A case study of the effects of posthypnotic suggestion on visual information processing: measuring behaviour and event-related potentials

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Abstract

The hypnotic phenomena have long been debated. In scientific research, disagreements on the conceptual and methodological approach have led to controversial results and interpretations which heat up the debate. Additionally, hypnotic suggestibility is often measured only behaviourally, subjects are studied in masses and the role of individual responders is largely neglected. One way to reach beyond mere behaviour to the level of experience without losing the individual variability is by combining posthypnotic suggestions, self-reports, psychophysiological measurement techniques and a case study approach.

The present study examined the effects of suggested changes in the visual colour perception of simple geometric shapes in the posthypnotic and the simulation condition as measured by self-reports, reaction times, error rates and event-related potentials (ERPs). The case study approach was chosen and the focus was set on two highly suggestible hypnotic responders. The comparative data for simulation were also obtained from a set of control subjects.

Results indicated differences in processing between the posthypnotic and simulation condition seen in the behavioural performance and to a lesser extent in the posterior N2 and P3 peaks of the ERP waves. Evident dissimilarities were found also among highly suggestible hypnotic responders. These results support the occurrence of inimitable hypnotic modulations in some individuals and point out the need to examine hypnotic responders on a more individual basis.

Keywords: Case study, Event related potential (ERP), Hypnosis, Hypnotic virtuoso, Visual hallucination

Tiivistelmä

Hypnoosi on jo kauan ollut hyvin kiistanalainen aihe. Erot lähestymistavoissa, käsitteiden määrittelyssä ja menetelmien valinnassa ovat johtaneet eriäviin tuloksiin ja tulkintoihin, jotka kasvattanut kuilua eri näkemysten välillä entisestään. Lisäksi herkkyys hypnoottisille suggestioille mitataan usein vain käyttäytymisen perusteella, koehenkilöitä tutkitaan joukkoina ja yksilöllisen vaihtelun osuus jää huomioimatta. Yksi tapa lähestyä käyttäytymisen taustalla olevaa kokemusta on käyttää posthypnoottisia suggestioita ja kyselyitä sekä mitata aivojen aktiivisuutta. Yksilöllinen vaihtelu taas voidaan ottaa huomioon käyttämällä yksilötutkimusasetelmaa.

Tässä tutkimuksessa käytettiin suggestiota, joka ohjeisti näkemään tietyn kolmesta geometrisesta muodosta toisen värisenä kuin mitä se todellisuudessa oli. Kaksi suggestioille erittäin herkkää yksilöä toimivat tämän suggestion mukaan joko posthypnoottisesti tai jäljitellen tätä. Kokeiden aikana tarkasteltiin muutoksia reaktioajoissa, virheiden lukumäärissä ja aivojen tapahtumasidonnaisissa jännitevasteissa. Lopuksi kokeiden aikaisia kokemuksia kartoitettiin. Vertailun vuoksi jäljittelyn aikaisia mittauksia tehtiin myös kolmelle kontrollikoehenkilölle.

Tulokset osoittivat, että tutkittujen suggestioherkkien yksilöiden havaintojen käsittely oli erilaista posthypnoottisessa ja jäljittelytilanteessa, mikä näkyi enemmän käyttäytymisessä ja vähemmän aivojen sähköisessä aktiivisuudessa. Myös suggestioherkkien yksilöiden välillä oli huomattavia eroja. Nämä tulokset vahvistavat käsitystä siitä, että hypnoosi voi vaikuttaa joihinkin yksilöihin tavalla, jota ei pystytä jäljittelemään, ja korostavat tarvetta tutkia enemmän hypnoosiin liittyvää yksilöllistä vaihtelua.

