pinheiro, A. P., Schwartze, M., Gutierrez, F., & Kotz, S. A. (2019). When temporal prediction errs: ERP responses to delayed action-feedback onset. *Neuropsychologia, 134*:107200. doi: 10.1016/j.neuropsychologia.2019.107200

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Pinheiro, A. P., Farinha-Fernandes, A., & Kotz, S. A. (2019). Self-voice perception and its relationship with hallucination predisposition. *Cognitive Neuropsychiatry, 24*(4), 237-255. doi: 10.1080/13546805.2019.1621159

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264/16 - "The influence of maternal bonding in neuroimmune synaptic sculpting"

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Duration: 2017/01 – 2020/09

Background: Exposure to early-life stress (ELS), such as that caused by maternal separation in the post-natal period, can induce maladaptive behaviors and increase the vulnerability to neurodevelopmental and neuropsychiatric disorders later in life. In addition to having a direct impact in neuronal function, stress can also trigger neuroinflammatory events that impact microglia activity.

Aims: With this work, we aim to elucidate how ELS contributes to microglia dysfunction and interferes with key microglia features, such as neurogenesis, synaptogenesis synaptic pruning and neuronal elimination, which occur during the first post-natal weeks and which are crucial for correct circuit wiring.

Method: Towards this purpose, we have used a paradigm of maternal separation and maternal stress (MSUS), that allows to mimic early life adversity in the form of maternal neglect, allowing to study the behavior consequences of ELS, as well as its impact on microglia number, morphology and gene expression profile. We have focused our evaluation in the medial pre-frontal cortex (mPFC), a brain region highly implicated in social behaviors and impulse control, which presents a delayed maturation profile and, thus, is more susceptible to stress exposure during the post-natal period.

Results: We have observed that exposure to MSUS causes changes in social interaction and impulsivity, as well as an increase in submissive behaviors in male mice, but no significant behavior changes in females. Exposure to ELS also leads to morphological and gene expression changes in male microglia that are compatible with activation towards a classical M1-like activation phenotype during the early life period and that are only partly reversed during the juvenile period. Juvenile male mice exposed to MSUS also present changes in myelination-related genes, an increase in the number of PV+ inhibitory neurons in the mPFC, as well as deficits in social interaction and a tendency to display increased anxiety, while female MSUS mice appear to be less susceptible to ELS-driven changes, despite showing early changes in microglia morphology and gene expression.

Conclusions: Taken together, ours results point towards a higher susceptibility of male mice to the negative impacts of ELS exposure. This feature may be directly connected with the different and stronger response of male microglia to this type of stress.
Keywords: Microglia, Early life stress, Neuroinflammation, Maternal neglect

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266/16 - "Early life stress and social hierarchies: The role of cortico-straital circuits"

Researchers: João Peça, Joana Guedes, Ana Luísa Cardoso, Mohammed Hussien, Lara Franco, Mário Carvalho
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Duration: 2017/01 – 2021/01

Background: Stressful experiences during the early life period have a critical impact in brain circuits and behaviors that persist into adulthood and may increase the risk to develop maladaptive behaviors and neuropsychiatric disorders later in life.

Aims: The major aims of this study were: 1) to understand the impact of exposure to early-life stress in social interactions and social hierarchy in adult animals and 2) to identify cellular and molecular correlates of stress-related behavior changes in the medial prefrontal cortex (mPFC).

Method: Towards these goals, and in order to mimic an environment of maternal neglect, we employed a maternal separation and unpredictable stress (MSUS) paradigm, in which mouse pups were separated daily from their dams for a 3h period, between P2 and P14, while the dams were subjected to one of two stress protocols: forced swimming or restrain.

Results: Using this paradigm, we observe that early life stress (ELS) induced a submissive phenotype in male animals inserted into a social hierarchy. These animals also displayed alterations in social recognition and foraging behavior. At the circuit level, ELS mice displayed dendritic atrophy in pyramidal neurons from layer II/III of the medial prefrontal cortex and enhanced inhibitory synaptic currents. Using RNA-seq, we identified a set of genes with altered expression in the mPFC of stressed animals. From these, our findings demonstrate that the synaptic NPY receptor 1 (NPY1R) is a marker for social subordinance both in ELS animals and in lower ranked wildtype mice.

Conclusions: These data illustrate the consequences of traumatic maternal separation and provide mechanistic insight into the behavioral and molecular adaptation animals undergo in the face of adverse rearing conditions. More broadly, the adaptive behavioral strategy in animals subjected to adverse rearing conditions implicstes NPY1r in dominance social behaviors, identifying this receptor and inhibitory synaptic activity as targets to better understand chronic stress and the deleterious effects of persistent social subordination.

Keywords: Social subordination, Social hierarchy, Early life stress, mPFC; NPY1r

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281/16 - "Motor imagery in speech processing"
Researchers: Patricia Martine Adank, Helen Nuttall, Gwijde Maegherman
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Duration: 2018/01 – 2020/04

Background: The grant aimed to elucidate the neural network supporting motor imagery in speech production. We will specifically focus on the roles of primary motor cortex and supplementary motor area in motor imagery of articulation of syllable sequences. Motor imagery is thought to involve motor cortex activation without effecting muscle movement. Research in this area focuses primarily on hand actions in the context of rehabilitation. However, people also regularly engage in other types of imagery, such as speech imagery, yet this orofacial imagery has not received as much attention, though it may play a critical role in speech development, disorders, and rehabilitation.

Aims: In this study, we investigated the activation of lip and hand motor cortex by testing whether motor-evoked potentials (MEPs) of lip motor cortex are facilitated during motor imagery of simple tasks and sub-phonemic speech. This finding would implicate the involvement of motor cortex in the process of not only motor execution, but also motor imagery of speech.

Method: Twenty participants were asked to execute or imagine performing a simple squeezing task involving a pair of tweezers, which was comparable across both effectors. MEPs were elicited at six time points (50, 150, 250, 350, 450, 550 ms post-stimulus) to track the time course of M1 involvement in both tasks. Electromyography was conducted throughout the experiment and participants underwent 18 blocks of 25 trials, accounting for 30 trials per timepoint, per prompt. The experiment lasted 2 hours.

Results: The results showed increased MEP amplitudes for action execution compared to baseline for both effectors at time points 350, 450 and 550ms. However, we found no evidence of increased cortical facilitation during motor imagery of the same task compared to baseline for the hand or lip results.

Conclusions: The results indicate that motor imagery does not involve M1 for simple tasks for manual or articulatory muscles, contrary to previous literature and our expectations. The results have implications for models of motor imagery of simple gestures, articulatory or otherwise, in that no evidence is found for somatotopic activation of lip and hand muscles in sub-phonemic contexts during motor imagery of such tasks, suggesting that motor simulation of relatively simple actions does not involve M1. We are now examining the role of M1 in more complex speech actions, such as complex consonant clusters.

Keywords: Motor imagery, TMS, MEP, Speech imagery

Publications:
Maegherman, G. G., Nuttall, H. E., Devlin, J. T., & Adank, P. (2019). Motor imagery of speech: the involvement of primary motor cortex in manual and articulatory motor imagery. *Frontiers in Human Neuroscience*, *13*, 195.

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286/16 - “Getting the aging brain to train: A working memory and neurostimulation approach”
Researchers: Adriana Sampaio, Ana C. Teixeira Santos, Sandra Carvalho, Jorge Leite, Ana Raquel Mesquita, Felipe Fregni
Institution: Psychology Research Center (CIPsi), School of Psychology, University of Minho, Braga (Portugal); Spaulding-Labuschange Neuromodulation Center, Spaulding Rehabilitation Hospital & Massachusetts General Hospital/Harvard Medical School, Charlestown (USA)
Estimated duration: 2017/06 – 2022/05

Background: Working memory training (WMT) has been proposed as a tool to enhance working memory (WM). However, there is limited evidence of transfer effects to other cognitive domains. Transcranial direct current stimulation (tDCS) has been suggested to enhance cognitive gains when coupled with cognitive training. Nevertheless, few studies have explored the synergetic effects of WMT coupled with tDCS in older adults.

Aims: To assess the effects of 5-days WMT coupled with tDCS on near- (Digit Span) and far- (Raven Advanced Progressive Matrices - RAPM) transfer tasks.

Method: 54 healthy old adults (M_{age} = 68.6; 32 females) were randomly assigned to one of three groups: 1) WMT (dual n-back task) + atDCS (anodal, 2 mA; 20min; placed over left dorsolateral prefrontal cortex); 2) WMT + sham tDCS; 3) double-placebo. Assessments were carried out at baseline; post-training; and at a 15 days follow-up.

Results: The analyses showed that only atDCS+WMT group displayed a significant improvement in reasoning (RAPM) at post training and follow-up and in short-term memory (forward digit span) at follow-up. Those results are in line with studies performed in the context of this project. First, our meta-analysis showed small significant and long-lasting near transfer effects of WMT. Additionally, by conducting a systematic review, we suggested that tDCS may modulate WM in older adults boosting their cognitive processes.

Conclusions: tDCS boosted WMT effects producing near and far transfer (to short-term memory and reasoning), which is observed especially at follow-up assessment.

