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Interpersonal Emotions as Emergent Phenomena: Social Neuroscience Beyond Western Cultural Constructions

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Interpersonal Emotions as Emergent Phenomena:

Social Neuroscience Beyond Western Cultural Constructions

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ABSTRACT

Because science as it exists today is a cultural construction of the West, studies of neuroscience have often been limited by Western perspectives. In particular, the Western proclivity towards individualism has led to a field of neuroscience which has historically focused on studying single individuals, as opposed to social or collective neuroscience. For the most part, it has just been assumed that collective phenomena such as interpersonal emotions must be able to be reduced in terms of individual phenomena such as individual emotions. However, closer review reveals that interpersonal emotions have emergent properties that individual emotions alone do not account for. In other words, there is more to the emotions within interpersonal relationships than the simple transmission of individual emotions from one individual to another. Rather, there appear to be unique emotions associated with the abstract interpersonal relationships between individuals. These interpersonal emotions are neuroscientifically and qualitatively different from individual emotions. This could have huge ramifications for any field involving human interaction, from economics, to international relations, to mobilization for causes like climate change. In order to better understand these complex phenomena, a greater diversity of thought is needed in neuroscience.

INTRODUCTION

What is Social Neuroscience?

Social neuroscience and collective neuroscience are the study of the relationship between neurobiology and social experiences. Social neuroscience focuses more on social behaviors, while collective neuroscience focuses more on interpersonal phenomena. One of the core tenets of social and collective neuroscience is that humans and other animals are social creatures, and to study individuals in a vacuum is to miss vital information about our inner workings (Miller 2011).

What Do We Know So Far?

Principles of the brain have been studied for thousands of years (University of Washington n.d.). However, neuroscience as we know it today is a relatively young discipline. The term 'neuroscience' was actually coined as recently as 1962 (MIT News 1995). Social neuroscience as a subfield is even younger, taking its roots in work by John Cacioppo in the 1980s and 1990s (Miller 2011). Because the field of social neuroscience is newer, the canon of social neuroscience is much smaller than those of other disciplines such as physics or chemistry. There are quite a few gaps in our understanding of social neuroscience concepts. But to say that social neuroscience has been understudied does not mean that it hasn't been studied at all. Some research has already occurred into the neural bases of social behavior, as well as into so-called emotional contagion between individuals.

Research on the Neural Bases of Social Behavior

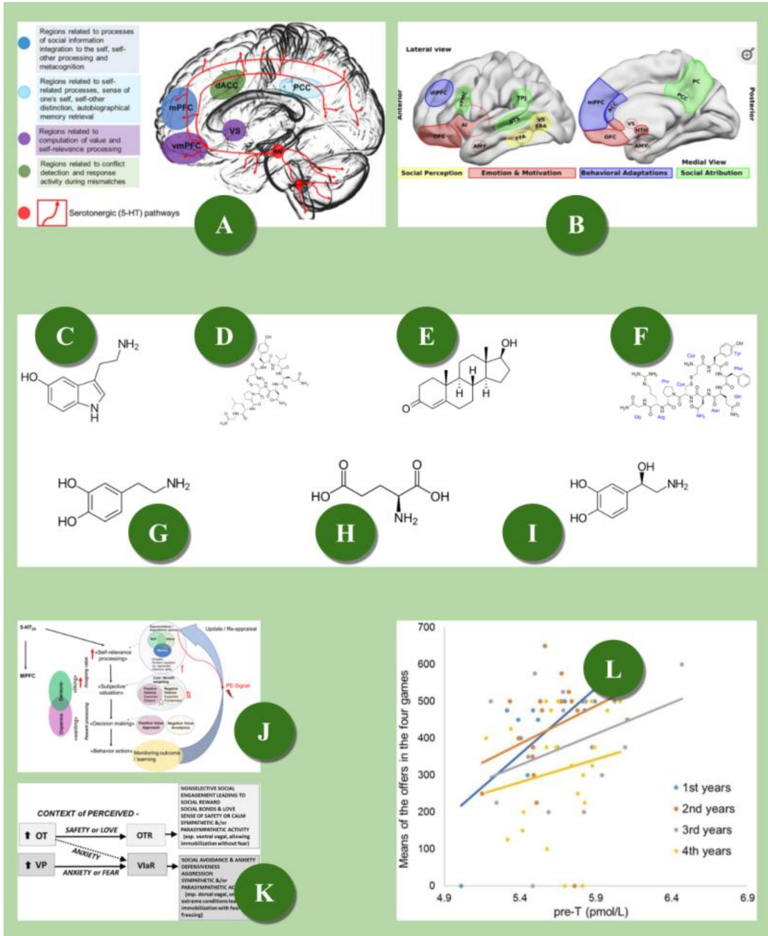

Fig. 1: Existing Research on Neurotransmitters & Brain Regions in Social Neuroscience.

(**A**) Proposed pathway of serotonin throughout the social brain (Duerler et al. 2022)

(**B**) Brain regions implicated in sociality (Billeke & Aboitiz 2013)

(**C - I**) Chemical structures of serotonin, oxytocin, testosterone, vasopressin, dopamine, glutamate, and noradrenaline ("Serotonin" n.d., Froemke & Carcea 2017, "Testosterone" n.d., "Vasopressin" n.d., "Dopamine" n.d., "Glutamic Acid" n.d., "Norepinephrine" n.d.)

(**J**) Serotonin & dopamine regulating social appraisals, learning, and behavior (Duerler et al. 2022)

(**K**) Differential pathway of oxytocin (prosocial behavior) vs vasopressin (aggressive behavior) based on perceived safety in humans (Carter 2017)

(**L**) Testosterone reinforcing roles in social hierarchy, making leaders more dominant and followers more submissive (Inoue et al. 2017)

Neuroscientists already know a lot about the neurochemicals involved in the regulation of social behavior. Much is known about the role of neurotransmitters such as oxytocin, serotonin, vasopressin, and testosterone in social relationships (fig. 1A, fig. 1C - 1I). Oxytocin is sometimes called the 'care molecule' because of its prominent role in a variety of important social functions such as parent-infant bonding, trust, empathy, social adaptation, interpersonal synchrony, romantic attachment and sexual arousal (fig. 1K) (Scatliffe et al. 2019, Schneiderman et al. 2012, Duerler et al. 2022). Serotonin is also involved in social functions, as serotonin levels have been shown to affect social perception, social feedback sensitivity, and prosocial behavior (fig. 1J)

(Duerler et al. 2022). Serotonin is generally involved in prosocial processes, but a lack of serotonin can also be associated with aggression ("Serotonin and Aggression" 2020). With that said, not all social neurotransmitters are primarily involved with prosocial behavior. An increase in other neurotransmitters, like vasopressin and testosterone, have been shown to increase aggression as well as behaviors maintenance of social hierarchy (fig. 1K & 1L) (Carter 2017, Inoue et al. 2017, Duistermars 2022). In terms of hierarchy, this means that dominant individuals act more dominant, or while submissive individuals act more submissive. Additionally, scientists have conducted research on how neurotransmitters involved in processes like reward and learning can also impact social interactions. This includes research into dopamine, which has been shown to be involved with the feeling of reward in response to social interaction as well as with social conformity (fig. 1J) (Ash 2022, Duerler et al. 2022). This also includes glutamate and noradrenaline, which have been implicated in social learning processes (Duerler et al. 2022) Altogether, social neuroscientists have developed a fairly good understanding of the neurotransmitters involved in the regulation of social behavior.

Neuroscientists have also implicated certain brain areas in social behaviors. These regions can be separated into roughly five categories. 1) social perception, 2) appraisals of one's own emotions, attitudes, and motivations concerning others, 3) behavioral adaptations 4) social attribution & theory of mind, and 5) tangential areas associated with the synthesis and release of social neurotransmitters (fig. 1B) (Billeke & Aboitiz 2013, Duerler et al. 2022, Borowski 2022, Spezio 2020, Carlson & Birkett 2021, Luo 2020, Latzman et al. 2015, Wang et al. 2019, Cavanna & Trimble 2006, Krall et al. 2015):

1. <u>Social perception:</u> the extrastriate body area (EBA), which recognizes the body motion of others, as well as the fusiform face area (FFA), which recognizes facial expressions.

2. Self-appraisals: the amygdala (AMY), which is generally involved in emotions as well as fear-based conditioning, the anterior insula (AI), which is involved with the processing of social emotions such as disgust, the anterior cingulate cortex (ACC), which is involved in long-term memory, and the orbitofrontal cortex (OFC), which is involved in impulse control, prosocial behavior, and humor. These regions function in interaction with the nucleus accumbens (NAc) which is also sometimes ventral striatum (VS), and is involved in the reward system, as well as the hypothalamus (HTS), which regulates the neuroendocrine system as well as bodily functions necessary to maintain homeostasis.
3. Social behaviors: the dorsolateral prefrontal cortex (dPFC), which is involved in planning and organization, the medial prefrontal cortex (mPFC), which is involved in processing social information, and the ACC once again.
4. Social attribution: for more simple cases, this has been found to occur in the premotor cortex (vPMC), which receives sensory input and relays it to motor regions, the superior temporal sulcus (STS), which can recognize faces, body movements, and tone of voice, the AI, the posterior cingulate cortex (PCC), which is involved in the interpretation of behavior, and the precuneus (PC), which is involved in neural representations of the self and the other. For more complex and ongoing cases of social attribution, activation occurs in the mPFC and the temporal-parietal junction (TPJ), which is involved in theory of mind processes.
5. Areas involved relevant neurotransmitters: for example, the Raphe nuclei (RN) for the release of serotonin or the nucleus accumbens (NAc) for the release of dopamine, could be said to be part of our social neuroanatomy as well.

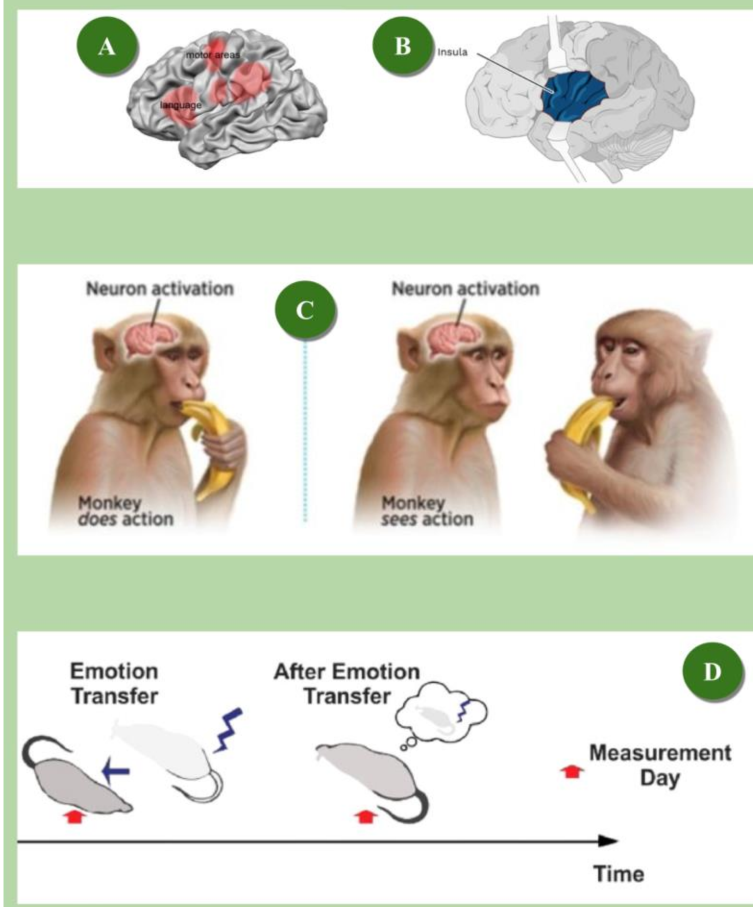

Fig. 2: Existing Research on Mirror Neurons and Emotion Transmission in Social Neuroscience.

(**A & B**) Locations of mirror neurons involved in mimicking movements, language, and emotions (Macedonia 2013, "Insula" 2023)

(**C**) Mirror neurons activate whether the individual experiences something themself or just watches another individual experience something (Wagar 2016)

(**D**) After one mouse has an induced anxiety experience, this anxiety can be transferred to the other mouse (Hernandez-Lallement et al. 2022)

One particularly notable aspect of the neuroanatomy of social behavior is mirror neurons. Rather than a single brain region, mirror neurons are a type of neuron that can be found in a variety of regions. Research indicates that, in humans, mirror neurons can be found in the inferior frontal gyrus (IFG) and the superior and inferior parietal lobules (SPL & IPL), which are all involved in skilled movement and Broca's area, a brain area involved in speech production, as well as the dPFC, the ACC, and the insula (fig. 2A & 2B) (Molenberghs et al. 2009, Baars & Gage 2010, Macedonia 2013, Singer et al. 2004, "Insula" n.d.). Some mirror neurons are located in motor regions, which regulate movement. These mirror neurons fire both when an individual performs an action as well as when an individual views another individual perform an action. In other words, even when Person A is not performing the action, their neural activity will ‘mirror’ that of Person B, who is performing the action, as if it was Person A themself carrying out the action. This internal representation of others’ physical actions is very meaningful for theory of mind, which is the ability to imagine the thought processes of others (fig. 2C) (Keysers & Gazzola 2006). Additionally, mirror neurons in Broca’s area have been speculated to be involved in language acquisition (Macedonia 2013, Luo 2020). Scientists speculate that these mirror neurons help learners to mimic the mouth movements and sounds made by those who can speak the language. But mirror neurons allow us to replicate more than just physical actions. Mirror neurons in the inferior frontal gyrus, the anterior cingulate cortex, and the insula have also been shown to replicate others’ likely intents and emotions, making them a key component in the neural basis of empathy (Singer et al. 2004, Blakeslee 2006). In neuroscience, empathy describes our ability to internally simulate the emotions and cognitions of others (Blakeslee 2006). For example, when we see someone picking up a cup off of a table, our mirror neurons allow us to predict if they are picking up the cup to take a sip or to clear the cup away. And when we see another person experiencing an emotion such as distress, anger, happiness, or surprise, our mirror neurons give us an experience of these emotions (Singer et al. 2004, Blakeslee 2006). And, in humans, mirror neurons in the insula allow us to experience social emotions such as pride, embarrassment, guilt, shame, disgust, and lust (Blakeslee 2006). All in all, mirror neurons serve a vital role in sociality.

Research on Emotional Contagion

There has also been some research into emotions that are shared between individuals. It is common for neuroscientists, psychologists, and sociologists alike to refer to what is called emotional contagion. Emotional contagion, which is sometimes also called emotional transmission, describes the idea that emotions in one individual can be spread to others. There is quite a bit of research supporting the existence of emotional contagion in both humans and other animals (Hernandez-Lallement et al. 2022, Sonnby-Borgström 2008, Kuang et al. 2019, Kimura et al., 2008, Parkinson & Simmons 2012, Zoratto et al. 2018). But while the discovery of emotional contagion has been a great breakthrough in social psychology and social neuroscience, theories of emotional contagion don’t necessarily describe the entirety of what interpersonal emotions might be (Wróbel & Imbir 2019, de Rivera & Grinkis 1986).