Avainsanat: Hypnoosi, Hypnoottinen virtuoosi, Tapahtumasidonnaiset jännitevasteet, Visuaalinen hallusinaatio, Yksilötutkimusasetelma

Foreword

I caught the inspiration for the Master's thesis on such a radical topic as hypnosis quite trivially, when writing my Bachelor's thesis on the common features of the neurophysiology of hypnosis and placebo. The process was long since I also translated and published that paper (Kirjanen, 2012), which allowed me to think over and over again what exactly was I getting myself in to. As a result, I decided to give it a try and contacted the only people currently conducting research on hypnosis in Finland, Ph.D., Professor Antti Revonsuo (Department of Psychology, University of Turku) and Ph.D., Docent Sakari Kallio (School of Humanities and Informatics, University of Skövde, Sweden). The reply did not come fast, but was more than welcoming and warm, so I headed west to the beautiful city of Turku. The topic of posthypnotic suggestions for visual hallucination came from the experience of these researchers, in whose hands I trusted myself completely, and the technical preparation of the experiment was mostly done by Ph.D., Docent Mika Koivisto (Centre for Cognitive Neuroscience, University of Turku), who also instructed me the direction in which to start the data analyses. I want to thank all of them and especially Sakari Kallio for valuable ideas and comments. My part of the experiment was the recruitment of controls and gathering the data in the facilities of the University of Turku during the spring of 2012. Both tasks were quite natural for me, since I have previously worked in the field of EEG research. Later on, when the data were gathered and my money for the train tickets ran out, I contacted DI Miika Leminen (Cognitive Brain Research Unit (CBRU), University of Helsinki), who was so kind to provide me with the software for EEG analyses in my home Helsinki. The scant evening hours after work and on weekends I spent alone learning to use new programmes, conducting analyses and writing. In Helsinki the latest version of the thesis was checked by one more of my supervisors Ph.D., Docent Petri Paavilainen (Department of Psychology, University of Helsinki) who I would also like to thank. I am grateful for the encouraging remarks on the text from Ph.D., Professor Mari Tervaniemi (CBRU, University of Helsinki) and my opponent Master's student Johanna Nohrström in the student seminar. I would also like to express my enormous gratitude to Ph.D., researcher Benjamin Ultan Cowley (Cognitive Science Unit, University of Helsinki) for the details, support and critical final revision of the language.

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Table of contents

Abbreviations

ANOVA	Analysis of variance
C+	Targeted colour
C-	Untargeted colour
CS1	Control subject number one
CS2	Control subject number two
CS3	Control subject number three
EEG	Electroencephalography
ERP	Event-related potential
F+	Suggestion-relevant shape
F-	Suggestion-irrelevant shape
ms	Millisecond
μV	Microvolt
N2	Second negative peak
P3	Third positive peak
PHC	Posthypnotic condition
RM	Case study subject number two: a highly suggestible hypnotic responder
SN	Selection negativity
SIM	Simulation condition
TS-H	Case study subject number one: the ‘hypnotic virtuoso’

1. Introduction

Hypnosis often refers to a strange condition resembling sleep, but marked by a peculiar involuntary activity. The reputation of hypnosis has varied over the centuries. During the latest decades the controversy over the origin and nature of hypnotic phenomena has turned into a heated state vs. non-state debate between those who view hypnosis as a specific altered state of consciousness enabling the automatic occurrence of hypnotic phenomena, on one side, and those who see no need to explain it by alterations in the brain state and all the hypnotic phenomena to be imitated in the normal state with a sufficient amount of effort, on the other side (Kallio & Revonsuo, 2003; Lynn & Green, 2011; Lynn, Kirsch & Hallquist, 2008).