Keywords: Working memory training, aging, tDCS

Publications:
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Teixeira-Santos, A. C., Pinal, D., Pereira, D. R., Leite, J., Carvalho, S., & Sampaio, A. (2020). Probing the relationship between late endogenous ERP components with fluid intelligence in healthy older adults. *Scientific Reports*, *10*, 11167. https://doi.org/10.1038/s41598-020-67924-4

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298/16 - “Empowering feedback connections in temporo-occipital network to boost visual perception of emotions” – only abstract available

Researchers: Sara Borgomaneri, Marco Zanon, Alessio Avenanti, Caterina Bertini

Institution: Center for studies and research in Cognitive Neuroscience, Department of Psychology, University of Bologna, Cesena (Italy)

Duration: 2017/09 – 2019/10

Background: Social life crucially depends on the ability to efficiently process emotional signals from other people. Yet, the cortical neural mechanisms underlying emotion recognition are still poorly understood. In study 1, we tested the hypothesis that reentrant connections from temporal (Superior Temporal Sulcus; STS) to visual cortices (V1) may play a critical role in emotional expression discrimination.

Aims: The ambitious aim of the present project is to shed new lights on the way the human visual system makes humans aware of emotional stimuli and as, ultimate goal, by improving its functioning, enhance visual emotion discrimination abilities.

Method: Using a novel Transcranial Magnetic Stimulation protocol, we transiently enhanced synaptic efficiency in the reentrant connections from STS to V1 and we tested facial emotion discrimination performances and possible neurophysiological changes (i.e., modulations in the visual evoked potentials recorded by electroencephalography).

Results: We found that boosting the STS-V1 connectivity enhances emotion discrimination abilities as well as modulates the amplitude of early visual components involved in emotional face perception or in cognitive performances.

Conclusions: We provide novel causal evidence that STS-to-V1 back-projections, are malleable and functionally relevant to emotion recognition. These findings have implications for theoretical models of visual perception and awareness and for the rehabilitation of visual deficits.

Keywords: Emotion discrimination, Transcranial magnetic stimulation, Feedback connections, Visual evoked potentials, Electroencephalography.

Publications:

Paracampo R, Montemurro M, de Vega M & Avenanti A (2018). Primary motor cortex crucial for action prediction: A tDCS study. *Cortex. 109*:287-302. doi: 10.1016/j.cortex.2018.09.019

Fiori F, Chiappini E & Avenanti A (2018). Enhanced action performance following TMS manipulation of associative plasticity in ventral premotor-motor pathway. *NeuroImage, 183*: 847-858. doi.org/10.1016/j.neuroimage.2018.09.002

Zanon M, Borgomaneri S & Avenanti A (2018). Action-related dynamic changes in inferior frontal cortex effective connectivity: a TMS/EEG coregistration study. *Cortex, 108*:193-209. doi: 10.1016/j.cortex.2018.08.004

Gallo S, Paracampo R, Müller-Pinzler L, Severo MC, Blömer L, Fernandes-Henriques C, Henschel A, Lammes BK, Maskaljunas T, Suttrup J, Avenanti A, Keysers C & Gazzola V (2018). The causal role of the somatosensory cortex in prosocial behaviour. *Elife, 7*. pii: e32740. doi: 10.7554/eLife.32740

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Bertossi E, Peccenini L, Solmi A, Avenanti A & Ciaramelli E (2017). Transcranial direct current stimulation of the medial prefrontal cortex dampens mind-wandering in men. *Scientific Reports, 7*:16962. doi: 10.1038/s41598-017-17267-4

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312/16 - "Mind-body interactions in writing (M-BW): Psychophysiological and linguistic synchronous correlates of expressive writing"

Researchers: Rui Alves, Teresa Limpo, Sara Costa, Ana Sousa, Mónica Moreira, José Leal, Teresa Jacques

Institution: Neurocognition and Language Research Group, Faculty of Psychology and Education Sciences of the University of Porto (Portugal); Faculty of Sciences of the University of Porto (Portugal)

Duration: 2017/04 – 2020/09

Background: The bodily manifestations of the mind while writing have barely been studied. Expressive writing is a particular form of writing in which a person narrates a personal deeply charged emotional event, typically a major trauma. Expressive writing has been associated with a considerable number of health benefits. These positive benefits might be due to an opportunity for increased emotion regulation during expressive writing.

Aims: In the two empirical studies of the M-BW project, we sought to explore emotion regulation during expressive writing as reflected on electrodermal activity (EDA), heart rate variability (HRV), handwriting activity and emotional vocabulary usage.

Method: Following the procedure aproved by the Ethics Committee of the University of Porto, participants were recruited from undergraduate psychology classes. In each experiment, participants were randomly assigned to one of two groups, the expressive writing group or the control group. Participants replied to several questionnaires and critically completed a writing task that was logged with HandSpy (Alves et al., 2019), while EDA and ECG were also recorded.

Results: Relative to the control group, the participants in the expressive group showed increased SNS activation during and after writing, as measured by HRV. As expected, both groups showed increased SNS and PNS activation from baseline. Interestingly, expressive writing participants paused for longer than the control group. Moreover, the longer the pauses, the higher the overall and PNS mediated HRV, and the lower the SNS activation after the writing exercise.

Conclusions: Both ANS and handwriting activity results suggest that mechanisms of emotional regulation seem active during expressive writing. Content analyses of the expressive texts showed that most participants seem to be using written language as a way to reappraise the traumatic event. These findings are a step forward in the study of expressive writing as a useful exercise for improving physical and psychological well-being.

Keywords: Emotional regulation, Expressive writing, Handwriting, Electrodermal activity, Heart rate variability

Publications:

Alves, R. A., Leal, J. P., & Limpo, T. (2019). Using HandSpy to study writing in real time: A comparison between low- and high-quality texts in grade 2. In E. Lindgren and K. P. H. Sullivan (Eds.), *Insights from Keystroke Logging and Handwriting* (pp. 50-70). Leiden: Brill.

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329/16 - “Exploring the correlates and nature of subjective apparitional experiences”
Researchers: Christine Simmonds-Moore, Donadrian Rice, Chase O’Gwin
Institution: Psychology Department, University of West Georgia, Carrolton (USA)
Duration: 2018/04 – 2020/06

Background: Prior research indicates that Transliminality, boundary thinness, hyperaesthesia, somatic tendencies and synesthesia are associated with apparitional experiences.

Aims: To explore frequencies of differently appraised ghost experiences in addition to the senses and spatial locations involved; to compare ghost experiences between synesthetes and non synesthetes; to explore the psychometric predictors of ghost experiences; to analyse ghost experiences using grounded theory; to explore how synesthesia, GMF, emf, heart rate variability, and the output of a random number generator (RNG) relate to exceptional experiences in the context of a psychomanteum.

Method: An online survey explored the correlates of ghost experiences. ExE were explored using a psychomanteum procedure.

Results: Synesthetes reported more ghost experiences with a paranormal appraisal. Boundaries, creativity, interoception and somatic focus correlated with ghost experiences with a paranormal appraisal. Transliminality was the strongest independent predictor. GMF and local emf influenced heart rate variability. GMF correlated with the extent to which experiences took up space. RNG output correlated with the extent to which ExE were rated as taking up space. Post hoc analysis indicates that this was for synesthetes only.

Conclusions: Synesthesia, creativity, boundaries and awareness of the body play a role in ghost experiences. The psychomanteum findings are suggestive of interactions between subjective experience and the local and non-local environment, particularly among synesthetes.

Keywords: Synesthesia, Boundaries, Interoception, Psychomanteum, RNG output

Publications:
Simmonds-Moore, C. O’Gwin, C. & Fountain, L. (2019). *A Grounded Theory of Ghost experiences.* Paper presented at the 2019 PA convention, Paris, France.
Simmonds-Moore, C. O’Gwin, C. & Steder, M. (2019). *Using a psychomanteum to explore the nature and correlates of subjective apparitional experiences.* Research brief presented at the 2019 PA convention, Paris, France. [Manuscript also under development for submission to the Journal of Parapsychology].

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346/16 - “The mind possessed project: Mapping the varieties of possession experiences”
Researchers: Miguel Farias, Romara Delmonte
Institution: Centre for Research in Psychology, Behaviour and Achievement, Coventry University (UK)
Estimated duration: 2017/12 – 2021/04

Background: Possession states are poorly understood and there is conflicting evidence about its potential mental health outcomes.

Aims: We conducted two studies to investigate the varieties of possession experiences and assess the psychological characteristics of individuals who regularly experience such possession states.

Method: Study 1 used a set of personality, cognitive, and mental health measures to compare religious participants who regularly experience possession with ritual attendants who have never experienced possession. Study 2 collected possession narratives from Afro-Brazilian and Christian Pentecostal religions.

Results: In study 1 we found that mediums were not significantly different across variables from the control group. Correlational and regression analysis showed that the level of meaningfulness attributed to possession and fusion with the spiritual entity were strongly correlated with most Quality of Life dimensions and negatively with anxiety. Contrary to expectations, there were no detrimental effects of a lower level of bodily control over the possession experience. Study 2 showed that possession experiences are associated with a wide variety of emotional and cognitive characteristics and that there are wide significant phenomenological differences associated with the religious context.

Conclusions: Together our results suggest that individuals regularly experiencing possession within an Afro-Brazilian religious context are psychologically very similar to others who never experienced the same phenomenon, and that the way they appraise their experiences as meaningful, as well as the level of spiritual fusion, are predictors of wellbeing. This project calls into question both the psychological work linking possession with poor mental health outcomes and the understanding of possession as a phenomenon with universal characteristics.