What Don’t We Know?

Metaphors to describe emotional contagion have typically been transmissive, not creatitive (fig 2D) (Hernandez-Lallement et al. 2022). Just like in disease contagion, where one individual’s illness is transmitted to another individual, much of the literature around emotional transmission describes the process as if an individual emotion from Person A is simply relayed into the brain of Person B. This obfuscates the possibility that interpersonal emotions are more complex than just the individual emotions of Person A as well as the individual emotions of Person B. There is reason to believe that, in fact, interpersonal emotions are not just a result of Person A’s individual emotions and Person B’s individual emotions, but rather emerge as a result of the abstract relationship between them (de Rivera & Grinkis 1986).

The metaphors we use to talk about science matter. The metaphors we use to speak about certain topics often belie our assumptions and biases around those topics (Lakoff & Johnson 2003, Sontag 1991). For example, scientific literature concerning reproductive processes has often painted a picture of a heroic, active sperm and a helpless, passive egg, when, in reality, egg cells have the ability to select which sperm will fertilize them (Martin 1991). Indeed, researchers have gone so far as to actually flip the naming conventions so as to make it seem like it is the sperm with a 'ligand' which binds to the egg's 'receptor,' when the egg actually has the ligand. Not only do these descriptions of the sperm and the egg reflect societal biases, they also perpetuate them. This story of the sperm and the egg becomes a part of sexual education, where students internalize harmful gender roles (Hendricks & Howerton 2011). This can affect their sexual and mental health for years to come (Sanchez et al. 2006, Fredrickson & Roberts 1997). This is not the only example of biased harmful nomenclature. When male researchers attempted to study orgasm in female apes, their definition of 'orgasm' only included orgasms occurring in male-female pairs, oblivious to the fact that the female-female and self-stimulated orgasms they observed should also be counted (Lloyd 1993). This also is a reflection of, and reinforces, societal stereotypes around human female sexuality as revolving around male partners, even though the incidence of orgasm in male-female sexual encounters is relatively low. Another example of metaphors in science is the way that social constructions of race have affected the scientific study of plant reproduction, and vice versa (Burns 2023). Mendellian heredity, specifically, having a male and female plant part each contribute their own alleles, having simple dominant and recessive traits, and having the ability to easily control what traits would be inherited in the offspring, was extremely appealing to 20th Century eugenicists. Proponents of eugenics, like Bateson and Davenport, thought that it would be possible to subdue the mysteries of nature and control the inheritance of social traits in humans in order to ‘evolve’ the human race towards white supremacist ideals. But Black thinkers pushed back against this intellectual racism, pointing out that most forms of inheritance are more complicated, and can involve both random mutations and more than just two alleles. They also looked to unruly and non-heterosexual forms of plant reproduction, such as examples of parthenogenesis, rhizomatic fruits, and grafting. Grafting in particular can also create hybrids of multiple species, allowing the grafted plant to take advantage of the beneficial traits of both species. These hybrids also troubled the eugenic paradigm, which is deeply troubled by human interracial reproduction. In this way, metaphors of plant reproduction were used both to perpetuate bias, and then later to fight against it. Indeed, the deeper one looks into the relationship between science and the language we use to describe it, the more clear it is that science and culture are co-constructed.

When speaking about social neuroscience being understudied, it isn’t enough to simply study social neuroscience more. Rather, as will be discussed more in upcoming sections, it is vital that future studies of social neuroscience keep the co-constructive nature of culture and science in mind.

WHY IS SOCIAL NEUROSCIENCE UNDERSTUDIED?

Cost & Technological Limitations

The easiest answer to this question would be to say that there have simply been too many cost and technological limitations, especially when it comes to studying collective neuroscience in humans. When studying collective neuroscience, it would be ideal to use a form of dynamic imaging technology. These technologies record changes in brain activity over time, so it is possible to see how brain activity changes in response to stimuli such as social interaction. It would be even better to image the brains of all subjects involved in social interactions, so as to see how the subjects influence each other in real time. This type of multi-brain measurement is called hyperscanning, and it is a relatively new technology (Valencia & Froese 2020). As an additional challenge, these types of studies would require figuring out a way for 'natural' interaction to occur between the individuals while they are all being imaged, which may be difficult. And the need for multiple scans per interaction would add to costs considerably.

The use of human subjects also adds to costs. Because of ethical standards around human research, many cheaper technologies common in animal research would be considered unethical. In lab animals, for example, it is common to repurpose special viruses in order to do what is called anterograde or retrograde tracing (Borowski 2022, Carlson & Birkett 2021). Because the virus can only spread through neurons that are activating each other, this technology allows researchers to then stain the brain sample for the virus, and by seeing where the virus is spread, also see the connectivity between neurons. For obvious reasons, this type of visualization technology would be completely unethical in humans! Not only does it require the use of viruses, but the staining process also requires brain samples to be excised and sliced before staining. This is just one example of a technology which is not permissible to use in humans. Ethical concerns limit the options for human study considerably.

Technologies used to study humans can be exorbitantly expensive. Even when cheaper alternatives exist, they may not be suitable for social neuroscience research (Borowski 2022, Carlson & Birkett 2021). For example, technologies like X-rays may only provide static snapshots of the brain at one point in time. This would not be ideal for studying change in brain activity throughout a social interaction. In other cases, when technologies do provide the proper type of dynamic imaging, they may have reduced quality or accuracy. For instance, PET may only give a vague sense of the location of neural activity, when more precision is required. For these reasons, there are times when expensive technologies simply must be used in order to obtain the information that researchers want.

Technologies of choice for dynamic neuroscience research on humans include fMRI, fNIRS, PET, EEG, and LFP (fig. 3), and employing these imaging techniques can cost many hundreds of dollars per hour (Borowski 2022, Carlson & Birkett 2021, Yale School of Medicine 2023, Tripment Health 2021, Costhelper 2023, "Functional near-infrared spectroscopy" 2023, "Local field potential" 2023, Agarwal 2023).

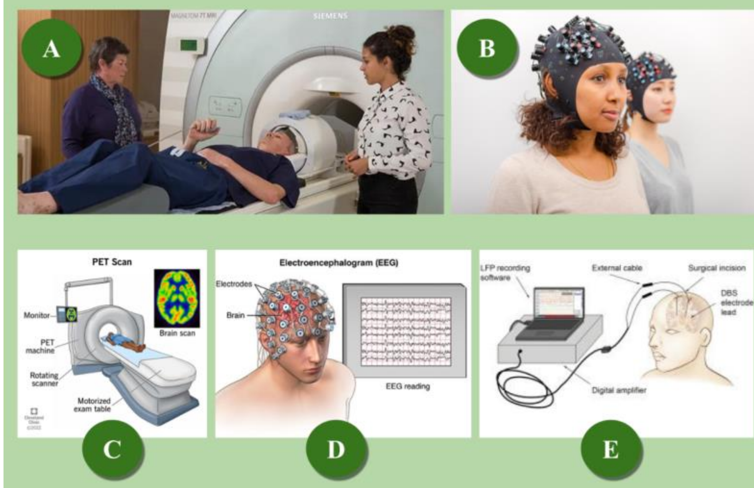

Fig. 3: Existing Research Methods in Social Neuroscience.

(A - E) Apparatuses used for fMRI, fNIRS, PET, EEG, and LFP (Nuffield Department of Clinical Neurosciences n.d., Brain Support 2023, "PET scan" n.d., Brain responses to structural violations in music and language n.d., Yin et al. 2021)

(F) How each method works (adapted from Borowski 2022, Carlson & Birkett 2021"Functional near-infrared spectroscopy" 2023, "Local field potential" 2023, Agarwal 2023)

F

Imaging technology	fMRI	fNIRS	PET	EEG	LFP
Description	Records magnetic changes in oxygen levels over time. Oxygen powers brain activity	Records optical changes in oxygen levels over time. Oxygen powers brain activity	Records changes in a radioactive tracer over time. The tracer binds to glucose, which powers brain activity	Records electric changes that occur when a neuron stimulates another neuron	Records electric changes in a region of neurons. This indicates changes in overall activity over time

When looking at the expense involved with these technologies, it is easy to understand why neuroscience research on humans can be incredibly inaccessible. But the technology does exist, and, as with many technologies, it will likely become more affordable and accessible over time (Flamm 2018). Even today, scientists are much more able to study social neuroscience than in the past (Dimensions 2023).

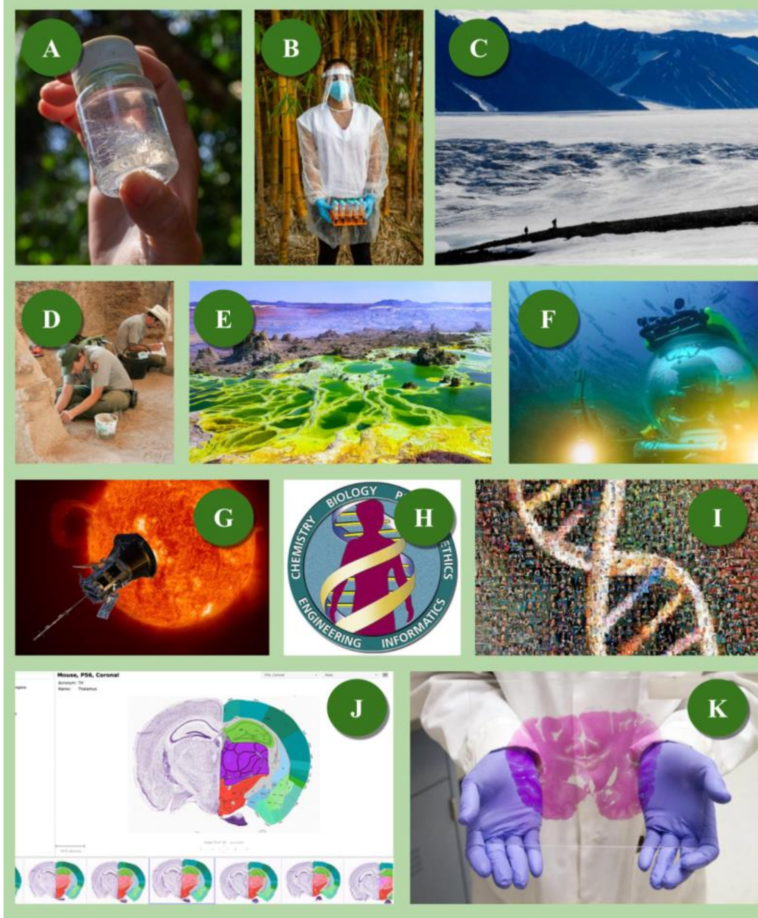

Fig. 4: Research at the Forefront of Science.

(**A - F**) Research in inhospitable environments (Grossman 2021, Pennisi 2019, National Park Service n.d., Robinson 2022)

(**G**) Research in outer space ("List of Solar System Probes" n.d.)

(**H & I**) The Human Genome Project ("Human Genome Project" 2023, Green 2021)

(**J & K**) The Allen Brain Institute studies mouse and human brains (Allen Brain Atlas n.d., Moore 2011)

This kind of research would be challenging, of course, but researchers have long conducted studies under far more unfavorable conditions than these. Scientific researchers have been on the forefront of some of the most costly and dangerous endeavors ever attempted. Researchers have explored vast ecosystems, from rainforests, to the desert, to the bottom of the sea (fig. 4A - 4F) (Grossman 2021, Pennisi 2019, Wattles et al. 2023). Researchers have built spacecraft in order to study other planets and solar systems (fig. 4G) ("List of Solar System Probes" 2023). And researchers are just as intrepid when it comes to studying the human 'ecosystem.' Take, for example, the Human Genome Project. Researchers for the Human Genome Project spent 2.7 million dollars and 13 years attempting to ascertain the complete genetic sequence of a single human genome (fig. 4H & 4I) (Mullin 2022). A similar project, seeking to map the features of a single human brain, was conducted by the Allen Brain Institute for a total cost of around 55 million dollars (fig. 4J & 4K) (Moore 2011). When considering the amazing skill and resourcefulness of scientists today, I simply do not believe that the gap in collective neuroscience research can be chalked up to only cost and technological limitations. Clearly, something else is limiting this research.

Science as a Cultural Construct of the West

One of the largest factors limiting social neuroscience research are the biases of the West. Science as a field, as we know it today, was invented in the West. It is a cultural construction of the West, and Western perspectives, such as individualism, are latent in the way that we study science even today.

Referring to science as a cultural construction may be controversial. So, in order to defend the idea that science is a construction of Western culture, it is important to consider two points. Firstly, that science as a field, along with all of its standards, norms, and methodologies, came to exist because humans invented it. Flawed humans invented it, and their own biases are ingrained into science as a field and a way of knowing. Secondly, even within the system of thinking that we call science, individual researchers are flawed humans, too. As such, the biases of the individuals and societies that conduct science are also incorporated into the canon we call our scientific knowledge.

The field of 'science' as we know it today wasn't invented all at once, rather, it has evolved over time (Shapin 2018). Some scholars believe that science has its roots in the ideas of Aristotle, a philosopher in Athens in the 4th Century BCE. Aristotle invented what is called deductive reasoning, where statements are laid out such that if they are all true, the conclusion made from them is necessarily true (fig. 5A) (Shields 2023). Other scholars attribute the birth of science to Galileo, a scientist in Florence in the 14th Century AD who further codified the scientific method, as well as applying deductive reasoning to experimentation (fig. 5B) (Machamer & Miller 2021). Still others would cite thinkers from the Scientific Revolution and Enlightenment periods in Europe (Shapin 2018, Encyclopedia Britannica 2019). For example, Descartes, a highly influential philosopher from Touraine in the 17th Century AD, who advanced empiricism in science (fig. 5C) (Hatfield 2023) . In truth, it was likely a combination of all three, in addition to the creation of science as an institution (Eduran & Dagher 2014).

However, because many of these foundational philosophers and scientists came from Western backgrounds, they imparted Western biases into science. Descartes, for example, subscribed to the theory of the closed body ("Indigenous intercultural health in Chile" 2020). This was the belief that the human body was a closed system, separate from and relatively impervious to outside influence. Remnants of this belief still exist in Western science today, where Western scientists tend to underestimate the interconnectedness between people and other people, as well as between people and their environment. Sciences informed by other cultures often place more emphasis on understanding the connections between humans as well as the flora, fauna, and geographical conditions that surround them in what is sometimes called a hybrid collectif (De Leon & Wells 2015). But the theory of the closed body is only one of the many cultural influences of these original Western thinkers of current Western science.