Keywords: Possession, Wellbeing, Quality of Life, Phenomenology

Publications:
The Mind Possessed short film: https://vimeo.com/430303432

Under review: Delmonte, R., Farias, M., Bastos, M., Madeira, L., & Sonego, B.
The Mind Possessed: Wellbeing, Personality, and Cognitive Characteristics of Individuals Regularly Experiencing Religious Possession

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2018

02/18 - "Neurobiological effects of Lourdes water: An fMRI study" - only abstract available
Researchers: Anne Schienle, Albert Wabnegger
Institution: Clinical Psychology, University of Graz (Austria)
Duration: 2019/01 – 2021/09

Background: It has been shown that religious beliefs and practices are associated with resting-state functional connectivity (rsFC) in the default-mode network.

Aims: We studied the association between a specific religious belief (miracle cures at Lourdes, a major Catholic pilgrimage site) and rsFC in three large-scale functional brain networks (default-mode, salience, control). The study had a placebo-centered approach.

Method: A total of 37 females with the belief that water from the sanctuary in Lourdes has positive effects on their well-being and health participated in a placebo study with a retest design. Before a 15-minute resting-state scan, they drank tap water that was labeled 'Lourdes water' in one condition and 'tap water' in another condition.

Results: 'Lourdes water' reduced rsFC in the frontoparietal control network and increased rsFC in the salience network (insular-cerebellar connectivity). This was accompanied by an increased intensity of bodily sensations (e.g. feelings of warmth, tingling) and positive feelings (e.g., gratefulness).

Conclusions: These findings provide the first evidence that specific religious beliefs can alter large-scale functional networks.

Keywords: Religious belief, Placebo, Functional magnetic resonance imaging, Resting state

Publications:
Schienle et al. (2021). Believing in miracles: a resting-state functional connectivity study on placebo effects. *Frontiers in Behavioral Neuroscience, 15*:653359

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13/18 - "Biological bases of music cognition" - only abstract available

Researchers: Juan Manuel Toro, Paola Crespo-Bojorque, Alexandre Celma-Miralles, Carlota Pagés
Institution: Center for Brain and Cognition, University Pompeu Fabra, Barcelona (Spain)
Duration: 2019/03 – 2021/10

Background: In western music, harmonic expectations can be fulfilled or broken by unexpected chords. Musical irregularities in the absence of auditory deviance elicit well-studied neural responses (e.g. ERAN, P3, N5). These responses are sensitive to schematic expectations (induced by syntactic rules of chord succession) and veridical expectations about predictability (induced by experimental regularities). However, the cognitive and sensory contributions to these responses and their plasticity as a result of musical training remains under debate.

Aims: To explore whether the neural processing of pure acoustic violations is affected by syntactic rules of chord succession and by experimentally-induced expectations. More specifically, we investigate whether the neural responses to dissonance change as a function of the position that the chords occupy in a harmonic sequence (Experiment 1). Second, we study whether these responses are modulated by the predictability of dissonant endings (Experiment 2). Crucially, we investigated whether these two factors interact with long-term musical training.

Method: We registered event-related potentials (ERPs) in both musicians and non-musicians while listening to 5-chord harmonic sequences. In Experiment 1, we compared the ERPs elicited by dissonant clusters placed either at the middle or the ending position of the cadences. In Experiment 2, we presented to the listeners with a high proportion of cadences ending in a dissonant chord. In both experiments, we compared the ERPs of musicians and non-musicians.

Results: At early time windows, we observed that dissonance is processed based on acoustic deviance independently of syntactic rules. At longer latencies, listeners may be able to engage integration mechanisms, which are enhanced in musicians. Musicians showed larger responses related to the detection of dissonance (EN) and the attraction of attention (P3a), suggesting that dissonance in a musical context are more surprising for musicians. At late latencies, the neural responses of musicians reflective of attention allocation (P3a) and model-updating (P3b) were indeed influenced by syntactic (but not experimental) regularities.

Conclusions: Our results show that, at early latencies, acoustic deviance may be processed independently of schematic and veridical expectations. They also show that musical training modulates the neural responses to unexpected dissonance by enhancing and refining them.

Keywords: Harmonic expectations, Musical training, Dissonance, Music cognition

Publications:

Pagès-Portabella, C., Bertolo, M. & Toro, J.M. (2021). Neural correlates of acoustic dissonance in music: The role of musicianship, schematic and veridical expectations. *PLoS ONE, 16,* e0260728.

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16/18 - "The psychology and parapsychology of spiritual emergency" - only abstract available
Researchers: Lance Storm, Monika Goretzki
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Duration: 2019/06 – 2021/09

Background: A defining aspect of Spiritual Emergency (SE) is 'psychic opening', characterized as psychic ability. SE may include psychic opening, which means individuals who had or were having experiences of Spiritual Emergency (i.e., 'SE-experients') may perform well on psi tests. SE is related to psychosis, but not the psychosis-related symptoms, alogia (poverty of speech), depression, anxiety, and stress, which may all be psi-inhibitive.

Aims: This study aimed to assess the psychological and parapsychological aspects of spiritual emergency and differentiate it from psychosis. Psi performance of SE-experients were compared with controls. The study also assessed psychological aspects of SE to differentiate it from psychosis and other proposed psi-inhibitive symptoms (alogia, depression, anxiety, and stress).

Method: Two groups of participants were formed: SE-experients and Controls (mainly psychology students). Participants either completed the study on a computer in the laboratory or online. Questionnaires on SE (which includes a subscale on Psychic Opening), positive symptoms of psychosis, alogia, spiritual identity, paranormal belief, mysticism, depression, anxiety, and stress, were administered to participants, who then completed a psi task—the Imagery Cultivation picture-identification psi task, which uses a shamanic-like journeying protocol (Storm & Rock, 2009a, 2009b).

Results: The differences between controls and SE-experients on the psi measures, Direct Hitting (as a percent hit-rate) and Mean Rank Scores, were not significant, but the Sum-of-Ranks difference was highly significant. Also, SE-experients had a marginally significant Mean Rank Score. Direct Hitting did not correlate significantly with any variable, except Rank Scores, which correlated significantly with Psychic Opening, spiritual identity, and paranormal belief, and marginally significantly with Spiritual Emergency. As expected, Direct Hitting, Rank Scores, and SE did not correlate significantly with alogia, depression, anxiety, or stress, but the psychosis measure did correlate significantly with alogia, depression, anxiety, stress, and SE.

Conclusions: The statistical evidence suggests that some proportion of SE-experients experience Psychic Opening. While SE and psychosis overlap, only SE was predicted by spiritual identity, extrovertive mysticism, and paranormal belief (but not alogia), whereas psychosis was predicted by alogia only.

Keywords: Imagery cultivation, Psychic ability, Psychosis, Sheep-goat effect, Spiritual emergency

Publications:
Storm, L., & Goretzki, M. (2021). The psychology and parapsychology of spiritual emergency. *Journal of Scientific Exploration*, *35*(1), 36-64.

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29/18 - “Mind-matter practical applications” - only abstract available
Researchers: Patrizio Tressoldi, Luciano Pederzoli, Marco Bilucaglia
Institution: EvanLab, Firenze (Italy); Dipartimento di Psicologia Generale, Università di Padova (Italy)
Duration: 2019/01 – 2021/05

Background: This project is based mainly on the hypothesis that the human mind can interact with electronic targets at a distance, that is, not through conventional means and without spatial and temporal constraints.

Aims: This project aims at demonstrating the feasibility of practical applications for portable devices based on the mind-matter interaction at a distance with random event generators and digital photographic camera sensors.

Method: The first protocol, pre-registered at https://osf.io/3g95p, requires mentally influencing true RNGs' normal functioning in order to achieve a predefined level of non-randomness (reduced entropy) within a predefined time window. The level of reduced randomness was analyzed by applying two tests of NIST statistical test suite (Rukhin et al. 2010) for testing random strings. The software is available open access at: https://github.com/tressoldi/MindSwitch
Participants: thirteen participants contributed to 100 trials
The second protocol is based on the mental influence on the memory cells forming the image-sensor of a digital photo camera: indeed each single cell forming a pixel of an image sensor requires little energy to change its level of charge, and then of the voltage controlling its output signal. The software is available open access at: https://github.com/mbilucaglia/PsyCam
Three male adults, with previous experience in mind-matter experiments, contributed to 50 trials overall.

Results: The raw data related to the first protocol are available open access at: https://figshare.com/articles/dataset/MindSwitch/8160269 .
With respect to the confirmatory hypotheses, the only dependent variable that seems influenced by the mental interaction is the detection of reduced randomness by both the Frequency Test and the Runs Test within the same sample of data. The raw data related to the second protocol, are available at: https://figshare.com/articles/dataset/Thoughtography/12151932 . The Structural Similarity Index (SSIM) of the target images was greater with respect to the control ones in 6 out of 49 trials (12.2%).

Conclusions: The results of these experiments represent a proof-of-concept of the possibility of both creating electronic devices that can be mentally controlled from a distance and imprinting predetermined images on digital sensors of professional photo cameras affecting their contrast parameters and structural similarity indices, opening the way to a new generation of mind-matter practical applications. An ongoing development of this technology is the use of modern video recorders instead of photo cameras, which allow the possibility to see how images are formed.

Keywords: Mind-matter; Digital sensors; Random-number-generator; Electronic devices.