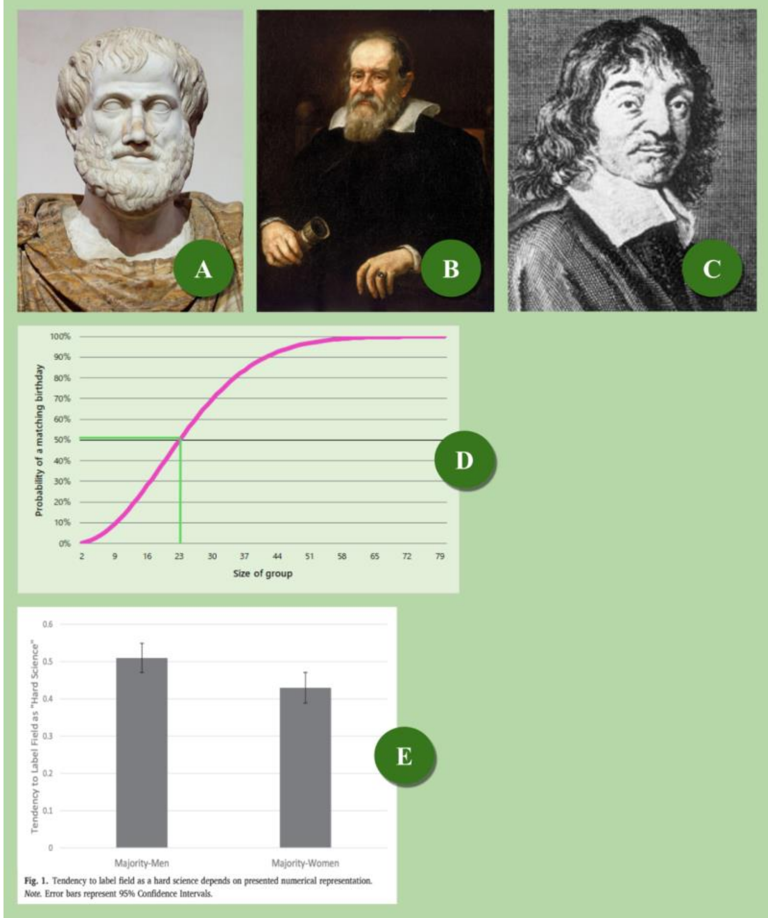

Fig. 5: Science as a Western Cultural Construction.

(**A - C**) Aristotle, Galileo, and Descartes (“Aristotle” n.d., “Galileo Galilei” n.d., Hatfield 2023)

(**D**) The birthday paradox (Farnworth 2020)

(**E**) Sexism in which fields are seen as ‘soft sciences’ vs ‘hard sciences’ (Light et al. 2017)

Western Science as Characterized by Distance and Difference

As noted by Kahnawà:ke Mohawk anthropologist Audra Simpson, one of the hallmarks of Western of science is the idea that good science must study phenomena through the lens of distance and difference (Simpson 2014, “Audra Simpson” n.d.). This principle applies both to how scientific hypotheses are formulated, as well as to ideas about the nature of the relationship between science and the world.

Western Biases in Hypotheses

Western scientific hypotheses tend to skew towards individualistic, atomistic, and simplistic interpretations of the world. There are certainly times when these ways of thinking are useful, such as when studying isolated, concrete phenomena, but there are other times when these tendencies severely limit the ability of Western science to understand whole systems.

Individualism describes a focus on individuals as opposed to relationships or groups (Grossman & Carlos Santos 2020). Individualism is just one way of thinking about individuals and relationships, and it is much more common in the United States and Europe (Fox 2020). Individualism has led to a field of neuroscience which has focused on studying single individuals, as opposed to social neuroscience.

Atomization describes the tendency to attempt to break wholes up into discrete parts, even when the parts themselves may be arbitrary or continuous in nature (Gould & Lewontin 1979). Atomization has led to the assumption that collective phenomena such as interpersonal emotions must be able to be explained simply through adding the effects of individual phenomena such as individual emotions, even when evidence indicates otherwise (de Rivera & Grinkis 1986).

Simplistic in this case describes cases where scientists may miss, or brush over, aspects of multifaceted phenomena. While this isn’t necessarily unique to the West, there are difficulties involved in studying phenomena that are very complex or multidimensional. One example of this is the tendency to assume that relationships are linear, as opposed to exponential or factorial

(Tanu 2020). A good example of this would be the birthday paradox (Bachman 2023, Science Buddies 2012). This is a situation where you ask a group of students in a class how likely it is that at least two people in their class have the same birthday. For many people, their first instinct when trying to answer this question would be to look at the problem through the lens of a single individual, simply comparing that one individual to everyone else in the room. However, the correct way to answer this question would be to use a factorial. This represents picking students one by one, and comparing them to all individuals who have yet to be picked. So a room of 23 students would actually have 22! = 253 comparisons, not 22 comparisons, making 23 students the threshold at which a room has a 50% chance of having a pair of birthdays (fig. 5D). A similar fallacy in thinking could be occurring in the study of interpersonal emotions, where scientists may not view interpersonal relationships as the network they truly are (Saggar 2020).

Western Biases in the View of Science's Role in Society

The Western cultural values of distance and difference also influence conceptions of science's relationship with identity, science's relationship with other academic fields such as the social and cultural sciences, and science's relationship with religion and spirituality. These values lead Western scientists to assume it is possible for science to be divorced from culture constructions, despite evidence to the contrary.

Western science is often portrayed as identity-neutral, with an impartial researcher studying phenomena from a distance (Simpson 2014). Importantly, though, only some identities have historically been considered to be 'impartial.' For example, research has shown that when participants were led to believe that a particular STEM field had more women, those participants were more likely to report considering that field to be a soft science as opposed to a hard science (fig. 5E) (Light et al. 2017). In other words, there is a perception that the same field is more or less rigorous and objective depending on who studies it. In the case of interpersonal emotions, both emotions and interpersonal emotions may be looked down upon by some as too nebulous or feminine in nature (Plant et al. 2000). This would certainly be an example of bias in Western science.

Western science in general, as well as its subfields, have historically been assumed to be siloed. This means that there has been a view that scientific subfields are, and should be, separate from each other, as well as from influences from other academic fields (Nature Biotechnology 2016). But to think this would be inaccurate. For example, there is an argument to be made that Western conceptions around economics and capitalism have influenced the study of interpersonal emotions. As mentioned before, Western science tends to talk about interpersonal emotions as if there are individual emotions which are then transmitted to another individual one at a time, as opposed to the science of other cultures, which may view interpersonal emotions as more of a network with bidirectional feedback occurring continuously ("Indigenous intercultural health in Chile" 2020, Sanjuan-Pastor 2023). These differences in perception actually mirror differences in economic systems. In the West, for example, the money system is transactional. There is an emphasis on equal exchange, such that no one individual gives more to another or receives more from another (Gregory 1982). In gift economies, however, such as the economy of the Trobriaders in Papua New Guinea, exchanges work very differently. Gifts are used to represent and strengthen familial and social bonds (Weiner 1988). Additionally, it is much rarer that gifts will be given on a one-to-one basis, with each gift having an equal worth. Instead, giving gifts of differing value, either greater or lesser, allows individuals to stay connected in a web of mutual indebtedness to each other (Gregory 1982). And, unlike in the West, this debt is not necessarily seen in a negative light. Rather, it is seen as part of what connects society together. If someone from Papua New Guinea, then, were to study interpersonal emotions, it is much less likely that they would subscribe to the individual transmission model that is favored by the West.

Western science is also often portrayed as secular. Interestingly, though, Western conceptions of secularism are actually quite specific to Chrisitan culture. There could be several reasons for this. One could be the fact that God and holiness in general are more concrete and set into the individual figures of the Father, Son, and Holy Spirit (Tuggy 2021). Another could be that Catholic Christianity especially emphasizes separation from God in a hierarchy, with individuals having to refer to a chain of superiors in order to speak with God ("Hierarchy in the Catholic Church" n.d.). But in cultures influenced by other religions, the idea that it could be possible to separate oneself from religion, almost as if it was a separate entity, would sound absurd. In Islam, for example, God is not seen as a single figure. Rather, every single aspect of life is seen as a part of God and a part of holiness (Shari'ati 1980). To study the science of the world, then, would necessarily be to study God. This is yet another example where Western culture does not acknowledge a larger continuous whole, which may influence Western conceptions of interpersonal emotions as well.

All in all, Western conceptions of distance and difference have clear flaws, and any claims that these principles make Western science superior should be examined critically (Simpson 2014, Latour 1993). In fact, the emphasis on supposed distance and difference from culture is, in itself, a cultural construction of the West. This provides strong evidence for the idea that science and culture are co-constructed.

ARGUMENT FOR THE INTERDISCIPLINARY APPROACH

Different Models, Different Insights

Science is a field, and like any other field, it has its own epistemologies. Epistemology is a word that describes how each field knows what it knows, or how each field uses evidence to build up to larger conclusions. Essentially, each field uses different models to understand the world around us (Kurzgesagt 2018).

We use models because they emphasize certain important information, but, by emphasizing certain information, other information is necessarily deemphasized. This can be seen even within the same field. Take, for example, the Bohr model of electron orbits. If you've taken an intro level chemistry class, you're likely to have seen this model, with concentric circles showing electrons revolving around the nucleus (fig. 6A) ("214.Molecular Model" n.d.). And this model is great for understanding a lot of the more basic ideas of chemistry. With it, it is possible to visualize in a simple way concepts like valence shells, or how many electrons a given atom can accept, as well as how different electron orbits have different energy levels. But this model also obscures a lot of how electron orbits actually work. In reality, electrons don't circle the nucleus in neat rings. Rather, surrounding the nucleus, there are a complex set of three-dimensional shapes, sometimes called clouds, where electrons are simply more likely to be at any given time (fig. 6B) (Holloway High School n.d.). This is called the quantum model of electrons. But this phenomena of differing models doesn’t just occur when creating physical maps. It also applies to theories and equations. In physics, for example, completely different models have to be used to understand phenomena that occur on different scales. Phenomena of the everyday, as well as large-scale phenomena across the universe, follow the rules of what is called classical physics. However, once you reach a small enough scale, the same materials appear to follow drastically different rules. This is called quantum physics. If this is confusing for non-physicists, it was even more confusing for the physicists who discovered that their classical model was woefully inadequate when studying quantum-level phenomena!

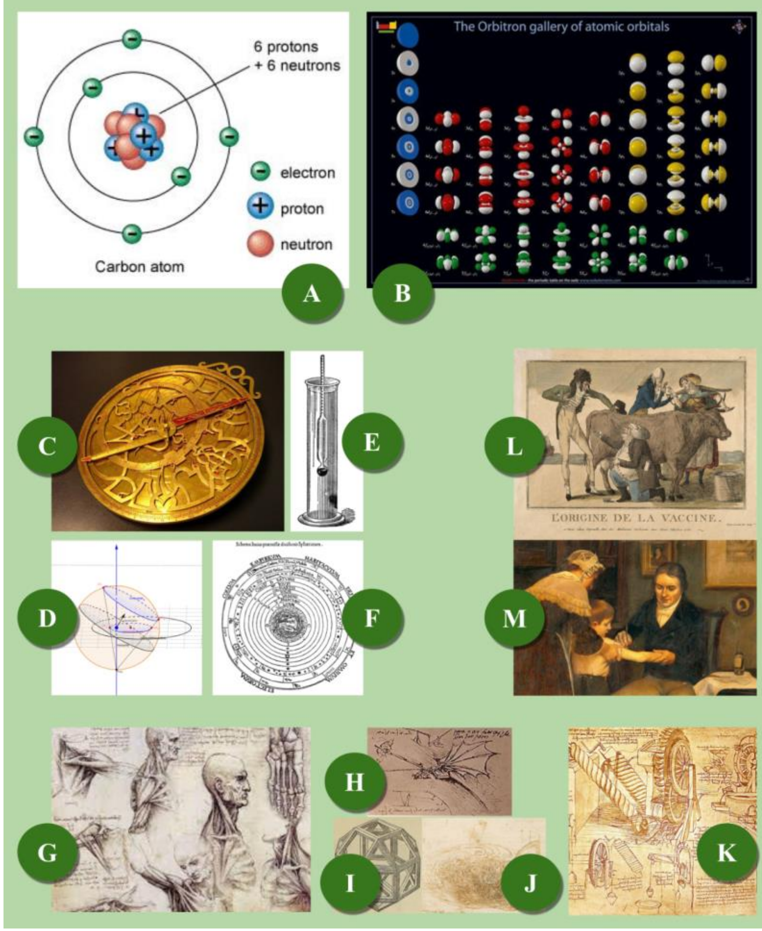

Fig. 6: Argument for the Interdisciplinary Approach.

(**A & B**) Bohr model vs Quantum Model of the atom (“214.Molecular Model” n.d., Holloway High School n.d.)

(**C - F**) Just a few of Hypatia’s many contributions to astronomy, philosophy, physics, and mathematics. She constructed astrolabes, part of the mathematics & geometry involved in creating an effective astrolabe, the hydrometer, astronomy (Lazarus 2022, “Astrolabe” n.d. “Hydrometer” n.d., “File: Ptolemaic System” n.d.,)

(**G - K**) Just a few of Leonardo da Vinci’s many contributions to fields such as anatomy, mathematics, chemistry, physics, and engineering. Studies of human anatomy, ornithopter flying machine model based on bat anatomy, the rhombicuboctahedron, studies of fluid dynamics, studies of water-based power systems (Particle Data Group n.d., “Ornithopter” n.d., “Leonardo da Vinci” n.d., “Fluid Mechanics” n.d., “Facsimile of Codex Atlanticus” n.d.).

(**L & M**) Edward Jenner’s invention of the smallpox vaccine after noticing the relationship to cowpox (University of Warwick, n.d., British Red Cross n.d.)

In a similar way to how these pairs of models study the same subject in different ways, different disciplines can also study the same subject in different ways. Upon watching the same social interaction occur in front of them, an anthropologist, a linguist, and a sociologist are likely to have very different takeaways. This is because they have each been trained to see certain aspects of interaction as important, and, necessarily, certain aspects of interaction as unimportant. One expert may not even notice something which appears vital to another expert. So what are we to do? It seems like no matter how much one expert knows, there will always be things that the expert takes for granted or ignores. And this is true! While we can never know everything about everything, by collaborating between different fields, we can at least introduce more perspectives and sources of information (Longino 1993).

The Interdisciplinary Approach in Action

It's not a coincidence that many of the great scientists have been so-called 'Renaissance men,' or, to put it more accurately, Renaissance people. That is, people who know a lot about, and draw inspiration from, a variety of fields. This is because experiences outside of the scientific tradition can lead to new inspiration and ideas.

Great thinkers like Hypatia and Leonardo da Vinci have often studied a variety of fields. Hypatia, who lived in Alexandria during the 4th Century, studied such disciplines as astronomy, philosophy, physics, and mathematics (fig. 6E & 6F) (History of Scientific Women n.d.). For example, Hypatia's deep understanding of geometry helped her to construct astrolabes, which were then used for navigation both via land and sea (fig. 6D & 6E) (Royal Museums Greenwich n.d.). Hypatia's contributions were so influential that even today there is an interdisciplinary academic journal in her name (Hypatia: A Journal of Feminist Philosophy 2018). Leonardo da Vinci, who lived in Milan during the 15th Century, also studied a vast number of fields, such as anatomy, mathematics, chemistry, physics, and engineering (fig. 6I - 6K) (Museum of Science n.d., "Da Vinci Inventions" n.d., "Leonardo da Vinci" n.d., "Scientific and Inventions of Leonardo da Vinci" n.d.). His knowledge of each field contributed to his overall creativity. For example, da Vinci employed knowledge about the anatomies of bats, birds, and other animals when designing prototypes for flying machines (fig. 6G & 6H) ("Leonardo da Vinci's Flying Machine Invention" n.d.). For both Hypatia and Leonardo da Vinci, then, having an understanding of multiple fields contributed to their ability to be creative and expand beyond the horizons of existing knowledge.

Other academic disciplines aren't the only source of interdisciplinary inspiration. A good example of this would be the invention of the first vaccine by Edward Jenner in Gloucestershire in 1796 (CDC 2021, "Edward Jenner" 2023). While it is true that vaccines work through a complex biomedical process, stimulating the immune system to form a preemptive defense for a given illness, the invention of vaccines wasn't based on careful research of microbiology. Instead, scientist Edward Jenner came up with the idea for the smallpox vaccine by noticing a pattern in his everyday life. During this period of history, smallpox routinely killed around 10% of the population. It was impossible to make one's way through life without encountering smallpox, as well as its deadly consequences. What Jenner noticed was a strange pattern in who was and wasn't dying of the disease. Specifically, Jenner noticed that milkmaids, for whatever reason, didn't appear to be dying from smallpox (fig. 6L). When investigating further, Jenner realized that this immunity to smallpox appeared to stem from prior contraction of the related, but much less deadly, cowpox virus. Upon realizing this, Jenner started experimenting. In the end, Jenner found that he could produce immunity to smallpox by purposefully infecting patients with the cowpox virus (fig. 6M). The exposure to the cowpox virus primed their immune systems, allowing them to more quickly and effectively defend themselves from smallpox. Because of this discovery, and the consequent rollout of smallpox vaccines worldwide, smallpox as an illness has been completely eradicated (WHO n.d.). This was a monumental achievement in the history of science, and it just goes to show that the scientific process isn't always as siloed or sterile as it seems. Sometimes the most banal or seemingly unrelated observations are the ones that have the greatest effect.

Deconstructing Western Epistemologies as a Means for Bias Reduction

Importantly, many other fields have already started to deconstruct Western bias, in a process that is sometimes called decolonization (Held, 2023). Decolonization is an ongoing process involving the incorporation of a variety of perspectives and backgrounds into fields that have historically had a Western bias. Experts from disciplines that have already done work to deconstruct bias may notice gaps in knowledge in scientific research that scientists themselves do not. This includes experts from other disciplines that were founded in the West, such as psychology and anthropology.

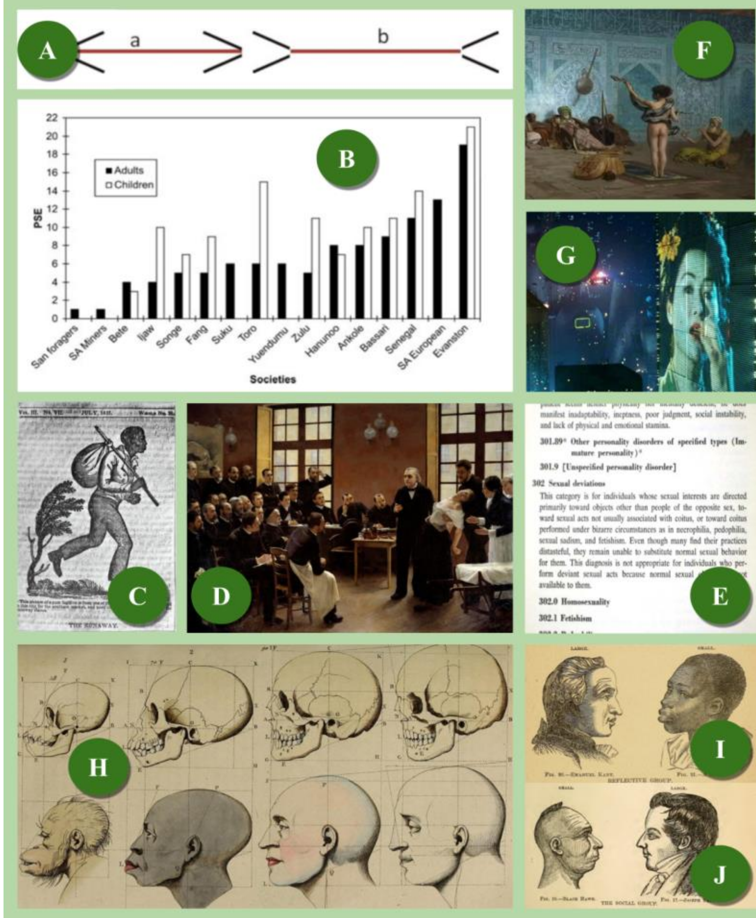

Fig. 7: Deconstructing Bias in Western Epistemologies.

(**A & B**) The Müller-Lyer Illusion shows that phenomena as simple as sight perception vary by culture (Henrich et al. 2010)

(**C-E**) Depictions of drapetomania, hysteria, and sexual deviancy ("Drapetomania" n.d., Cleghorn 2021, Nuckols n.d.)

(**F & G**) Orientalism in depictions of the Middle East and East Asia (Said 1978, McIntosh 2022)

(**H - J**) Phrenology, racism, and white supremacy in neuroscience (Wiedeman 2017, Wells 1891)

Psychology has already undergone a lot of work to combat Western bias. One part of the issue with psychology in particular is that the majority of psychological studies have been conducted on individuals from Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies (Henrich et al. 2010). Research on these populations is still valuable, no one is disputing that. The problem arises when psychologists use research primarily conducted on WEIRD societies and extrapolate that the findings of these studies must apply universally to all cultures and societies. This is not the case, and many psychological findings simply fail to replicate when conducted in another cultural context (Milfont & Klein 2018).

One might expect more complex psychological phenomena to fail to replicate, but even simple phenomena can vary from culture to culture. One extremely simple example is how long individuals would guess that a given line is. When given the Müller-Lyer illusion (fig. 7A & 7B), people who grew up amidst very square, angular architecture were indeed fooled into thinking that line B was longer than line A. But people who grew up amongst more natural, rounded surroundings weren't susceptible to the illusion at all. Before conducting a study like this, one might take for granted that, of course, everyone would perceive the line to be the same length. But that isn't true. And if something as simple as how long we think a line is can vary based on culture, who knows how many differences might exist between cultures? And who knows how many phenomena we assume are universal simply aren't?

In more recent years, there has been an attempt to divide psychology, so that each culture has its own unique set of principles. This division avoids the tendency to view principles from WEIRD psychology as universal, and does allow for more diversity between cultures. But there are still some issues with this solution in practice. Because it is impossible to study every single culture in existence, psychologists tend to lump cultures into groups. This can quickly become problematic. In today's social psychology, for example, it is common to divide societies into either the Western, individualistic category, or the Eastern, collectivistic category (Grossman & Carlos Santos 2020). Individualistic societies, located in Europe and North America, are said to view the individual as having the utmost importance. Individualistic societies typically value independence and personal autonomy. Collectivistic societies, located in East Asia, are said to place the highest value on interpersonal relationships. Collectivistic societies tend to place emphasis on interdependence, harmony, and the well-being of the group. When cultures from Latin America, Africa, and other regions are included at all, they are generally lumped into the category of collectivistic societies, making ‘collectivistic’ almost synonymous with ‘non-Western.’ These are vast generalizations, and the idea of putting around 86% of the world’s population into the single category of ‘collectivistic’ is absurd (Worldometer 2023). The efforts to diversify psychological research are good, but it is important that psychologists continue to study cultural differences with nuance and depth.

Another part of the bias in psychology has been attributed to a skew in who has been conducting psychological research. Psychological researchers, who have often been heterosexual, cisgender men from WEIRD backgrounds, have had a tendency to medicalize phenomena which didn’t ‘make sense’ under their frameworks (The Chicago School 2021, Hegarty 2021, Foucault 2001, Foucault 1977). This means that these psychologists essentially made up mental illness diagnoses for people whose existences, lifestyles, goals, and beliefs did not match their own. For example, in 1851, American psychologist Samuel Adolphus Cartwright came up with the term Drapetomania to describe the so-called psychological disorder of enslaved African Americans wanting to escape (fig. 7C) (Broyld n.d., “Diseases and Peculiarities” n.d.). Because of Cartwright’s own bias, he was either unable or unwilling to see wanting to be free as a natural response a human being would have under such circumstances. In another example, European psychologists in the 1800s and 1900s created the diagnosis of Hysteria to explain situations where women acted in a way that didn’t fit their assigned social role (fig. 7D) (Tasca et al. 2012) This included such transgressions as being loud, being difficult, being overly sexual, or just generally suffering from any kind of unexplainable physical or mental distress (Tasca et al. 2012, M. 2017, Young et al. 2019). Hysteria, then, was used as a catch-all term created by men who wished to regulate unruly women. Hysteria went so far as to be added to the second edition of the Diagnostic and Statistical Manual (DSM) in 1968 (Medical News Today 2020).

This is particularly significant because the fifth edition of the DSM is the gold standard of psychological diagnosis to this day (American Psychiatric Association n.d.). But Hysteria is not the only biased entry that has made it into the DSM. In both the first and second editions of the DSM, the definition of Sexual Deviations included anyone who felt sexual interest in an individual who was not "of the opposite sex" (fig. 7E) (Nuckols n.d.). In other words, the DSM declared homosexuality, and all other queer sexualities, to be a mental illness for more than two decades ("DSM-5" n.d.). While homosexuality has since been removed from the DSM, this does not mean that bias no longer exists in psychology or other Western sciences. Instead, the cases of Drapetomania, Hysteria, and Sexual Deviations should be taken as an indicator that contemporary researchers, too, ought to examine their biases.

Anthropologists have also spent a lot of time trying to decolonize their field. The specific focus on decolonization in anthropology is in part because of the controversy about the existence of anthropology as a field. Anthropology, or the study of culture, began as an enterprise of Western intellectuals who wanted to catalog cultures that they saw as foreign or other (Simpson 2014, Tremlett n.d.). This Western colonial perspective shaped the vast majority of early studies in anthropology. The colonial perspective can be summarized as follows: Western society is the default and the ideal; other societies are either less developed, and should be looked down upon, or more developed, and should be exoticized and feared. The pattern of seeing the West as the default and looking down on other cultures is called Eurocentrism (American University 2020, "Eurocentrism" 2023). The pattern of fetishizing and fearing other cultures is a form of a phenomena called Orientalism (Said 1978, Roh et al. 2015).

Examples of Eurocentrism are everywhere. To give one example, historically, when anthropologists have studied traditions of dance throughout the world, they have applied a

Eurocentric lens. In the world of dance, Western dance styles like ballet have been viewed as the default, the ideal, and the universal (Kealiinohomoku 1970). In dance schools, the majority of dancers are expected to know about ballet, a dance with origins in Italian, French, and Russian cultures. However, dancers are not expected to know dance styles from non-Western cultures, such as the Hopi snake dance. This expectation places Western and non-Western dances into different levels of prestige. And the same expectation extends into how Western anthropologists have described the value of Western versus non-Western dance. Dances like ballet are highly idealized, often described as elegant and sophisticated. Non-Western dance styles, on the other hand, have often been described as disorganized, primitive, and animalistic. Finally, there has been a tendency in the anthropology of dance to view Western styles as the universal. In other words, there has been a view that Western dance styles like ballet have somehow transcended the cultural contexts in which they were created. Western anthropologists would never have dreamed of describing ballet as an 'ethnic,' 'cultural,' or 'folk' dance, despite placing these labels on non-Western dance. And yet, that's exactly what Western dance is. Ballet terminology is rife with French language and expressions. And ballet performances often tell stories related to Christian beliefs and traditions. Every dance style is a reflection of the culture where it was created. Western styles are cultural dances just as much as non-Western dances are.

Examples of Orientalism are also widespread. The term Orientalism was first coined by Palestinian academic Edward Said in 1978 (Said 1978). Upon entering academia, Said noticed a troubling pattern in the way in which Western anthropologists were discussing the Middle East. Said noticed that Western anthropologists would describe the Middle East as simultaneously mysterious and exotic, while also describing it as scary, backwards, stagnant, and underdeveloped (fig. 7F). And this pattern of Orientalism exists in more than just depictions of the Middle East. More recently, East Asian scholars have pointed out a similar pattern in how anthropology, literature, and popular media have depicted Chinese and Japanese culture (Roh et al. 2015). In these realms, Chinese and Japanese aesthetics are often used to represent the Western apprehension about an increasingly technological future (fig. 7G). In research and nonfiction, East Asian cultures are portrayed as a threat to Western society: both superhumanly smart while also lacking personality or human qualities (Linshi 2014). In fiction, dystopian stories often take place in vaguely Asian-inspired cities, and Chinese and Japanese individuals are frequently portrayed as alien, robotic, or otherwise not human (Roh et al. 2015). East Asian academics have already been working to try to dismantle these Orientalist perceptions. As biases have evolved, Western anthropology has had to continually work to deconstruct them.

Because of this history, anthropology today is a very different field. While it is impossible to eliminate Western bias completely, anthropology is a lot less biased than it used to be. This is in part due to the emphasis on what is called insider anthropology (Liu & Burnett 2022). In insider anthropology, anthropologists study their own cultures of origin, rather than projecting their own biases onto outside societies.

There have been some efforts to decolonize neuroscience, such as the debunking of phrenology. Phrenology, founded in the 1790s, was a pseudoscience that claimed to use cranium shape as an indicator of traits such as virtue and intelligence. Concerningly, phrenology was used to perpetuate racism and white supremacy (Greenblatt 1995). Phrenologists claimed, despite evidence to the contrary, that different races had different head shapes, and used this to argue that non-White races were inferior or less developed. Phrenology diagrams often depicted non-White individuals as closer to apes and therefore more primitive (fig. 7H - 7J) (Wiedeman 2017, Wells 1891). After a countermovement in the 1840s, phrenology is widely considered to be a pseudoscience and a stain on neuroscience research (Greenblatt 1995). This countermovement was a good start, but phrenology is far from the last relic of Western colonial bias in neuroscience.

Even today, some neuroscientists continue to perpetuate misogyny and cisheterosexism in science. The phrases ‘male brain’ and ‘female brain’ have become increasingly popular in research and popular culture, despite evidence that no such binary exists (Hignett 2018, Glezerman 2016, Rosalind Franklin University of Medicine and Science 2021). While it may be true that some neuroanatomical features are more common in women or men, there is a lot of overlap, such that some women would have more ‘male’ brains than some men, and some men would have more ‘female’ brains than some women (Joel et al. 2015, Joel 2021). Additionally, these concepts ignore a lot of nuance around gender, sex, and biology. Both human bodies and human brains can vary across several spectrums. Intersex individuals, who make up around 1% of the world’s population, challenge a male-female brain binary which has no place for them (Gold 2001, McLaughlin et al. 2023). Intersex individuals can have a variety of biologies that fall between what we would normally call male or female biology, including variation in sex chromosomes, variation in hormones, and variation in primary and secondary sex characteristics. Similarly to people of all other sexes, intersex individuals can have a variety of neuroanatomy (Joel et al. 2015, Joel 2021). Descriptions of the ‘male brain’ and ‘female brain’ also tend to leave out transgender and gender diverse individuals. For example, research suggests that while most individuals contain a mosaic of male-typical and female-typical neuroanatomy, many transgender women have brains that are on average less similar to the stereotypical ‘female brain’ than their cisgender counterparts (Kurth et al. 2022). All of this goes to show that neuroscience is complicated, and research into topics like sex and gender still need to be examined for bias.