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50/18 - “Changes in the temporal witdth of the present moment after meditation”

Researchers: Marc Wittmann, Stefan Schmidt, Karin Maissner, Damisela Linares Gutiérrez
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Estimated duration: 2019/07 – 2021/08

Background: In meditation the three state dimensions of awareness, affect and time can reach extreme levels leading to changes in the sense of self.

Aims: This study examines the effects of meditative states in experienced meditators on the present moment awareness, subjective time and the awareness of the self while exploring its relationship with meditation-induced physiological changes.

Method: Following a within-subject design, a sample of long-term mindfulness meditation practitioners was recruited (n=22; on average 19.5 years of practice; a mean of 3.95 meditation sessions per week over the last two months). Participants accomplished a metronome task, as an operationalization of the present moment awareness, before and after 20-minutes meditation session and a 20-minutes reading session. Electrocardiogram and respiratory activity were recorded during both sessions. Self-report scales related to subjective time and to the awareness of the self were filled in after both conditions.

Results: Concerning physiological indices, there was a mixed pattern of more sympathetic and parasympathetic activity during meditation: breathing intervals were prolonged during meditation; heart-rate variability parameters had higher α-1 and lower α-2 levels in the meditation condition. There were lower levels of ApEn and SampEn, measures of HRV complexity, during meditation. In the metronome task no significant differences between conditions became apparent. Regarding subjective states, participants perceived their body boundaries as less salient during meditation than while reading the story; they also felt time as passing more quickly and they had less attention to time during meditation.

Conclusions: Meditation led to several changes in physiological parameters and subjective experience, i.e. less pronounced body boundaries and less awareness of time but no changes in the accentuation of metronome beats. This is probably the first quantitative study to show how the experience of the duration of the meditation session is altered in relation to the bodily self.

Keywords: Time perception, Sense of self, Present-moment awareness, Meditation

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72/18 - “Temperamental influences on social cognition under stress” – only abstract available
Researchers: Frederike Beyer, Ulrike Krämer
Institution: Psychology Department, School of Biological and Chemical Sciences, Queen Mary University of London (UK); Departement of Neurology, University of Lubeck (Germany)
Duration: 2019/02 – 2021/09

Background: While humans have extraordinary skills of understanding the mental states of others, significant individual differences in social cognition exist. Previous work and theoretical frameworks suggest a link between low-reactive, low-anxious temperamental traits and better development of social cognition. However, evidence for this link in humans is scarce to date.

Aims: This project aimed at assessing the link between emotional reactivity and social cognition in human participants, particularly focusing on the impact of stress on social perspective taking.

Method: Participants completed a reaction-time task designed to measure automatic perspective taking, combined with a mental arithmetic stress task, and a non-stressful control task. One group of participants additionally underwent functional magnetic resonance imaging to measure brain activity, while completing the tasks. As measure of emotional regulation, we measured heart-rate variability (HRV) at rest. Current levels of physical exercise were also measured, as known moderator of stress regulation.

Results: In the main behavioural study, participants engaging in regular physical exercise showed higher perspective taking under stress, compared to participants low in physical exercise. We also observed a negative relationship between resting HRV and the impact of stress on perspective taking. Contrarily, in the brain imaging environment, no perspective taking was observed, behaviourally or at the neural level.

Conclusions: The findings regarding HRV suggest that good physiological regulation can support perspective taking under stress. Regular physical exercise emerged as an important variable in participants’ ability to maintain social perspective taking in situations of high stress. Potentially, improved physiological regulation due to exercise improves social cognition in challenging situations. Yet, perspective taking as measured with this task seems easily interrupted by highly demanding environments such as being in the MRI scanner, or by the dual-task nature for the MRI study setup.

Keywords: Social cognition, Exercise, Stress, Perspective taking, Emotion regulation

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82/18 - "Neuropsychological and cognitive-perceptual characteristics of mediums and psychics"
Researchers: Ken Drinkwater
Institution: Health, Psychology and Communities, Manchester Metropolitan University (UK)
Estimated duration: 2019/09 – 2021/09

Background: Mediums/psychics are individuals who claim to communication with discarnate spiritual entities. Historically, the study of mediumship is important because it has influenced the development of psychological and parapsychological concepts. Although healthy/well-adjusted subjects often report supernatural experiences, previous research indicates that experiencers differ in subtle cognitive/perceptual ways. Accordingly, this three-phase project examined whether individuals with self-professed paranormal ability possess a unique psychological profile.

Aims, Method & Results: PHASE 1 Identified neuro/psychological differences as a function of level of self-ascribed paranormal ability. This method was important because it revealed characteristics typically found in anomalistic experiencers. Specifically, it compared three groups differing in personal ascription of paranormal powers: no ability, self-professed ability, and paranormal practitioners (i.e., Mediums, Psychics, Spiritualists, and Fortune-Tellers). A sample of 917 respondents (329 males, 588 females) completed online self-report measures. Multivariate analysis of variance (MANOVA) revealed an overall main effect. Discriminant analysis indicated that paranormal practitioners scored higher on proneness to reality testing deficits, paranormal belief, and emotion-based reasoning. Findings revealed subclinical delusion formation and thinking style varied as a function of self-professed paranormal ability and were congruent with preceding research.
PHASE 2 This study investigated relationships between inter-class variations in paranormal experience and executive functions of mediums/psychics, experiencers & normal population. A sample of 516 adults completed self-report measures assessing personal encounter-based paranormal occurrences (i.e., Experience, Practitioner Visiting, & Ability), executive functions (i.e., General executive function, Working and Everyday Memory, Decision Making, and Emotion Regulation), and Belief in the Paranormal. Latent profile analysis (LPA) combined experience-based indices into four classes, whilst multivariate analysis of variance (MANOVA) then examined interclass differences. Results revealed breadth of paranormal experience was associated with higher levels of executive functioning difficulties for General Executive Function, Working Memory, Decision Making, and Paranormal Belief.
PHASE 3 This study examined personal perceptions (involvements) and comprehensions (interpretations) of self-ascribed paranormal abilities across 12 semi-structured interviews. Analysis revealed that self-ascription is a complex/sophisticated process. Interviewees narrated rich and detailed accounts that made sense of declared capabilities. They contextualised, rationalised, and provided evidence to support claims.

Keywords: Self-professed paranormal abilities, Cognitive/executive functions, Latent profile analysis, Emotion-based reasoning; Semi-structured interviews

Publications:

Drinkwater, K. G., Dagnall, N., Denovan, A., Parker, A., & Escolà-Gascón, A. Paranormal experience profiles and their association with variations in executive functions: A latent profile analysis. *Frontiers in Psychology - Psychopathology*, Submitted on: 16 Sep 2021 (Awaiting Publication 2022).
Drinkwater, K. G., Dagnall, N., Walsh, S., Sproson, L., Peverell, M., & Denovan, A. Self-ascribed paranormal ability: Reflexive thematic analysis. *Frontiers in Psychology - Consciousness* Research, Submitted on: 29 Dec 2021 (Awaiting Review 2022)
Drinkwater, K. G., Dagnall, N., Denovan, A., & Parker, A. (2021). Executive Functioning: Assessing the Role of Perceived Paranormal Ability. *Frontiers in Psychology, 12*, 60-93. doi: 10.3389/fpsyg.2021.798283
Drinkwater, K. G., Dagnall, N., Denovan, A., & Williams, C. (2021). Differences in cognitive-perceptual factors arising from variations in self-professed paranormal ability. *Frontiers in Psychology, 12*, 22-58. doi: 10.3389/fpsyg.2021.681520
Drinkwater, K. G., Dagnall, N., Denovan, A., & Williams, C. (2021). Paranormal belief, thinking style and delusion formation: A latent profile analysis of within-individual variations in experience-based paranormal facets. *Frontiers in Psychology, 12*. 25-53. doi: 10.3389/fpsyg.2021.670959

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93/18 - "Meditation-induced neuroplasticity of the embodied self and its role in social processing" – only abstract available

Researchers: Aviva Berkovich-Ohana
Institution: The Edmond J. Safra Brain Research Center, university of Haifa (Israel); Gonda Multidisciplinary Brain Research Center, Bar-Ilan University (Israel)
Duration: 2019/02 – 2021/09

Background: The embodied sense of self is usually understood as a basic feature of consciousness and involves a sense of agency, ownership and 1st person perspective. Currently, there is no consensus if states of consciousness devoid of such features are possible at all, let alone their potential benefits. Previous research indicates that deep meditative states might be a suitable candidate to investigate these questions.

Aims: The aims of the currents study were: a) to map the neurophenomenology of malleability of the embodied self in meditation b) to study the relationship between meditation, embodied self-flexibility and social processing.

Method: Forty-six long-term meditators underwent a 3-weeks meditative training of embodied-self flexibility. Subsequently, they underwent a lab session including magnetoencephalography (MEG) measurement during rest, meditative states of dissolved and meditative states of maintained self-boundaries. In a second lab session, meditators as well as a group of matched controls completed a series of social processing tasks measuring facial emotion recognition, behavioral response bias to the self, implicit ingroup bias and empathy.

Results: SB dissolution states were characterized by changes in six experiential features including the sense of location, agency, first-person perspective, attention, body sensations and affective valence, as well employed meditative technique and overall degree of dissolution. Quantitative analyses of these features highlighted a unitary dimension of boundary dissolution. Notably, passive meditative gestures of "letting go", reducing attentional engagement and agency, drove the depth of dissolution. Neurophysiologically, boundary dissolution was characterized by broadband decreases in oscillatory power, which peaked in a high beta range and were localized to medial and parietal regions. These reductions were more pronounced in phenomenologically deeper states of dissolution. Preliminary analyses of behavioral data indicated differences between the meditation group and controls in emotion recognition, self-bias and ingroup bias. In future analyses these effects will be related to neural and phenomenological dissolution measures.

Conclusions: The results demonstrate that states of strongly diminished embodied self-experience can be produced reliably in meditation, and that suspension of active attentional engagement is a key process in such states, mirrored by reductions in parietal beta power.

Keywords: Self, Meditation, Magnetoencephalography, Neurophenomenology.

Publications:

Berkovich-Ohana, A., Dor-Ziderman, Y. Trautwein, F-M., Schweitzer, Y., Fulder, S., Nave, O., & Ataria, Y. (2020). The hitchhiker's guide to neurophenomenology - Examples from studying self-boundaries with meditators. *Frontiers in Psychology – Consciousness Studies*, 1-19, (Special issue: Integrating Philosophical and Scientific Approaches in Consciousness Research). https://doi.org/10.3389/fpsyg.2020.01680

Nave, O., Trautwein, F.-M., Ataria, Y., Dor-Ziderman, Y., Schweitzer, Y., Fulder, S. & Berkovich-Ohana, A. (2021). *Self-Boundary Dissolution in Meditation: A Phenomenological Investigation. Brain Research*, 11(6), 819; https://doi.org/10.3390/brainsci11060819.

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101/18 - "Hypnosis and cognition: Neural basis of hypnotic suggestion on executive functions and percpetual awareness" – only abstract available
Researchers: Rinaldo Livio Perri, Francesco Di Russo, Enrico Facco
Institution: Faculty of Psychology, University Niccolò Cusano, Rome (Italy); Cognitive Neuroscience of Action lab, University Foro Italico, Rome (Italy)
Duration: 2019/03 – 2021/09

Background: Compelling literature has suggested the possibility of adopting hypnotic suggestions to override the Stroop interference effect. However, most of these studies mainly reported behavioral data and were conducted on highly hypnotizable individuals. Thus, the question of the neural locus of the effects and their generalizability remains open.

Method: In the present study, we recorded the ERP activity during the Stroop task in a within-subject design to test the neurocognitive effects of two hypnotic suggestions: the perceptual request to focus only on the central letter of the words and the semantic request to observe meaningless symbols.

Results: Behavioral results indicated that the two types of suggestions favored more accurate performance compared to the control condition. As for the neurophysiological results, both types of suggestions increased sensory awareness and reduced discriminative visual attention, but the perceptual request selectively engaged more executive control of the prefrontal cortex (PFC), and the semantic request selectively suppressed the temporal cortex activity devoted to graphemic analysis of the words.

Conclusions: The present findings demonstrated that the perceptual and the semantic hypnotic suggestions reduced Stroop errors through common and specific top-down modulations of different neurocognitive processes. Finally, as most of the present subjects expressed a medium level of hypnotizability, the present data might be considered potentially representative of the majority of the population.

Keywords: Hypnosis, Hypnotizability, Stroop, EEG, ERP

Publications:

Perri, R. L., Bianco, V., Facco, E., & Di Russo, F. (2020). Now you see one letter, now you see meaningless symbols: Perceptual and semantic hypnotic suggestions reduce Stroop errors through different neurocognitive mechanisms. *Frontiers in Neuroscience*, *14*.

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106/18 - "How does consciousness work in real life?" – only abstract available
Researchers: Adrià Tauste Campo, Rodrigo Quian-Quiroga
Institution: Center for Brain and Cognition, University Pompeu Fabra, Barcelona (Spain)
Estimated duration: 2019/02 – 2021/05

Background: Cognitive-relevant information is processed by different brain areas that cooperate to eventually produce a response. The relationship between local activity and global brain states during such processes, however, remains for the most part unexplored.

Aims: We aim to investigate how local activity and global brain states relate to each other when performing cognitive processes.

Method: We designed a simple face-recognition task performed in drug-resistant epileptic patients with intracranial EEG. Based on our observations, we developed a novel analytical framework (named "local-global" framework) to statistically correlate the brain activity in every recorded gray-matter region with the widespread connectivity functions as proxy to assess the level of influence of local neural activations into the brain's global state during cognition.

Results: The application of our analysis to the data from two subjects was able to detect the local activity in task-relevant brain areas including the primary visual and motor cortices. Despite substantial differences in the recorded regions of each subject, the connectivity functions consistently showed a significant global desynchronization occurring a few hundred milliseconds after the stimulus onset. In this context, the local-global framework revealed that the reported desynchronization was better explained by the local activity of brain areas involved in face information processing.

Conclusions: Overall, our work provides evidence that the global measures might be a novel signature of functional brain activity reorganization taking place when a stimulus is processed in a task context.

Keywords: Intracranial EEG, Local neural activity, Spectral estimation, Global brain connectivity, Cognitive task.

Publications:

Vila-Vidal, M., Khawaja, M., Carreño, M., Roldán, P., Rumià, J., Donaire, A., Deco, G. & Tauste Campo, A. (2022). Assessing the influence of local neural activity on global connectivity fluctuations: Application to human intracranial EEG during a cognitive task. *Human Brain Mapping*, under review. *bioRxiv*, doi: 10.1101/2021.06.25.449912

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113/18 - "Psi in everyday social interaction"
Researchers: Robin Wooffitt, Alicia Fuentes-Calle
Institution: Anomalous Experiences Research Unit, Department of Sociology, University of York (UK)
Duration: 2019/03 – 2021/04

Background: This project examines how psi communication emerges in talk-in-interaction, its poetic configurations, what this reveals about intersubjectivity processes. Previous research on poetic confluence phenomena has established their robustness, features, what they tell us about human relationality (e.g.: embodied intersubjectivity, interpersonal resonance, permeability of the physical body).

Aims: To explore the poetics of accounts of ostensibly telepathic moments that occur in everyday life. A main assumption is that the (psi) event described in the accounts (the *aboutness*) feeds back in specific ways with the narrative(poetics)-in-interaction displayed to convey it.

Method: Our current data collection consists of 52 accounts (nearly 50 people represented) on enigmatic communication. Analysis is framed in the overlapping methodologies of narrative and talk-in-interaction.

Results: The cases involve: identity work; metacommunication; influence of interactional dynamics (intersubjectivity, interpersonal resonance) over *aboutness*; a poetic infrastructure including a narrative framework ('small stories') and the operation of the poetic principle of parallelism. We see how apparent speech errors or unusual turns of phrase are fulfilling an interactional function: to trigger and mark convergence/resonance between interlocutors (between a spoken utterance and unarticulated thoughts). It is observed that the expression of those micro-events is achieved through manifestations of parallelism across different levels of the structure. These aesthetic qualities appear both in features of the production of the data, and in the experiences reported on in those. The results suggest that the poetic principle of parallelism might provide an overarching perspective (descriptive and explanatory) to advance in the analysis of an aesthetics of communication that includes enigmatic instances.

Conclusions: In accordance with a growing acknowledgement on the narrative nature of consciousness, this project contributes to refine concepts on the poetic/narrative articulation of intersubjectivity via psi communication in everyday interaction. In particular, through the lens provided by the narrative framework of 'small stories' and by the poetic principle of parallelism. Finally, the project makes a case for the value of anecdotal data as valid evidence in academic research, esp. with respect to empirical inquiry for which conventional data sources are absent or difficult to obtain.

Keywords: Psi communication, Interactional poetics, Narrative, Intersubjectivity

Publications:

Wooffitt, R., Fuentes-Calle, A., Campbell, R. (2020) Small stories with big implications. Identity, relationality and aesthetics in accounts of enigmatic communication. *Narrative Inquiry*. **doi:** 10.1075/ni.20013.woo

Theoretical article (in progress), after presentation "Poetic patterns of connectedness (parallelism) in episodes of 'anomalous' communication" Fuentes-Calle, A., in panel 'The poetic function and social meaning in language' at the 17th International Pragmatics Conference, Winterthur, 2021.

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117/18 - "The neuronal basis of biases" – only abstract available
Researchers: Rubén Moreno-Bote, Roozbeh Kiani
Institution: Center for Brain and Cognition, Department of Technologies of Information and Communications, Universitat Pompeu Fabra, Barcelona (Spain); Center for Neural Science, New York University (USA)
Duration: 2019/01 – 2021/04

Background: For an optimal behaviour our choices should be based on all relevant information available at hand which in the field of perceptual decision making is reflected as a dependence of the choice on the current stimulus and the prior history of stimuli, choices and outcomes. Those prior expectations create biases which might be beneficial especially when sensory information is weak or ambiguous. However when the current choice is unrelated to the prior history, the bias can be detrimental.

Aims: We aimed to establish if the history-dependent biases exist in the behavior of highly-trained monkeys performing a discrimination task in which there was no incentive to develop them. We wanted to determine a neuronal representation of the these biases in the prefrontal cortex activity and to reveale how such bias signal combines with the sensory evidence signal to form the final decision.

Method: We recorded population activity of prearcuate gyrus (PAG) neurons while two monkeys performed a direction discrimination task. In the task stimulus direction and strength varied randomly across trials making previous history irrelevant for the current choice. In a window of tens to hundreds of trials we calculated slow bias as a monkey's preference towards one of the motion directions. Fast bias was defined as a categorical variable reflecting previous choice and outcome. We used a logistic regression model to predict choice from the linear combination of the stimulus strength, slow and fast biases. Next we used a linear regression model to determine if the pre – stimulus activity of PAG population represents behavioral biases.