Neuroscientists could stand to learn a lot from the insights of psychology and anthropology. By empowering people from a greater variety of backgrounds to become neuroscientists, we can gain valuable perspective. To this end, neuroscience should become a more inclusive field. Research indicates that reducing institutional barriers in the sciences, such as the cost of education and the lack of accessibility of neuroscience resources, significantly improves the retention of under-represented minorities in STEM (Woods 2023). This applies to race and ethnic minorities, but also women, queer people, and others. Changes like these are important because research has shown that diversity of race, ethnicity, and cultural background have the most outsized influence on paper impactfulness in terms of paper citations (fig. 8A) (AlShebli et al. 2018, Powell 2018). And other forms of diversity, such as gender and academic discipline, have also been shown to lead to more impactful research (Powell 2018). The subjective perspectives of researchers affect what types of hypotheses they tend to study (Okruhlik 2015). It could even be argued that as more and more perspectives are incorporated into science, we can improve the objectivity and rigorousness of science as a field (Longino 1993).

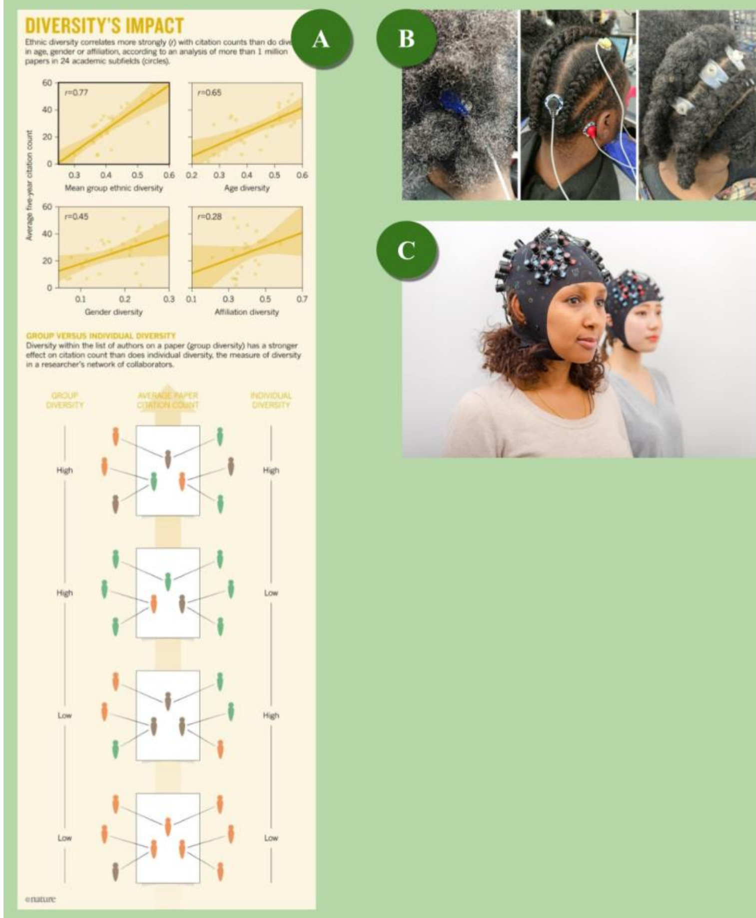

Fig. 8: Diversity in Researchers & Study Populations.

(**A**) Diversity, in particular ethnic diversity, improves scientific research (Powell 2018)

(**B & C**) Need for improvement of EEG on textured hair and fNIRS on darker hair and skin (Nadin 2020, Brain Support 2023).

Besides diversifying researchers themselves, running studies on more diverse cohorts may illuminate how people with different life experiences have different reactions to the same stimuli (Aronson 2013). But, in order to do this, research methods may need to be improved. Many current research apparatuses, such as EEG and fNIRS, were created to study white populations. These technologies are often less accurate when studying non-white populations, such as individuals with textured hair, darker hair, and/or darker skin (fig. 8B & 8C) (Nadin 2020, Doherty et al. 2023). Recently, there has been a great effort by young Black scientists to improve these technologies (fig. 8B). But continued efforts to make neuroscience more inclusive should still be a priority.

Altogether, improving diversity in neuroscience research can only provide better and more nuanced understanding of concepts in neuroscience.

Employing Alternative Epistemologies as a Means for Bias Reduction

Another important point is that not all epistemologies stem from a Western context, and, as such, they may not need to combat Western bias. Indigenous knowledge systems are a great example of this. Science as it is constructed in the West is one of many cultural forms of science, and it should not be taken as the only valid knowledge system. Although indigenous knowledge systems may not employ the same methodologies and ways of thinking as Western scientists are used to, this does not mean that they aren't valuable or rigorous. Rather, Indigenous knowledge systems often contain wisdom that people from the West have a hard time understanding and appreciating (Simpson 2014, Bhambra 2015).

The phrase "indigenous science is science" is used on social media to bring awareness to the fact that indigenous knowledge systems hold valuable insight (Held 2023, Jenson 2022, reid 2022, Uluak n.d.). Indigenous sciences pass down information about the world from generation to generation. This information is not only just able to predict future events, but it can also be used in practice.

Many indigenous science systems prioritize passing down information so that new generations can utilize and build off of prior knowledge. This just may not occur in the form of written journal articles. Instead, information may be passed down in the form of oral storytelling, quipus with words coded into their knots, maps, or art, just to name a few (fig. 9) (Molenaar

2020, Favela 2021, Phillips 2014, "Inca Science, Innovation, & Technology" n.d., Thompson 2016, Wroe 2021, Ho 2023, Wilkinson 2023, University of Edinburgh 2018, "Astronomy in Africa" 2020).

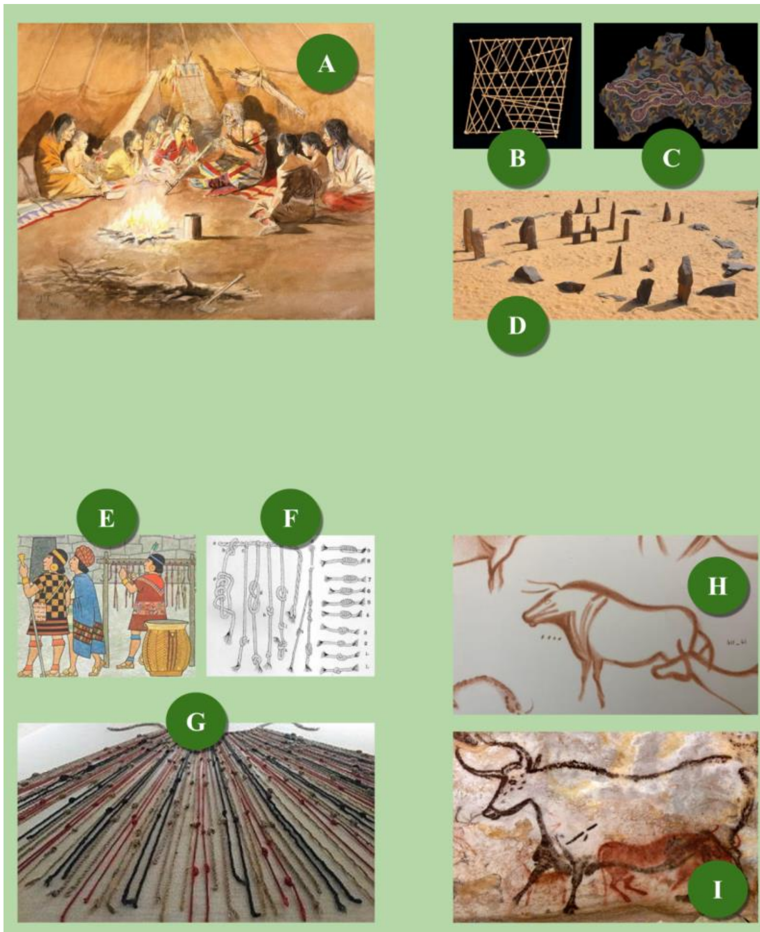

Fig. 9: Alternative Epistemologies Pass Down Knowledge.

(**A**) Passing down information orally. Storytelling all over the world (Molenaar 2020)

(**B - D**) Passing down information through maps. Aboriginal myths include geography, Polynesian stick charts use maps of the stars to aid navigation while at sea, Egyptian stone calendar tracks time via the positions of celestial bodies (Wroe 2021, Thompson 2016, "Astronomy in Africa" 2020)

(**E - G**) Passing down information through textiles. Incan quipus ("Inca Science, Innovation, & Technology" n.d., Phillips 2014, "File: Quipo" n.d.)

(**H & I**) Passing down information through art. Spanish & French cave paintings track animal breeding cycles (Wilkinson 2023, Ho 2023)

Many of these knowledge systems use evidence from the world around them to make educated predictions about the future. For example, even before science was invented, groups indigenous to the European continent were conducting science when they tracked and recorded the breeding cycles of animals (Ho 2023). Paintings depicting this knowledge still exist today, and continue to accurately predict animal life cycles. Indigenous cultures have studied and put into practice knowledge from a variety of other fields, including agriculture, ecology, physics, chemistry, architecture, and engineering (see fig. 10D - 10K for more information) (National Science Institute 2005, Indigenous Fellowship of Hamilton Road 2016, Cartwright 2015, National Park Service 2023, Apostos 2017, Hansen n.d., British Broadcasting Corporation n.d., Dawson 2010).

And almost every culture has some form of indigenous medicine, from traditional Chinese Medicine, to Ayurveda, to Muthi (“Traditional Medicine” 2023). Europe has its own forms of indigenous medicine as well (“Medieval medicine of Western Europe” 2023). Healers around the world have learned over time to use native flora to treat a myriad health issues, recording a causal link between chemical compounds in plants and health outcomes in patients. When these plant remedies are analyzed chemically, it is indeed possible to isolate compounds with therapeutic value, like morphine from the poppy plant and neferine from lotus seeds (fig. 10A - 10C) (“Traditional Medicine” 2023, Punia Bangar 2022, Li & Weng 2017). Astonishingly, about 40% of pharmaceutical compounds used in Western medicine today have their roots in traditional plant medicines (WHO 2023). It is highly likely that further study into traditional medicines would yield viable treatments that Western medicine is unaware of.

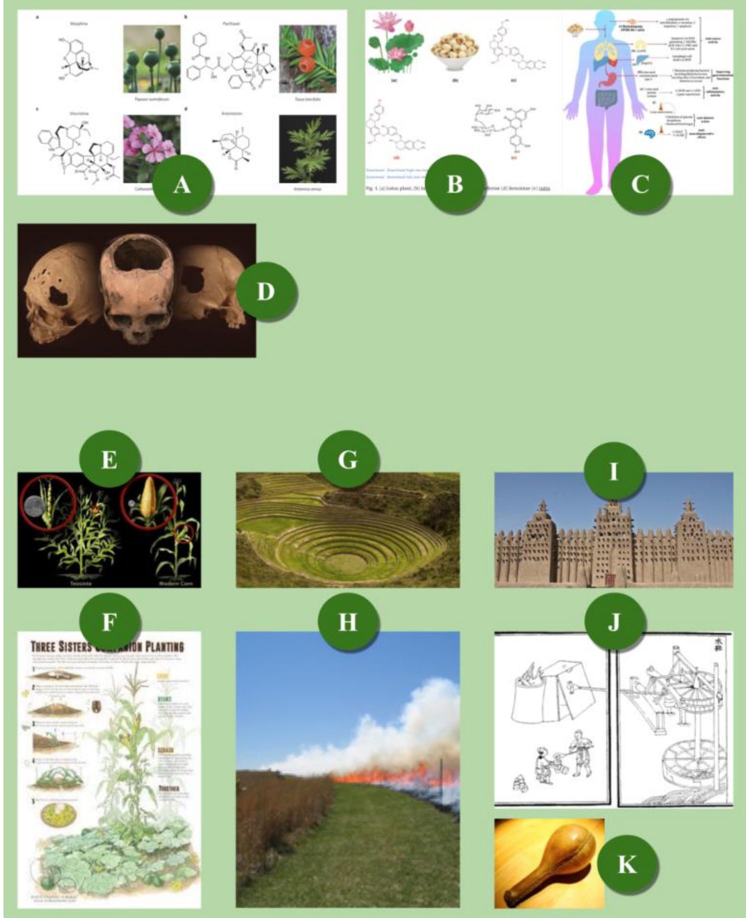

Fig. 10: Alternative Epistemologies Predict Future Occurrences & Put Science into Practice.

(**A - C**) Administration of medicinal compounds in traditional medicine across the world (Punia Bangar 2022, Li & Weng 2017)

(**D**) Incan brain surgery techniques (Daley 2018)

(**E - F**) Agriculture. Native Oaxacan genetic engineering of maize via selective breeding. Haudenosaunee nitrous soil fertilization via companion planting (National Science Institute 2005, Indigenous Fellowship of Hamilton Road 2016)

(**G - H**) Ecology. Incan terraforming. Native American, Native Alaskan, & Native Hawaiian controlled burning to improve ecosystem health (Cartwright 2015, National Park Service 2023)

(**I**) Songhai thermodynamics, architecture, & engineering (Apostos 2017)

(**J**) Chinese engineering, chemistry & metallurgy (Hansen n.d.)

(**K**) Nuche generation of light using quartz crystals, also known as mechanoluminescence ("Triboluminescence" 2023)

Indigenous sciences should not be underestimated. The Western world, and Western science, tend to underestimate the power of indigenous sciences (Simpson 2014). Oftentimes, it will take Western scientists years to 'discover' phenomena that indigenous peoples already knew about. Take, for example, the fact that controlled burns of forests can improve ecosystem health (National Park Service 2023). Or the fact that after thousands of years of Māori storytelling about voyaging to Antarctica, it has only recently been 'confirmed' by science that the Māori have indeed been visiting Antarctica thousands of years before Europeans (Triponel 2021, Wehi 2021). The Western world often tends, wrongly, to assume that indigenous sciences are a thing of the past (Luger 2018). But this is not the case. Indigenous scientists from around the world continue to make scientific breakthroughs (Powell 2018).

Clearly, the Western practice of science is not the only form of science out there. When scientists who have been trained in the West study phenomena, it is important that they respect the sciences of other cultures. Western scientists also ought to learn from the sciences of other cultures when it is possible to do so without harming the cultures that they come from (Duke Law n.d. Robbins 2018, Zabari 2019). And, when possible, use of these indigenous sciences should also empower indigenous communities (Dirik 2022, Andrea Wolf Institute 2022, Simpson 2014).