Results: We showed that even extensively trained monkeys exhibit small but significant biases. These biases fluctuated at distinct slow and fast time scales. Both significantly improved our ability to predict monkeys' upcoming choice on individual trials compared to a situation when choice was predicted solely based on the stimulus strength. Pre – stimulus PAG activity represented both the fast and slow biases. Crucially, the same activity was predictive of upcoming choice, suggesting a functional role for the bias representations.

Conclusions: Our results indicate that the prefrontal cortex activity carries the information about the history biases and demonstrate the mechanisms how such bias signal is integrated into the decision-making process.

Keywords: Behavioural bias, Decision making, Prefrontal cortex, Macaque monkey

Publications:

Mochol, G., Kiani, R., & Moreno-Bote, R. (2021). Prefrontal cortex represents heuristics that shape choice bias and its integration into future behavior. *Current Biology*, *31*(6), 1234-1244. doi: 10.1016/j.cub.2021.01.068

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138/18 - “The neuronal signatures of leadership: Two-brain directed synchronization during eye contact”

Researchers: Caroline Di Bernardi Luft, Isabelle Mareschal
Institution: School of Biological and Chemical Sciences, Queen Mary University of London (UK)
Estimated duration: 2019/07 – 2020/06

Background: Studies using *hyperscanning* (monitoring two people’s brains simultaneously) have shown that when people interact, their brains synchronize; the more in sync, the more successful the interaction. Higher inter-brain synchronization was also observed during eye-contact, suggesting that subtle synchronization processes occur even during non-verbal communication. However, there are many unknowns regarding how and why people’s brains synchronize and whether inter-brain synchronization during eye-contact interacts with social relationships.

Aims: We compared hyperbrain synchronization and network characteristics during eye-contact between pairs of friends and strangers and analysed directed connectivity between leaders and followers.

Method: We measured brain-to-brain synchronization (EEG) as pairs of participants engaged in a two-person time reproduction task. Participants were asked to reproduce the duration of an auditory tone that they heard through earphones by making eye-contact for the duration of the tone (monitored using eye-tracking). They were told to break eye-contact once they thought the tone duration had passed. In the control condition, participants completed the same task, but without looking into each other’s eyes. We evaluated whether a leader emerged by analysing whether one member of the pair member consistently gazed back first. We measured brain-to-brain synchronization using undirected (ciPLV) and directed (PSI) phase synchronization measures in frequency bands theta, alpha, beta and gamma. We compared the conditions (eye-contact vs. control) using non-parametric cluster permutation. We measured the network characteristics during eye-contact using graph theory.

Results: We observed a stronger gamma band inter-brain synchronization during periods in which the participants made eye-contact. Friends showed significantly stronger inter-brain synchronization and more efficient hyperbrain networks than strangers. The hyperbrain networks displayed rich-club characteristics, with a few nodes showing disproportionately higher number of connections. Furthermore, we found an increase in theta synchronization from leader to follower. Leaders presented higher access to the entire network compared to followers (i.e. local to global efficiency).

Conclusions: Eye-contact modulates undirected and directed synchronization between brains more than the synchronization within brains, demonstrating that eye-contact is a communicative and social signal.

Keywords: Hyperscanning, EEG, Inter-brain synchronization, Eye-contact, Eye-tracking, Hyperbrain

Publications:

Luft, C., Zioga, I., Giannopoulos, A., Di Bona, G., Civilini, A., Latora, V., & Mareschal, I. Social synchronisation of brain activity by eye-contact. *Communications Biology* (undergoing revisions).

Zioga, I., Harrison, P. M., Pearce, M. T., Bhattacharya, J., & Luft, C. D. B. (2020). Auditory but Not Audiovisual Cues Lead to Higher Neural Sensitivity to the Statistical Regularities of an Unfamiliar Musical Style. *Journal of Cognitive Neuroscience*, *32*(12), 2241-2259.

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163/18 - "Effects of a short-term mindfulness intervention on hypnotisability and mental health" – only abstract available

Researchers: Zoltan Dienes, Peter Lush
Institution: School of Psychology, University of Sussex (UK)
Duration: 2019/04 – 2020/04

Background: Cold control theory claims that people can alter their subjective experiences in responding to hypnotic suggestions, by having an intention to perform the cognitive or behavioural act required (e.g. lift an arm for an arm levitation suggestion), while being unaware of the intention to perform that action (in fact thinking "I do not intend to lift my arm"). That is, according to the theory, hypnotic response entails not being mindful of a relevant intention.

Aims: The aim was to test the hypothesis that hypnotic response may be harder for people who have been trained to be more mindful of mental states, compared to an active control.

Method: Participants were randomly assigned to one of three groups: mindfulness of mental states intervention; mindfulness of the world intervention (active control); no intervention ("waiting list" control). The mental states condition involved daily exercises in being aware of one's mental states over two weeks. The world condition was similar in all respects except participants practiced being mindful of the world. Hypnotic response was measured before and afterwards; as was mindfulness, stress, and depression and anxiety for comparison with other mindfulness interventions.

Results: Consistent with the hypothesis that the mental state intervention increases mindfulness of intentions, the mental state group increased in the mindfulness facet Acting with Awareness compared to the waiting list control, difference = 0.35 Likert units. A correlational study we ran showed a change of -0.13 subjective units in hypnotic response per unit change acting with awareness. Thus, we would expect a change in hypnotic response of 0.35 x -0.13 = - 0.05 subjective units in the mental state group compared to the control group.
The amount by which hypnotic response reduced in the mental states condition vs the control condition was -0.18 (SE = 0.18), t(60) = 1.00, BH(0,.05) = 0.79, which is insensitive (that is, no conclusion follows). Based on the error variance in these data we can estimate we would need about 3,000 participants in total to detect such an effect.
Mindfulness of mental states compared to controls reliably reduced depression and anxiety by 0.2 Likert units.

Conclusions: Showing an increase in mindfulness reduces hypnotic response will need a multilabs study. We found however that mindfulness of mental states rather than the world reduces depression and anxiety.

Keywords: Mindfulness, Hypnosis, Depression

Publications:
Dienes, Z., Lush, L., Palfi, B., Rooseboom, W., Scott, R., Parris, B., Seth, A., & Lovell, M. (2020). Phenomenological control as cold control. Submitted to *Psychology of Consciousness*; minor revisions have been requested. (Available on PsyArXiv https://psyarxiv.com/7jn8q)
Lush, P., Botan, V., Scott, R. B., Seth, A. K., Ward, J., & Dienes, Z. (2019). Phenomenological control: response to imaginative suggestion predicts measures of mirror touch synaesthesia, vicarious pain and the rubber hand illusion. https://psyarxiv.com/82jav/ (To be re-submitted)

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180/18 - "Exploring the effects of linguistic versus non-linguistic mentation in a remote viewing protocol, with coincident micropsychokinesis detection using a novel matriz REG" – only abstract available

Researchers: Paul Stevens, Ben Roberts

Institution: University of Derby (UK)

Estimated duration: 2019/05 – 2020/06

Background: This project explores psi-related processes — mode of mentation and possible microPK coincident effects — within a remote-viewing (RV) protocol. Exploring the mentation mode, two conditions were used in which participants (Ps) expressed their mentation non-linguistically (drawing their impressions) versus linguistically (typing their impresssions). As language structures any experience, verbal description of inner states can only convey an approximation of what occurs within the body. It was hypothesised that verbally describing psi experiences (which appear to occur within such inner worlds rather then being mediated via a specific organ or site) may therefore be less successful in terms of 'hits' than if language is avoided. The idea of coincident effects is based on previous research on psi as a unitary phenomenon[1], and uses a novel random event generator (REG) based on a CMOS imaging sensor under dark conditions. This design was intended to expand on previous research which gave limited/ inconsistent evidence of patterning from commonly used filtered-output REGs. While the original rationale for filtering was to ensure that REGs were unresponsive to 'non-paranomal' events, this explicitly assumed that microPK is not a direct influence — where underlying processes of generation are important — but instead depends only on final output, despite evidence to the contrary (Ibison, 1998)[2]. Our REG more directly relates to the underlying physical process and provides more information for analysis.

Aims: To explore differences in the way the mode of communication (linguistic vs. non-linguistic) might affect access to psi-mediated information, and whether ESP processes might be accompanied by coincident microPK effects. Based on a remote viewing protocol, with a novel REG as the coincident detector.

Method: 60[3] participants (Ps) were recruited — 33 Ps in the online condition, taking part from anywhere in the world, and 27 in-person, on the Derby University campus. All sessions were carried out using a website interface that gave standardised instructions, handled randomisation, and securely recorded data. Target sites were visited in real-time by the RV agent. Each session consisted of 20 minutes RV, during which Ps either typed their mentation or uploaded a drawing, depending on assigned condition. Concurrently, the REG recorded session and control data (both pre- and post-session) at the target site. Ps then ranked 4 360° video-clips (target site and 3 decoys), with later independent ranking for comparison.