In the case of social neuroscience, scientists could glean valuable insight from indigenous models of the body, brain, and mind, as well as ideas from other cultures around social interconnectivity. Interestingly, when it comes to these topics, many indigenous sciences emphasize two things that current Western science does not. Firstly, many indigenous sciences emphasize a balance between a variety of forces. And secondly, many indigenous sciences emphasize that we as human beings are not separate from our geographical and social environments. This differs from Western science, which has typically subscribed to Descartes' model of the body as a singular unit which is closed and divided from its environment, and tends to emphasize distance and difference ("Indigenous intercultural health in Chile" 2020, Simpson 2014). Examples of focus on balance and integration can be found all over the world.

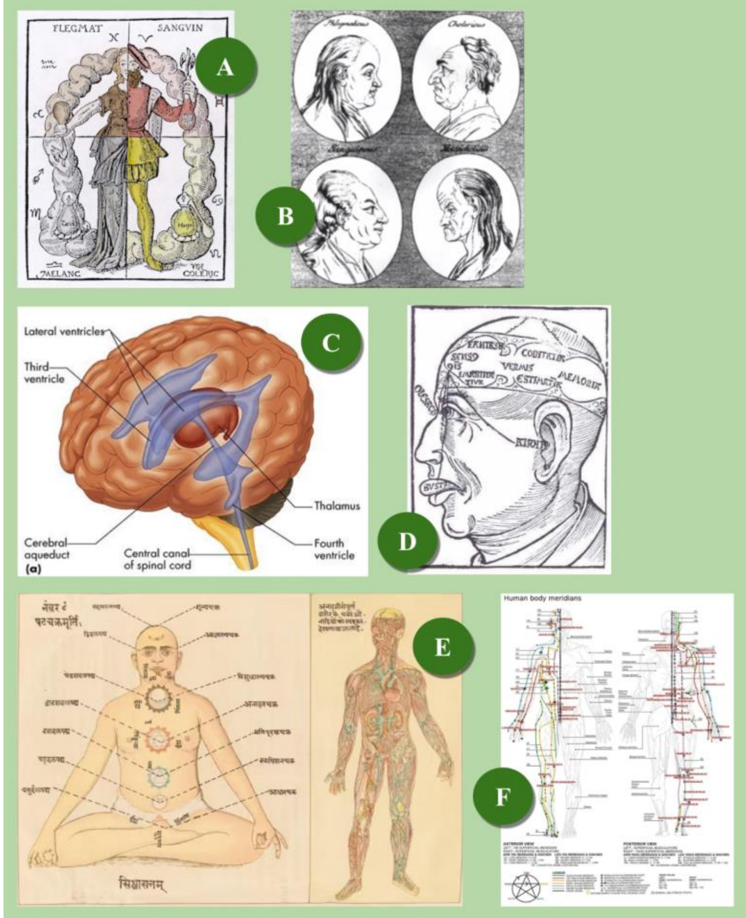

Fig. 11: Alternative Models of the Body & Mind

(**A & B**) Greek, Roman, and European concept of the four humors & four temperaments, popularized by Hippocrates ("Hippocrates & the humors" n.d., Smith 2021)

(**C & D**) Byzantine, European, & Middle Eastern aqueduct model of the brain, popularized by Nemesius (Keeley & Scott-Kalkures 2020, Parry 2018, Bailey 2016)

(**E**) Ayurvedic chakras and the three doshas (Newcombe 2017)

(**F**) Chinese Qi (气) Meridians ("Meridians (Chinese Medicine)" n.d.)

Beginning in Ancient Greece, through the Roman Empire, and into the Medieval period, European indigenous sciences subscribed to the Four Humors model ("Ancient Theory of Elements and Humors" 2023, Harvard Library n.d.). In this model, the body is host to four main fluids. Each fluid was associated with a particular bodily state, as well as a particular relationship with the environment (fig. 11A). Blood was associated with the spring season, and as such with illnesses that were hot and wet. Yellow bile was associated with the summer as well as with illnesses that were hot and dry. Black bile corresponded to the autumn and to illnesses which were cold and dry. Finally, phlegm was associated with the winter and illnesses that were cold and wet. This theory also extended to mental health, where it was said that there were four main temperaments (fig. 11B) (Smith 2021). In this case, it was believed that an excess of a particular humor would lead to an excess of a certain temperament. Too much blood led to hyperactivity, happiness, and mania, too much yellow bile led to hypoactivity, too much black bile led to melancholia and depression, and too much phlegm led to anger (Duchan 2023). Good physical and mental health, then, would rely on balance within oneself as well as with one's environment.

Likewise, beginning in the Byzantine Empire, European and Middle Eastern indigenous sciences tended to have a fluid-based view of the brain. Nemesius is credited with creating this aqueduct-like model (Keeley & Scott-Kalkures 2020). He theorized that different functions were localized in different fluid-filled ventricles of the brain (fig. 11C & 11D). According to this theory, the two lateral ventricles were involved in perception, the middle ventricle was involved with cognition, and the posterior ventricle was involved in memory. Here, too, different fluids were associated with different aspects of human functioning. To damage one ventricle, then, would be to impair the body and put it out of balance (Parry 2018, "Nemesius of Emesa" n.d.).

In Ayurveda, Siddha, and Unani, which have roots in South Asia and the Middle East, there is also an emphasis on the balance of different elements, sometimes called doshas (दोषः) (fig. 11E) (Jaiswal & Williams 2017, Newcombe 2017, Kandula & Tirodkar 2018, Raul & Padvi 2021, Travis & Wallace 2015, "Dosha" n.d.). In Ayurvedic tradition, each person has own unique composition of these doshas, called their prakruti (प्रकृति). Each element serves important functions for human life and health. However, if the elements become imbalanced, it can lead to sickness and mental health issues. Vata (वात) is the element of wind, and it is associated with cold, dry environments. Vata regulates kinetic activity, or movement. Vata also regulates catabolism, or the breakdown of larger substances into smaller parts that the body can use. It is associated with longevity and flexibility. However, when individuals have too much Vata, they may experience physical health issues like fainting, dehydration and dry skin, as well as mental health issues like anxiety or fear. Pitta (पित्त) is the element of fire, and it is associated with hot environments. Pitta serves to regulate body heat and metabolism. Pitta is also said to be the source of intelligence and understanding. However, when there is too much of it, it can lead to issues like fever and pain, as well as jealousy, hatred, and anger. Kapha (कफ) is the element of water. It serves to regulate bodily fluids and the immune system. It is also associated with love, vitality, serenity, and memory. But when there is too much Kapha, individuals may lead to heaviness, coldness, drowsiness, and delirium, as well as issues like greed, envy, and unhealthy attachments. In order to restore balance between the doshas and improve health, practitioners of Ayurveda will often suggest changes to a patient's social environment, physical environment, exercise, or diet.

In Chinese traditional medicine, energy (气) is said to flow throughout the body, and specific meridians or paths of energy are associated with each of the five elements (fig 11F) (Ling 2020, Liao et al. 2017, “Meridian (Chinese Medicine)” n.d., “Wuxing (Chinese philosophy” n.d.). The elements are wood (木), fire (火), metal (金), earth (土), and water (水), and imbalances in these elements can lead to dysfunction in both external, physical systems (腑) and internal, emotional systems (臟). Chinese medicine seeks to rectify these imbalances by targeting the elements via interventions such as acupuncture, introspection, diet, exercise, clean environment, and social connection (Koithan & Wright 2010).

In the Mapuche, Quechua, and Aymara cultures of South America, mental and physical health are seen as innately intertwined with one’s social network (“Indigenous intercultural health in Chile" 2020). Physical illness and mental unwellness are believed to stem from a lack of harmony between the self, others, and the environment. As such, when someone in one of these communities is having issues, one of the first reactions is to try to heal their relationship with their community (Sanjuan-Pastor 2023). It is in the past few years that Western research has confirmed that community is indeed an effective way to aid the healing of physical and mental health issues (Pressman et al. 2005, Rediger et al. 2020, Rohrbaugh et al. 2008). The tendency to look to one's community for healing, which does not exist in the West, may speak to the power of interpersonal relationships and emotion.

It is clear that indigenous sciences are valuable in many realms of study, and would be incredibly valuable for interdisciplinary study. In the future, more in-depth study of these models could be particularly informative to social neuroscientists, as they may elucidate environmental and interpersonal influences on the body, brain, and mind. As such, they may hold insight into the biopsychosocial bases of interpersonal emotions.

ARGUMENT FOR THE INTERDISCIPLINARY APPROACH TO INTERPERSONAL EMOTIONS

Now that the value of interdisciplinary study more generally has been established, let us proceed in more detail into the argument for interdisciplinary study of social neuroscience, and, more specifically, interpersonal emotions. One important reason for interdisciplinary study is the ambiguity about what, exactly, and emotion is. Perhaps unsurprisingly, the answer to this question depends a lot on what discipline you come from. This is one of the huge reasons that the integration of many disciplines has added a lot of value to more recent study of interpersonal emotion, which has integrated such disciplines as phenomenology, sociology, psychology, biology, chemistry, and others (Bello-Morales & Delgado-García 2015, Kyzar & Denfield 2023). Indeed, interdisciplinary connections may be vital to a deeper understanding of emotions.

In the humanities, which study emotions from the level of the human condition, emotions are intangible qualia. Many academics in the humanities believe that emotions such as rage, jealousy, hope, and despair are a key component of the human experience (Internet Encyclopedia of Philosophy n.d., Dines Johansen 2010).

But, as we enter the social sciences, the answer to this question becomes more complicated. An anthropologist, looking at the issue on the level of societies, might emphasize the fact that different emotions exist in different cultures. For example, Schadenfreude, or a specific feeling of taking joy in another person's suffering, is an emotional construct from the culture of Germany (Fox 2019, "Schadenfreude" 2023). And Amae (甘え), or the presumption of being spoiled, is an emotion unique to the culture of Japan (Fox 2019, Intercultural Word Sensei n.d.). A sociologist, looking at the level of a society, might discuss emotions as primarily a method for communication between individuals (Lucerne n.d.). A sociologist might also emphasize how even emotions within the individual are shaped by the cultures and individuals around them (Hochschild 2012). A psychologist, looking at the level of the individual, would also have trouble answering this question. In psychology, while it is common to administer surveys asking about participants' moods, psychologists realize that emotions are more complicated than we talk about them colloquially. For example, the Two-Step Theory of Attribution in psychology would indicate that emotions are primarily physiological states, which we then can impose a variety of meanings upon (Aronson 2016, Chick 2022). For example, a person with an adrenaline rush could attribute this rush to either anger or excitement depending on context clues around them.

Questions of emotion become even more complicated when it comes to the natural sciences, like neuroscience and biology. These scientists look at processes occurring within single individuals. The question of where, exactly, emotions lie in the brain has troubled neuroscientists for centuries. And this is mostly because at least as of yet there is no clear answer. While some emotions do have clear neural circuits, such as fear in the amygdala and the anticipation of reward in the nucleus accumbens, the majority are not so clear-cut (Borowski 2022, Luo 2020). Even when emotions do appear to involve specific neural circuits, there is often asymmetry between what the circuit actually creates and the set of qualitative experiences we label as a particular emotion colloquially. Like we talk about happiness colloquially, but to simplify all of the myriad experiences of happiness to the simple ‘anticipation of reward’ feels inadequate and reductive.

This lack of clarity is actually quite common in neuroscience due to what is called the top-down vs bottom-up problem (De 2017). This problem describes the difficulties in conceptualization and linguistics between psychology and neuroscience. Psychology as a science takes a top-down approach. This means that psychologists start by looking at thoughts, feelings, and behavior, and then try to extrapolate what this could mean about the brain. Neuroscience, on the other hand, takes a bottom-up approach. This means that neuroscientists start by looking at biological mechanisms in the brain and peripheral nervous system, and then try to extrapolate what they might mean for our thoughts, feelings, and behavior. Unfortunately, there are many times when concepts that are created in psychology don’t map one-to-one onto models created in neuroscience, and vice versa. One good example of this is the concept of depression, now known as Major Depressive Disorder (MDD) (De 2017). Concepts of depression have existed for thousands of years, and they have been in the DSM since its first edition in 1952 (Smith 2021, “DSM-5” n.d.). However, neuroscientists who attempted to study depression in the brain quickly discovered that there is no single neural condition associated with depression. Rather, there appear to be several distinct neural types of depression, which have until now fallen under the same psychological umbrella (Drysdale et al. 2017, Tokuda et al. 2019, Liang et al. 2020, Wang et al. 2021, Smith 2021). This discovery led to what is called the Umbrella Theory of Depression, and it makes a lot of sense when considering the vast variety of psychological profiles that can be classified as depressed (De 2017). According to the DSM-5, in order to be diagnosed with MDD, a patient must only meet 5 of 9 criteria (National Library of Medicine 2016). That means that it is possible for two individuals to have MDD, yet to only have a single symptom in common. Psychological designations like MDD, Generalized Anxiety Disorder (GAD), and others are still useful, but they appear to speak more to symptoms than underlying conditions (Roseberry et al. 2023, Drysdale et al. 2017, Tokuda et al. 2019, Liang et al. 2020, Wang et al. 2021). At least for the time being, there is a vast disconnect between what we experience at a top level and the mechanisms at the bottom level. This is one of the major issues in the study of emotions as well.

Even though this is not the case, let’s say that hypothetically there was a clear neural circuit for each emotion or mental state, and that activation of this circuit one-to-one predicted the experience of an emotion. What meaning would these circuits have? Would knowing which neurons were involved actually capture the full qualitative experience of emotions we have as humans? In other words, could emotions as a qualitative experience, despite arising from simple biological parts, be something new and different from their constituent neurons?

These questions about the nature of emotions only become more complicated when multiple humans influence each other in interpersonal interactions. Is there something about interpersonal emotions, for example, which make them qualitatively new and different from individual emotions? This emergent property would certainly explain the discrepancies between disciplines mentioned above, as each discipline looks at emotion at a different scale.

In order to answer these types of questions, I turn to philosophy, and, more specifically, the theory of emergent phenomena. I argue that interpersonal emotions are, indeed, a form of emergent phenomena, and therefore new and different from individual emotions.

ON EMERGENT PHENOMENA

What is an Emergent Phenomenon?

Emergent phenomena occur when smaller, simpler parts come together to form a whole that has at least one property that the constituent parts do not. In other words, the term ‘emergent phenomena’ describes situations in which a new property ‘emerges’ from the combination of smaller parts that do not have that property.

Emergence is one of the most fascinating concepts in science. It is often seen as the connection between the concrete and the abstract. For example, many scientists believe that life is an emergent property (Kurzgesagt 2017). Some clusters of atoms together are not alive, while other clusters of atoms are. Scientists have postulated that the property of being alive emerges from the combination of certain types and configurations of atoms.