Results: There were 57 fully completed sessions with useable data, with 18 direct hits, giving a $\Pi = 0.58$ ($p = 0.12$), slightly less than mean value for $\Pi = 0.62$ given by Bem and Honorton (1994) in their ganzfeld meta-analysis and not statistically significant ($p = 0.21$). There was a marked difference in hit rate when comparing in-person (6 hits out of 27, $\Pi = 0.46$, $p = 0.31$) versus online Ps (12 hits out of 30, $\Pi = 0.67$, $p = 0.02$), possibly due to in-person Ps being primarily course-credit students with lower motivation. Non-linguistic (drawing) mode Ps achieved 9 hits out of 28 sessions ($\Pi = 0.59$, $p = 0.10$) and linguistic (typed) mode Ps had 9 hits out of 29 sessions ($\Pi = 0.57$, $p = 0.14$). Given the only evidence of remote viewing was in the online group, that group was analysed on its own, but still showed no significant difference between non-linguistic and linguistic modes ($p = 0.75$). Independent judge rankings did not match participant rankings. The REG did show significantly greater deviation from baseline (based on per participant Stouffer Zs) for remote-viewing hits versus misses ($p = 0.03$). Hits versus misses for control periods showed no significant difference ($p = 0.24$). RV periods overall (hits and misses combined) were not significantly different from the control periods overall ($p = 0.23$), nor were there any significant differences between RV and Control data for hits ($p = 0.88$) or misses ($p = 0.18$). Complexity measures, based on fractal dimension of the REG activity as a continuous stream and as a set of surfaces, did not show any significant differences between conditions. No correlation was found between local magnetic field activity and REG activity, confirming that this type of device is relatively

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1 Roe, C.A., Davey, R. & Stevens, P. (2003). Are ESP and PK aspects of a unitary phenomenon? A preliminary test of the relationship between ESP and PK. *Journal of Parapsychology*, 67.

2 Ibison, M. (1998). Evidence that anomalous statistical influence depends on the details of the random process. *Journal of Scientific Exploration*, 12, 407-423

3 80 Ps were originally planned but recruitment became difficult due to the pandemic. A decision was therefore taken to stop the study once 60 sessions had been completed. No analysis, including calculation of hit rate, was performed prior to these studies being completed, to avoid 'optional stopping' concerns.

robust against external influences (other than temperature, though this is a consistent trend easily compensated for).

Conclusions: RV can successfully be performed with a minimal setup, using a standardised webpage interface. There was evidence of successful remote viewing only with online Ps, probably due to probable differing levels of motivation of Ps and possibly non-naive subjects in the online condition. No differences were seen based on the mode of mentation (linguistic or non-linguistic). The novel REG did show significant differences in activity for hits versus misses, suggesting its usefulness as a co-incident detector, but there are doubts as to whether the more complicated design is needed, as opposed to the simpler REG used in microPK studies.

Keywords: Remote viewing; Coincident detection; Non-linguistic mentation

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211/18 - "Correlating accurate intuition with learning styles and sensory modality preferences" - only abstract available

Researchers: Julie Beischel, Lisa Conboy
Institution: Windbridge Research Center, Tucson, Arizona (USA); Beth Israel Deaconess Medical Center at Harvard Medical School, Boston, Massachusetts (USA)
Duration: 2019/01 – 2021/10

Background: A person's learning style is consistent across long time periods and many activities. Learning style assessments may be useful in categorizing and quantifying inherent individual preferences.

Aims: Mediums' learning styles and sensory modality preferences (LS/SMPs) questionnaire responses were compared to their accuracy scores when asked specific questions about a deceased person under blinded conditions. The accuracy scores for the different questions were also compared.

Method: The Index of Learning Styles© (ILS), the Barsch Learning Style Inventory (BLSI), and the Learning Channel Preference (LCP) were used to assess LS/SMPs. The medium participants were 12 Windbridge Certified Research Mediums (WCRMs); 11 females, 1 male; average age: 58.9 ± 2.4 years.

Results: The means of 21 accuracy scores for each of four question types varied (physical description: 53.9% ± 5.2%; personality: 67.0% ± 7.1%; hobbies: 49.4% ± 5.5%; and cause of death: 41.3% ± 6.5%) but no differences requiring further statistical analysis existed. Correlation analyses were completed to compare the accuracy scores for the four question types with ILS Active, Reflective, Sensory, Intuitive, Visual, Verbal, Sequential, and Global scores; BLSI Visual, Auditory, and Tactual Preference scores; and LCP Preferred Visual, Auditory, and Haptic Channel scores. No significant correlations were found.

Conclusions: Though this sample size was not large, it may be appropriate to conclude that none of the four types of information requested is more or less difficult to acquire or report during a mediumship reading than any other. Further, individual characteristics categorized as LS/SMPs may not impact mediumistic abilities.

Keywords: Mediums, Accuracy, Sensory modality preferences, Learning styles, Psi

Publications:

Beischel, J., & Conboy, L. (2021). Correlating mediums' accuracy with learning styles and sensory modality preferences. *Threshold: Journal of Interdisciplinary Consciousness Studies*, *4*(1), 1-20. http://www.tjics.org/index.php/TJICS/article/view/ 33/26

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228/18 - “Blurring the line between human and robot? Mapping and manipulating the socialness gradient in the brain” – only abstract available
Researchers: Ruud Hortensius, Emily Cross
Institution: Centre for Social, Cognitive and Affective Neuroscience – cSCAN, Institute of Neuroscience and Psychology, University of Glasgow (UK)
Duration: 2019/05 – 2021/09

Background: The process of understanding the minds of other people, such as their emotions and intentions, is mimicked when individuals try to understand an artificial mind. The assumption is that anthropomorphism, attributing human-like characteristics to non-human agents and objects, is an analogue to Theory-of-Mind, the ability to infer mental states of other people.

Aims: Here, we test to what extent these two constructs formally overlap. Specifically, using a multi-method approach, we test if and how anthropomorphism is related to Theory-of-Mind using brain (Experiment 1) and behavioural (Experiment 2) measures.

Method: In a first exploratory experiment, we examine the relationship between dispositional anthropomorphism and activity within the Theory-of-Mind brain network (n = 108). In a follow-up, pre-registered experiment, we explored the relationship between Theory-of-Mind and situational and dispositional anthropomorphism in more depth. Participants (n = 311) watched a short movie while simultaneously completing situational anthropomorphism and Theory-of-Mind ratings, as well as measures of dispositional anthropomorphism and general Theory-of-Mind.

Results: Results from a Bayesian regression analysis showed no consistent relationship between dispositional anthropomorphism and activity in regions of the Theory-of-Mind network. Only situational anthropomorphism predicted the ability to understand and predict the behaviour of the film’s characters. No relationship between situational or dispositional anthropomorphism and general Theory-of-Mind was observed.

Conclusions: Together, these results suggest that while the constructs of anthropomorphism and Theory-of-Mind might overlap in certain situations, they remain separate and possibly unrelated at the personality level. These findings point to a possible dissociation between brain and behavioural measures when considering the relationship between Theory-of-Mind and anthropomorphism.

Keywords: Anthropomorphism, Theory-of-Mind, Social cognition, Attribution of socialness

Publications:

Hortensius, R.+, Kent, M.+, Darda, K. M., Jastrzab, L. E., Koldewyn, K., Ramsey, R., & Cross, E. S. (2021). Exploring the relationship between anthropomorphism and Theory-of-Mind in brain and behaviour. *Human Brain Mapping*, 42:13. Open access: https://onlinelibrary.wiley.com/doi/10.1002/hbm.25542

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*de Jong D., Hortensius R., Hsieh T., & Cross E. S. (2021). Empathy and schadenfreude in human–robot teams. *Journal of Cognition 4(1), 35.* Open access: doi: 10.5334/joc.177

Timmerman R.H., Hsieh TY., Henschel A.+, Hortensius R.+, Cross E.S.+ (2021) Individuals Expend More Effort to Compete Against Robots Than Humans After Observing Competitive Human–Robot Interactions. In: Li H. et al. (eds) Social Robotics. ICSR 2021. Lecture Notes in Computer Science, vol 13086. Springer, Cham. Open access: doi: 10.1007/978-3-030-90525-5_60

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230/18 - "Unraveling the mechanisms behind automatic and emotional control: Psychophysiological, cortical excitability and functional connectivity measures"

Researchers: Ignacio Obeso, Jose Ángel Pineda Pardo, Claudia Ammann, Lina Guida, Úrsula Alcañas, David Mata-Marín

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Estimated duration: 2019/02 – 2021/12

Background: Sufficient repetition of similar contextual information leads to automatic behaviours. The ability to inhibit actions, thoughts or emotions may also run under automatic control. Yet, little is known on what behavioural and neural mechanisms turn inhibition automatic, whether emotional cues interfere the process and its underlying neurobiology.

Aims: We will test the presence of a brain network behind automatic inhibition. Also, how emotional influences on automatic inhibition mechanisms.

Method: On 3 experiments, a modified Go/NoGo learning task (automatic inhibition task) assessed learning of stimulus-stop associations throughout days of training. Formation and expression of automatic inhibition was assessed by comparing first vs last behavioural sessions. Subjects had to learn to emit or withhold a keypress upon the presentation of a primary object picture (6 neutral images: 3 go vs 3 no-go) with varying feedback probabilities. Reversal and slips of action tests were performed on the first and last sessions to assess automatic behaviour. In 3 experiments, behavioural, emotional cues and neuroimaging tools (fMRI and TMS) were used.