It is important to note that not everyone is convinced that it is possible for phenomena to be emergent. Some scientists are reductionists. This means they believe that all properties of the whole must be able to be reduced to properties of the individual parts, and, as such, it is impossible for properties to emerge (Wildman et al. 2018). Reductionists tend to believe at least one of the following:

I. Ontological reductionism: although the individual parts are combined in a particular structure, the whole doesn't have causal power that the parts alone do not
II. Explanatory reductionism: although the individual parts are combined in a particular structure, all properties of the whole can be explained in terms of the individual parts
III. Value reductionism: although the individual parts are combined in a particular structure, changes in properties that do occur do not have any special value

So, while it is probably impossible to prove that a particular phenomena is emergent, it is important to keep the concerns of reductionists in mind. Any effective definition of emergence will have to contend with objections like the ones above. To that end, it is helpful to pin down exactly what makes something an emergent phenomena. Typically, in order for a phenomena to be considered emergent, it needs to follow four guidelines (Kurzgesagt 2017):

Requirements for Emergence:

1. There is more than one individual part

2. No one part is ‘in charge,’ or fully determines the behavior of all of the parts. Rather the parts function together as a group
3. The individuals in the group follow a set of rules
4. The sum of the individuals is more than the parts. In other words, there is at least one resulting property that is qualitatively different than the properties of the original parts

Most important to notice here are conditions 2 and 4. Condition 2 is important because it shows that the phenomena cannot be reduced to the causal power of an individual part. Condition 4 is probably the most crucial for refuting the concerns of reductionists. If the whole has at least one novel property, it has causal power that the parts do not (refuting concerns of ontological reductionism). Additionally, if the property is qualitatively different from the properties of the individual parts, this would appear to show that the whole can not be explained entirely in terms of the parts (refuting explanatory reductionism). Furthermore, this qualitative difference leads to the whole having a value that the parts alone do not (refuting value reductionism). Of course, what exactly is considered to be a qualitative difference can be subjective, so this may be the most difficult requirement to engage with.

As previously stated, it may be impossible to prove that a particular phenomenon is emergent. It is always possible that we are simply missing critical information about the constituent parts, the whole, or both. However, I would argue that whether or not a particular phenomenon is emergent, theories of emergence have a lot of explanatory power (Kurzgesagt 2017). This means that, correct or not, theories around emergence appear to accurately predict future occurrences. As such, they ought to be of interest to scientists whether or not those scientists believe in emergence.

Examples of Emergent Phenomena

Emergent phenomena exist in both so-called hard sciences like chemistry and physics as well as so-called soft sciences like biology, neuroscience, and the social sciences

In the hard sciences, emergent phenomena occur when smaller particles come together in a way that changes their physical properties. For example, when two hydrogen atoms and one oxygen atom bond together into a water molecule, the water molecule behaves differently than hydrogen or oxygen alone. For instance, water is one of the only compounds that becomes bigger (and therefore less dense) in solid form than in liquid form (Khan Academy n.d.). In other words, when water freezes into ice, the ice will take up more space than the water once did, and will contain less water molecules per unit of volume in the ice than in the water, as they are spaced further apart. Both hydrogen alone and oxygen alone do the opposite: they become smaller (and therefore more dense) in solid form than in liquid form (IChemE n.d., “Gaseous elements and compounds” n.d.). We can codify this into our requirements as follows:

Emergence in Water Molecules (fig 12A):

1. There is more than one individual atom
2. No one atom is ‘in charge’ of the molecule, lending it all of its properties
3. The atoms bind together in a set structure. Both hydrogens form a polar covalent bond with the central oxygen (Khan Academy n.d.). The hydrogens tend to bond at a specific angle, as well, leading to the characteristic bent shape of water molecules

4. Once bonded, the water molecule has a new, different property. Water molecules become less dense in solid form than in liquid form, unlike hydrogen or oxygen atoms alone. This is a clear qualitative difference between the individual parts and the whole

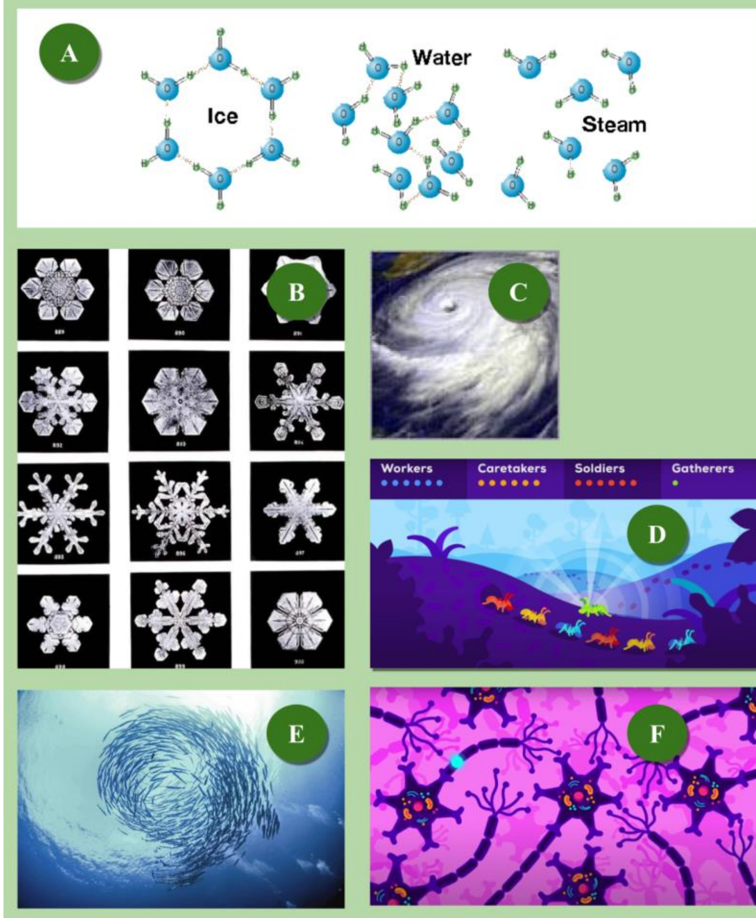

Fig. 12: Examples of Emergent Phenomena.

(**A**) Unlike oxygen alone or hydrogen alone, water molecules take up more space when in a solid phase than when a liquid phase ("Why the latent heat of vaporization" n.d.)

(**B**) Formation of snowflakes (Santa Fe Institue 2014)

(**C**) Formation of hurricanes (Public Broadcasting Service, n.d.)

(**D**) Ant colony class maintenance (Kurzgesagt 2017)

(**E**) Schooling behavior in fish (MacDonald 2017)

(**F**) Complex thought & behavior from neurons in the brain (Kurzgesagt 2017)

While this is a fairly simple example, there are other, more complicated examples of physical properties emerging. For example, more complex formations such as snowflakes and hurricanes (fig. 12B & 12C) (Santa Fe Institute 2014, "Emergence > Everyday Examples" n.d.). Snowflakes form unique, intricate structures. And hurricanes display very different movement patterns than their constituent parts normally would. For both of these formations, there are concrete, easy to observe differences in properties between the original parts and the resultant whole.

There are also many examples of emergent phenomena in the soft sciences. Common examples include differences in properties between individual ants and ant colonies, individual fish and schools of fish, and individual neurons and the brain:

Emergence in Ant Colonies (Kurzgesagt 2017) (fig. 12D):

1. There are multiple individual ants
2. While there are different classes of ants, no individual ant or ant class is in charge. No one ant can tell another ant to change class
3. Ants follow specific rules about when to remain in the same class or switch classes. When ants encounter too few ants of a certain class, they change to that class
4. Without communication between ants, the ant colony maintains a stable ratio of ants in each class

Emergence in Schools of Fish (MacDonald 2017) (fig. 12E):

1. There are multiple individual fish
2. No one fish directs the movement of the school
3. In general, the fish try to stay oriented in the same direction. However, each fish has a set space bubble, called a zone of repulsion. If a neighboring fish gets too close to its space bubble, the fish will turn away so that they don’t collide. One fish turning often causes its neighbors to turn, and so on until the whole school has turned

4. Fish schools make simple and complex movements as a coordinated whole, appearing almost like a hive mind

Emergence in Neurons in the Brain (fig 12F):

1. There are multiple individual neurons
2. No one neuron initiates all action potentials
3. Neurons can generally be grouped by type. For example, some neurons are excitatory and activate downstream neurons. Other neurons are inhibitory and suppress downstream neurons. Still others are modulatory, and regulate whole sets of neurons. Particular neurons also tend to only release certain types of neurotransmitters (Luo 2020). One neuron may release dopamine, while another might release serotonin. Some neurons are even capable of releasing several types of neurotransmitters (Seal & Miller 2008).
4. Neural activity across neurons leads to complex thought, feeling, and behavior. One neuron alone is incapable of producing this level of complexity

While the resulting ‘whole’ in each of these cases is certainly more abstract than a simple water molecule, that doesn’t necessarily mean that ant colonies, schools of fish, or brains are any less substantive. Emergence is also studied in the so-called soft sciences. For example, culture is considered to be an emergent phenomenon that is created by individual people but exists outside of them (Wood et al. 2013). So while interpersonal emotions may seem abstract, this doesn’t necessarily mean that they don’t exist or that they aren’t indeed a form of emergent phenomena.

ARE INTERPERSONAL EMOTIONS EMERGENT?

In order to answer whether or not interpersonal emotions are emergent, we must investigate whether interpersonal emotions follow the four criteria for emergence. In other words, we have to demonstrate the following:

Emergence in Interpersonal Emotions

1. There are multiple individual people
2. No one person is in charge of the emotions within the interpersonal relationship
3. There are set rules that govern the creation of and role of interpersonal emotions
4. The emotions within interpersonal relationships have different properties than the emotions that exist in one individual alone. Interpersonal emotions are qualitatively different from individual emotions

In this section, evidence will be presented to support that interpersonal emotions do indeed follow the four criteria that characterize an emergent phenomenon.

Part 1: There are Multiple Individual People

While it may seem obvious at first that, of course, an interpersonal emotion will involve multiple people, demonstrating that interpersonal emotions follow this requirement is more complicated than it may initially appear. In order to clearly demonstrate that interpersonal emotions meet this criteria, it must first be shown that cases where there are the least possible components involved, or cases involving just two individuals in an interpersonal relationship, contain enough people for new properties to emerge by their interacting.

Research has shown that properties can indeed emerge from only two individual parts. For example, when a single sodium atom is combined with a single chlorine atom, the resulting molecule, salt, is able to give us a qualitative experience of ‘saltiness’ that the sodium or chlorine alone could not (Gentili & Sinjab 2012). Because in this case it is only two components which create the quality of saltiness, it is much clearer that the quality of saltiness is emergent. Likewise, much research into interpersonal emotions concerns dyads, as they are the simplest possible case where emergent neural phenomena have been observed (Koul et al. 2023). The simplicity of dyads makes it easy to reduce confounding variables in order to study the true nature of emergence in interpersonal emotion.

Part 2: No One Person is In Charge of Interpersonal Emotions

It is true that there are situations where one individual has more power over the interpersonal relationship than others. Researchers have studied the effects of leader and subordinate roles on interpersonal relationships and emotions. Specifically, research has shown that when there is a power imbalance in an interaction, individuals in a subordinate role are more sensitive to the feelings and perceptions of individuals in a leader role (Snodgrass 1985).

However, this does not mean that one individual is able to force another to feel a specific feeling, nor can they fully control the nature of the interpersonal emotion. Research has shown that whether or not an individual wants to be influenced by the emotions of another can actually moderate how strongly they are affected (Stanford University 2019). Individuals who want to be calm are three times less likely to be affected by angry people than individuals who want to become angry. And in the opposite case, individuals who want to be calm are three times more likely to be affected by calm people than individuals who want to become angry.

Additionally, philosophers and scientists alike have long speculated that it may be impossible to ever fully replicate the full scope of qualitative experiences of one individual within another (Nagel 1974, Perring on Gold & Stoljar 1999, Gunderson on Gold & Stoljar 1999, Watts & Stenner 2005, Nummenmaa et al. 2018). Philosophers hypothesize that this is due to physiological asymmetry between individuals. In order to completely understand the subjective experience of a particular individual, one would have to experience their entire physiological reality. But, the only way to experience their physiological reality would be to be them, and to therefore no longer be oneself. If this is true, it follows that it is impossible for one individual to replicate in another individual the exact emotion they want them to experience.

Part 3: Emotions Within Interpersonal Relationships Follow Set Rules

Universal Ruleset of Interpersonal Emotion

While more research needs to be done to elucidate the full ruleset of interpersonal emotions, there do appear to be set rules that govern the formation and role of emotions within interpersonal relationships. Some of these rules vary across context, but others remain constant.

The clearest constant rule is that increased emotional closeness leads to increased interconnectedness of emotions and physiological states (Cook, 2020, Kimura et al. 2008). This includes synchrony in positive affect, negative affect, cortisol levels, salivary alpha amylase just to name a few. But synchrony occurs on more than just a physiological level.

Within the brain, when individuals are closer emotionally, their brainwaves are quite literally more closely synced when they interact (fig. 13B) (Denworth 2023). The phenomenon of emotional closeness moderating closeness of neural synchrony within an interaction is so strong, in fact, that it is conserved across species. This same phenomenon has also been observed in rodents and bats (Denworth 2023).

Neural synchrony involved with interpersonal emotions goes beyond just mirror neurons, which have already been found to internally replicate the actions and emotions of others (Denworth 2023). They can involve synchrony in a variety of brain regions, to be discussed in an upcoming section (Blakeslee 2006, Landa et al. 2007, Britton et al. 2006, Burnett & Blakemore 2009). And in addition to being associated with close relationships, such as a parent and their child, friends, and lovers, neural synchrony is also common during cooperative activities (Nguyen et al. 2023, Kimura et al. 2008, Kinreich et al. 2007, Li et al. 2021, Perišić et al. 2023, Czeszumski et al. 2022). And this neural synchrony can occur even when individuals aren't physically together, such as during cooperative online gaming (Wikström et al. 2022). In one study, two individuals who did not know each other were paired together to play a racecar driving game. One of the individuals controlled the speed of the car, while the other controlled the car's steering. Even though the pairs had never met before, and could not communicate in any way, the sheer fact of trying to interpret what the other player was doing allowed their neural activity to sync up. This indicates that neural synchrony is an important constant across many different types of interpersonal interactions and relationships.

Future research could illuminate more constant rules of interpersonal emotion.

Cultural Variation in Rulesets of Interpersonal Emotion

Interestingly, not only do emotions in interpersonal relationships follow set rules, but the rule sets can vary across cultures. It is by comparing the differences between cultural rulesets, actually, that some of the most interesting rules around interpersonal emotions are illuminated.

Research comparing the United States and Singapore, for example, has found that while Americans tend to experience similar interpersonal emotions within all of their relationships, Singaporeans tend to have more disparate interpersonal emotions in each of their relationships (Koh et al. 2014). While it is possible that there are some confounding variables in play, such as the possibility that Americans may tend to choose more similar friends, this data is still very interesting. Regardless of how different interpersonal emotions are between different relationships, the fact that there is a difference between different interpersonal relationships could lend credence to the idea that we associate people, and our interactions with them, with different ‘vibes.’ Indeed, scientists have coined the term affective presence to describe the idea that individuals, regardless of what emotion they themselves are feeling, impart a baseline emotional signature on the people around them (Beck 2019). In this case, this would mean that Singaporeans have a more distinct experience of different affective presences than Americans.

Overall, though, it indicates that there is a pattern of each interpersonal relationship having its own affective signature.

Even within the same country, different ethnocultural groups may have more or less separation between interpersonal emotions and individual emotions. Research comparing the Dai, Han, and Jingpo ethnocultural groups of China found that experiences of interpersonal emotion in their relationships affected their overall emotions state differently. Specifically, some groups experienced more effect of prior interpersonal emotion on their future individual emotions (Kuang et al. 2019). This would seem to indicate that depending on one's ethnoculture, interpersonal emotions are more or less ingrained into the individual outside of the context of the interpersonal relationship. And, on a broader level, it indicates that there is a complex relationship between individual and interpersonal emotions.

Identity-Based Variation in Rulesets for Interpersonal Emotion

The rules mediating emotions within interpersonal relationships can also vary based on identity factors. This could be due to a variety of causes, such as differential social conditioning (Snodgrass 1985, Smith 2002).

One's gender has been found to affect sensitivity to interpersonal emotion, sensitivity to emotions from facial expressions, and level of intimacy in friendships, with women often being more tuned into these aspects of interpersonal emotion than men (Snodgrass 1985, Sonnby-Borgström 2008, Poláčková Šolcová & Lačev 2017, Aukett et al. 1988).

Additionally, because of external and internalized stigma towards queer individuals, gender and sexuality minorities may experience more shame, difficulty trusting, and attachment issues in interpersonal relationships than heterosexual, cisgender individuals (American Psychiatric Association 2023, McCann et al. 2021, Cook & Calebs 2016, Wells & Hansen 2003). This could affect the extent to which these populations' individual emotions are influenced by their interpersonal emotions.

Race and ethnicity make an impact. As mentioned before with the ethnocultural groups of China, they can affect the relationship between one's individual and interpersonal emotions (Kuang et al. 2019). African-American sociologist W.E.B. Dubois was one early academic who pointed to the emotional effects of racialization, noting that many Black Americans experienced a 'double consciousness,' with one authentic self and one self that is viewed through the lens of, and constructed to be appropriate for, white norms (Pittman 2023). More recently, Puerto Rican sociologist Eduardo Bonilla-Silva has coined the term 'racialized emotions' to describe those emotions which arise from one's positionality amongst race relations and prejudice (Bonilla-Silva 2019). Bonilla-Silva defines these emotions as mostly racialized in nature, although he also acknowledges the intersectionalities of related constructs like socio-economic status, gender, and queerness. Specifically, Bonilla-Silva describes emotions related to racialized fear and suspicion, racialized ideas of beauty and ugliness, and racialized power structures which place people of color's emotions at the bottom of the hierarchy. All of these differences would lead to differences in interpersonal emotions, as well as in the relationship between racialized individual's interpersonal emotions and their individual emotions.

Language can also have an important effect. Languages with different words to express emotions and feelings of connection have qualitatively different experiences of interpersonal emotion (Lomas 2018, McCulloch & Gawne 2022, Brandeis University n.d.). For example, Spanish distinguishes between levels of love more than English does, with a less strong way of expressing love (te quiero) and a stronger way of expressing love (te amo). For Spanish speakers who try to communicate their interpersonal emotions in English, then, it may feel like a key emotion that they feel does not exist in the English-speaking world. On the other hand, English distinguishes between surprise and fear more than Austronesian languages, and English also distinguishes between anxiety, fear, and grief more than some West Asian languages. In these cases, an English speaker may feel a greater variety of emotions that are not salient in these other languages. But there are other ways that language can have an effect, too. Different languages have different norms for interpersonal communication. In some languages, it is encouraged to do what is called backchanneling. Backchanneling is a phenomenon where the listener interjects feedback while the speaker is talking, as opposed to waiting to respond until after the speaker has finished talking ("Backchannel Facts" n.d.). Backchanneling is common in languages like Persian, Vietnamese, Japanese, Korean, Finnish, Polish, Czech, and Swiss German just to name a few ("Common Backchannels" n.d.). Because it is common for backchannel statements to express one's emotional reaction, it would not be surprising if languages with backchanneling had different interpersonal emotion dynamics than languages without backchanneling (Aghblagh 2017, White 1989, Nguyen et al. 2023). All of these differences in language shape the ways that people who see the world through the perspectives of these languages feel they can relate to each other (Lomas 2018, McCulloch, Scholz et al. 2023, Phan 2017).

Religion also plays a role, as religious values can shape norms around individual and interpersonal emotions, as well as creating perceived closeness to others both past and present (Vishkin et al. 2014, Cummins & Stille 2021, Pauketat et al., 2020). This has implications for how religious, spiritual, and nonreligious individuals regulate their own emotions, and likely has an effect on their interpersonal emotions as well.

Finally, one's age relative to others matters, as juniors tend to be more responsive to interpersonal emotions than their seniors than vice versa (Kimura et al., 2008). This could be connected to other research involving leader and subordinate roles in interpersonal emotion (Snodgrass 1985). Although this effect may vary depending on a particular culture's perspective on age and aging (Colorado State University). Regardless, relative age likely does impact interpersonal emotions in cross-age relationships.

These are likely just a few of the many aspects of interpersonal emotion that can be made more or less impactful by identity factors. All of these identity-specific differences, too, can elucidate elements of how emotions within interpersonal relationships are governed.

Variation due to Intersectionality, Cross-Cultural and Cross-Identity Interactions

It is worth noting that there are intersectional interactions between all cultural and identity factors, as one's interpersonal emotions are often influenced by one's intersectional role in society. One example of this would be the influence of gender constructs in each culture, such as Machismo and Marianismo in Latin American cultures (Nuñez et al. 2016). The culture of Machismo encourages Latin men to take a dominant position in social relationships, as well as to emphasize displaying pride, bravery, and honor. The culture of Marianismo, on the other hand, encourages Latin women to take a passive role in social relationships, as well as to emphasize family and self-sacrifice. These roles lead to differences in how Latin men and Latin women experience emotions both in relation to each other and in relation to men and women from other cultures.

Differences in the formation and role of interpersonal emotions also affect interactions between people of different cultures and identities, such as between Israelis and Palestinians, between Black Americans and White Americans, and between Christians, Muslims, Buddhists, and Atheists living in the United Kingdom and Latin America. (Goldenberg et al., 2014, Pauketat et al., 2020). This is partially due to actual differences between individuals' backgrounds, such as what group emotions they've grown up around. It is also partially due to the emotional norms they are used to, such as what sorts of conflict strategies they've learned growing up (Oetzel 1998). Finally, this is also partially due to the effects of stereotyped emotionality, such as the tendency to overestimate the anger of Black women (Motro et al. 2022).

Altogether, the ruleset for interpersonal emotions is complex and varied. When trying to codify the rules of interpersonal emotion, it is important to keep cultural and identity-based variation in mind.

Part 4: Interpersonal Emotions have Different Properties than Individual Emotions

In this section, I will be discussing three main arguments that interpersonal emotions have qualitatively different properties than individual emotions. Firstly, the existence of emotions that are specifically social in nature. Secondly, the fact that interpersonal emotions are associated with different neural circuits than individual emotions. And, thirdly, the argument that the synchrony between people, as well as senses of “we-ness” are in themselves emergent properties.

Certain emotional states are fundamentally relational in nature. For example, jealousy, envy, pride, embarrassment, guilt, shame, disgust, and lust (Blakeslee 2006, Hareli & Parkinson 2008). This is most obvious in the case of jealousy, which requires someone or something else to be jealous of. Lust, too, generally requires someone or something to lust for (Herzberg n.d.). But other emotions are also relational. For example, whether one feels proud or embarrassed of oneself is oftentimes determined by one’s perceived position relative to others. Guilt and shame, too, are often based on others’ perceptions (Hareli & Parkinson). Disgust is not always a social emotion, as one could be disgusted by negative sensory input. However, human beings can also experience disgust in response to perceived social or moral infractions, which are shaped by social norms (Munch-Jurisic 2023). And while not every relational emotion exists in every culture, this could actually be seen as evidence that relational emotions do indeed emerge from different relationships between people, as these relationships also differ from society to society (Paul Ekman Group 2020). These relational emotions appear to be qualitatively unique manifestations of interpersonal emotion.

Research has also indicated that interpersonal emotions arise from distinct neural circuits than individual emotions (Blakeslee 2006, Landa et al. 2007, Britton et al. 2006, Burnett & Blakemore 2009, Luo 2020, Carlson & Birkett 2021, Oane et al. 2020, Coppin 2016, Knights et al. 2022, Anzellotti 2017). There is some overlap in activity, such as in the thalamus (Thal), which is involved with relaying sensory input to the rest of the brain, the posterior insula (PI), which is involved in sensory processing, and the medial frontal gyrus (MFG) which is involved in the regulation of dopamine and noradrenaline release. However, there are other regions that are more active in specifically individual emotions or specifically interpersonal emotions (fig. 13A):

1. More active in individual emotions: the ventral anterior cingulate cortex (vACC), which is part of the ACC and is involved in emotional valence, the PCC, which was discussed earlier for its role in the interpretation of behavior, the middle cingulate cortex (MCC), which is involved in affective and motor functions, the inferior parietal cortex (IPC), which is involved with speech, and certain parts of the superior temporal gyrus (STG), which is involved in auditory processing and speech comprehension. While it’s not certain why speech areas might be implicated in individual emotion, it is possible that this is due to some sort of internal monologue or thought (Alderson-Day et al. 2016, Stephane et al. 2021).
2. More active in interpersonal emotions: the anterior temporal cortex (ATC), which is involved in appetite as well as mental representations of knowledge about others, the middle frontal gyrus (MFG), which is involved in auditory processing, and other parts of the STG. And, notably, the mPFC, the STS, the TPJ, and the AI, which were all discussed earlier for their important roles in social self-appraisals, attributions and behaviors (Billeke & Aboitiz 2013, Duerler et al. 2022). Altogether, many more so-called social regions are recruited during interpersonal emotions.

The level of distinctness between the neural networks for individual vs interpersonal emotions provides good support to the idea that interpersonal emotions are emergent phenomena not based on individual emotions alone.

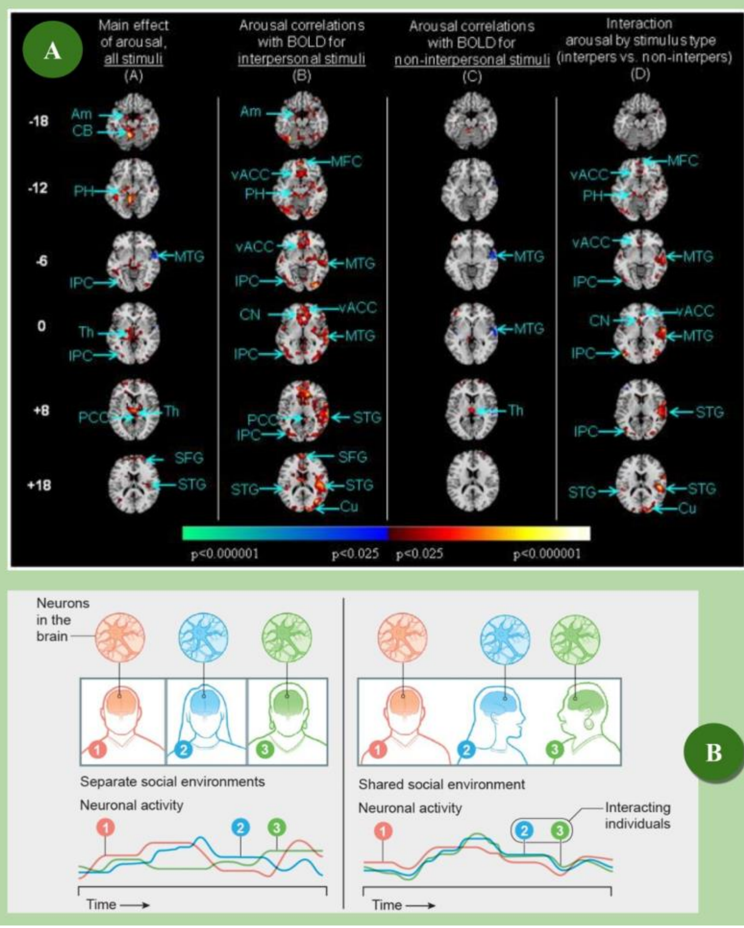

Fig. 13: Evidence for Interpersonal Emotions as Emergent Phenomena.

(**A**) Brain regions recruited in individual vs interpersonal emotions (Landa et al. 2007)

(**B**) Depiction of neural synchrony (Denworth 2023)

Lastly, I would make the argument that the emotional, physiological, and neural synchrony across individuals that is created by interpersonal emotions would in itself count as an emergent property (fig. 13B) (Cook, 2020, Kimura et al. 2008, Denworth 2023). While it is true that individual emotions can lead to synchrony, interpersonal emotions can lead to synchrony in neurons when they aren’t spatially or even temporally connected (Denworth 2023, Wikström et al. 2022, Bachmann et al. 2022). I believe that with future research, this could also be considered a form of emergent phenomena.

All in all, I believe that this evidence supports the idea that conceptualizing interpersonal emotions as emergent phenomena could open up many avenues for future research.

CONCLUSION

With everything considered, it is possible to make three main conclusions:

I. There is a Lack of Complexity and Nuance in Current Neuroscience of Interpersonal Emotion. While there has been quite a bit of research into social neuroscience up until this point, there are clear areas where further research is required. Specifically, breaking apart from Western tendencies towards individualism and atomization in order to see the true complexity and scope of interpersonal emotions.

II. Complexity and Nuance Can Be Illuminated via Diversity in Scientific Thought. By breaking down academic barriers between science, other disciplines, and the outside world, it is possible to generate novel hypotheses.

III. Better Understanding of Social Neuroscience Would Have Far-Reaching Effects. Social neuroscience affects all of our daily lives. And if interpersonal emotions are truly emergent, this could change the way that we conceptualize ourselves with relation to others. It could have a profound effect on the way that we study fields like economics, where emotions affect decision-making and consumer behavior, and international relations, where diplomats and states alike could be said to experience emotions (Rick & Loewenstein 2007, Hamelin et al. 2017, Sasley 2011, Gustafsson & Hall 2021, Cornut 2022). Better understanding of interpersonal emotions would also radically change the way that we mobilize for issues like climate change, where defeating emotions of hopelessness and helplessness is vital, as well as improving advocacy for social issues like gay and transgender rights, where research has shown that fostering interpersonal empathy and shared emotion can change the minds of prejudiced individuals (Brosch 2021, Yale University 2023, Livingstone et al., 2011, Broockman & Kalla 2016).

Altogether, the main takeaway of this research should be that better understanding of interpersonal emotions truly has the power to create a more empathetic world.

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