Results: After considerable training, significant better performance was seen across go and no-go learning trials and harder to suppress when asked to revert automatic actions. Emotional cues did not influence mean average on automatic inhibition but exploring single-trial changes showed negative images enlarged costs to revert inhibition automaticity. The neural circuitry responsible for the automatic inhibition engaged the SMA, putamen, caudate, substantia nigra and subthalamic nucleus. Finally, cortical excitability across different stages of learning (analysis of changes in MEPs) did not reveal significant time-related disparity between go and no-go trials compared to baseline trials.

Conclusions: We have defined automatic inhibition using a novel behavioural measure and how emotional cues may modulate the expression of automaticity. Importantly, a neural circuitry associated to automatic inhibition recruits fronto-striatal areas. This behaviour and associated brain responses may be of value to neuropsychiatric conditions were automatic control over pleasant cues becomes largely impaired.

Keywords: Cognitive control, Emotions, Automatic cognition, fMRI, TMS

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261/18 - "Phenomenological experience and neurophysiological correlates of shamanic trance in healthy individuals"

Researchers: Olivia Gosseries, Nolween Marie
Institution: GIGA research center, GIGA-Consciousness, University of Liège (Belgium)
Duration: 2019/07 – 2021/11

Background: Trance is a modified state of consciousness that has been used for millennia in ancient traditions. Almost no scientific research has investigated the phenomenology and the neuronal underpinnings of trance. Self-induced cognitive trance is inherited from shamanic practice and can be practiced by any individual.

Aims: Characterize the phenomenological experiences of trance and measure its neurophysiological signatures.

Method: We included 27 experts in cognitive trance. Each expert underwent a series of high-density EEG/ECG/breathing recordings: during normal wakefulness at rest, with auditory stimulations and with an imaginary task (previous intense trance), as well as during trance with and without auditory stimulations. Behavioural assessments were conducted after each condition, including a free recall, levels of arousal, absorption, and dissociation, as well as the Greyson scale and the Mystical Experience Questionnaire. We also quantified trance intensity. Behavioural analyses were expressed as mean±std, analyzed using t-tests. EEG preprocessing and statistical analyses included spectral power, functional connectivity, and complexity. Heart rate and respiration measured were also calculated.

Results: Phenomenological results showed that all participants entered in trance and rated the intensity of the experiences as high. During trance, they felt more awake, more absorbed and more dissociated. Their trances were comparable to a near-death experience, with mystical-type experiences. Analysis of the text corpora (Iramuteq) showed that trance had a specific speech compared to rest, auditory stimulations and imagination. The length of the subjects' reports (i.e., total word count) was higher for trance compared to the other conditions, reflecting more richness and vividness in trance. Neurophysiological results showed that trance was associated with increased power spectral density in high and low frequency bands, and changes in functional connectivity and complexity. In trance, heart rate increased while breathing decreased compared to the other conditions.

Conclusions: These results show phenomenological and neurophysiological changes in trance, different from the other conditions.

Keywords: Cognitive trance, Modification of consciousness, Phenomenology, Neurophysiology, EEG

Publications:

Gosseries O*, Fecchio M*, Wolff W, Sanz LRD, Sombrun C, Vanhaudenhuyse A*, Laureys S* (2020) Behavioural and brain responses in cognitive trance: a TMS-EEG case study. *Clin Neurophysiol,131(2)*, 586-588. *Contributed equally.

Grégoire C, Sombrun C, Gosseries O*, Vanhaudenhuyse* (2021) A. La transe cognitive auto-induite: caractéristiques et applications thérapeutiques potentielles. *Revue Hegel*, ALN edition, *11(2)*, 192-201. *Contributed equally.

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284/18 - "Testing a neurophysiological model of inner speech processing"
Researchers: Bo Yao
Institution: Division of Neuroscience and Experimental Psychology, University of Manchester (UK)
Duration: 2019/09 – 2022/01

Background: Growing evidence shows that theta (4–7 Hz) oscillatory activity in the auditory cortex phase-locks to rhythms of overt speech. We asked if theta activity also encode the rhythmic dynamics of inner speech.

Previous research established that silent reading of direct speech quotes (e.g., *Mary said: "This dress is lovely!"*) elicits more vivid inner speech than indirect speech quotes (e.g., *Mary said that the dress was lovely*). As this quotation-induced inner speech shares temporal rhythms of overt speech, we hypothesized that it could also be tracked by theta oscillations.

Aims: We tested if quotation-induced inner speech is phase-locked by theta oscillatory activity.

Method: Because we cannot observe inner speech objectively, we could not directly track the phase alignment between inner speech and theta activity over time. Instead, we used electroencephalography (EEG) to measure the brain's phase-locked responses to the onset of speech quote reading where a phase reset is likely to occur as it adapts to the rhythms of inner speech.

Results: We found that direct (vs. indirect) quote reading was associated with increased theta phase-locking at 250–500 ms post-reading onset, with sources of the evoked activity estimated in the speech processing network.

Conclusions: The findings likely reflect synchronous phase resetting at the onset of inner speech and suggest a functional role of theta phase modulation in reading-induced inner speech.

Keywords: Inner speech, Neural oscillations, Phase-locking, Reading, Theta activity

Publications:
Yao, B., Taylor, J. R., Banks, B., & Kotz, S. A. (2021). Reading direct speech quotes increases theta phase-locking: Evidence for cortical tracking of inner speech? *NeuroImage*, *239*, 118313. doi : 10.1016/j.neuroimage.2021.118313

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339/18 - "Analysis of brain activity in adolescents with different levels of emotional regulation" – only abstract available

Researchers: Jordi Solbes Matarredona, María Àngeles Gómez Climent, Samuel Hernández González, Carlos Caurín Alonso, Albert Clemente Soriano, Jose Luis Alba Robles, Rodrigo Zequeria Cotes

Institution: Faculty of Education, University of Valencia (Spain); Faculty of Psychology, University of Valencia (Spain); Faculty of Psychology and Education, International University of Rioja, Logroño (Spain)

Estimated duration: 2019/02 – 2020/10

Background: One of the common social scenarios in the adolescents that guide the development of emotional intelligence (EI) is the academic context. In this sense, it has been found that certain variables of EI can predict students' academic success. At the brain level, it is known that empathy, involve the temporoparietal junction and the posterior Superior Temporal Sulcus, as well as specific regions of the frontal cortex (Lamm et al., 2011; Bernhardt & Singer, 2012).

Aims: In this paper, empathy was studied through a comparative analysis of two groups of adolescents with different levels of academic adaptation problems (AAP). Empathy was analyzed from three different levels: social, behavioral and electrophysiological.

Method: For this purpose, the Basic Empathy Scale, assessment of pain in others and facial expression recognition tests and the corresponding electroencephalographic activity were used.

Results: The results show a lower cognitive empathy and accuracy in facial expression recognition in adolescents with school adaptation problems. Groups showed differences in the distribution of oscillatory activity when the stimuli were assessed. Adolescents with better academic achievement generated greater oscillatory activity between theta and high gamma in the right temporoparietal, medial parietal (precuneus) and bilateral dorsolateral prefrontal cortices.

Conclusions: The AAP group presented a lower development of cognitive empathy and closely related skills, as well as a lower oscillatory activity in cortical regions involved in this type of empathy. Moreover, the AAP group would not take advantage during emotional appraisal of facial expressions due to the temporal and frontal activity focused on the left hemisphere.

Keywords: Adolescence, empathy, academical achievement, cerebral cortex, oscillatory activity

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356/18 - "Neural mechanisms underlying unconscious working memory" – only abstract available

Researchers: Albert Compte, João Barbosa, Josep Valls-Sole
Institution: Institut d'investigacions Biomèdiques August Po i Sunyer – IDIBAPS, Barcelona (Spain)
Duration: 2019/05 – 2021/09

Background: Previous studies have found neurophysiological evidence for common neural mechanisms of serial dependence (Barbosa et al, bioRxiv 2019) and subconscious working memory (Trübutschek et al eLife 2017, PNAS 2019).
On the one hand, previously stored, currently irrelevant memories leave an "activity-silent" (Stokes, Trends Cogn Sci 2015) trace that biases upcoming memories (Barbosa et al, bioRxiv 2019). These traces decay with a time constant of seconds, so long inter-trial-intervals lead to weaker serial dependence (Bliss et al, Sci Rep 2017). Moreover, serial dependence is known to increase with memory period durations (delay durations, Bliss et al, Sci Rep 2017). This is because active memories rely on persistent neural activity, thus drift (Wimmer et al Nat Neurosci 2014) instead of decaying like previous memories traces. Active memories tend to drift towards previous memories' traces, leading to serial dependence.
On the other hand, recent empirical and theoretical work suggest that subconscious memories are also stored in 'activity-silent' traces (Trübutschek et al eLife 2017, PNAS 2019). Serial dependence has not yet been characterized during subconscious working memory trials. Given the proposed mechanism for subconscious memories (i.e. 'activity-silent'), we predict that serial dependence for subconscious trials should decrease with longer delay periods, similarly to the known effect of inter-trial-intervals on conscious working memory.

Aims & Methods: With this aim, we will change the delay duration (1 or 3 s) and focus exclusively on the correct trials. We will then group those trials based on their reported visibility (seen or unseen). We predict that correct trials that were reported to be invisible (subconscious working memory) will have weaker serial dependence with long (3 s) than with short (1 s) delay duration. In contrast, correct trials that were reported to be visible will have stronger serial dependence for the longer delay duration condition (as previously reported, e.g. Bliss et al, Sci Rep 2017)

Keywords: Subconscious perception, Working memory, Serial dependence

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