Nowadays, understanding hypnosis is hoped to give insight on and take into use the full potential of the human mind. In order to achieve this, scientists try to find the very essence by peeling off hypnosis from its reputation, unnecessary components and confounding variables by using new brain imaging techniques and novel experimental paradigms. However, so far the field of hypnosis is torn apart by uncertainties and the research has yet a long way to go to form a solid ground. From the theoretical point of view, hypnosis as an altered state is hard to approach, since there is no commonly accepted definition of an altered state of consciousness (Kallio & Revonsuo, 2003) and disagreements about whether hypnosis deserves to be called a state at all. Even the wealth of empirical research, conducted on the behavioural and neurophysiological concomitants of hypnosis, has many controversial findings (Oakley, 2008; Spiegel, White & Lynn, 2010). Some components of hypnotic procedure have been found to play a crucial role in hypnotic responding, while others have not gained any systematic empirical support for their importance in occurrence of hypnotic phenomena.

Though sometimes viewed separately, the theoretical and empirical sides of hypnosis are strongly intertwined. Thus, the empirical lack of recurrence could be at least partially explained by the dissimilarities in methodology among studies of different theoretical camps (Oakley, 2008). The state view defenders focus their research on the extraordinary experiences and behaviour awoken by the hypnotic induction, while the non-state viewers search for explanations of the hypnotic phenomena in the social agreement, overall responding to imaginative suggestions and being influenced by expectations.

The main characteristic of hypnosis both parties agree on is the increase of sensitivity to suggestive communications. Hence, what usually unites the studies of hypnosis is that in most of them subjects are selected by their scores on the classical suggestibility scales. In these, scores are given based on the display of the suggested behaviour by the subject. However, there seem to be notable individual differences in the effect of hypnosis even among those who score highly on these scales (Howard & Coe, 1980; Schuyler & Coe, 1981; Szechtman, Woody, Bowers & Nahmias, 1998; Terhune, Cardeña & Lindgren, 2011b). This fact has set the need to find new ways to differentiate among hypnotic responders. Until then the case study approach is proposed to be a fruitful method to get closer to understanding the full depth of the phenomenon (Kallio & Revonsuo, 2005; McConkey, Glisky & Kihlstrom, 1989; Raz, Moreno-Íñiguez, Martin & Zhu, 2007; Weitzenhoffer, 2000).

One of the results of increased sensitivity to suggestions is an ability to hallucinate. Having been described already long ago hallucinations are still used in the scales measuring suggestibility. The hypnotically suggested changes in the visual domain are known as hypnotic visual hallucinations and are thought to be particularly indicative hypnotic phenomena and an essential target for research (Revonsuo, Kallio & Sikka, 2009). There is evidence that suggestion has the potential to produce hallucinations by overriding even automatic visual functions such as word recognition (Raz, Fan & Posner, 2005; Raz, Kirsch, Pollard & Nitkin-Kaner, 2006; Raz et al., 2007; Raz, Shapiro, Fan & Posner, 2002) and colour perception (Kallio & Koivisto, in press; Kosslyn, Thompson, Costantini-Ferrando, Alpert & Spiegel, 2000; Mazzoni, Rotriquenz, Carvalho, Vannucci, Roberts & Kirsch, 2009; McGeown et al., 2012). Nevertheless, results in this area are not consistent and the exact magnitude of this effect is yet to be discovered.

The present study was designed to take part in the empirical research on hypnotic visual hallucinations. It examines the influence of the condition (hypnotic vs. normal), in which the suggestion for visual hallucination is received, on the modulation of colour perception as measured by reaction times and accuracy rates as well as brain electrical activity potentials. In order to control for individual dissimilarities, subjects are treated as cases. This chapter will introduce the topic more closely, take stock of the key points in the state vs. non-state debate, main theoretical and practical findings in the field of hypnosis and lead into the research question.

1.1. Defining the topic

Hypnosis is defined by Division 30 of the American Psychological Association (APA) (Green, Barabasz, Barrett & Montgomery, 2005) the following way:

> "Hypnosis typically involves an introduction to the procedure during which the subject is told that suggestions for imaginative experiences will be presented. The hypnotic induction is an extended initial suggestion for using one's imagination, and may contain further elaborations of the introduction. A hypnotic procedure is used to encourage and evaluate responses to suggestions. When using hypnosis, one person (the subject) is guided by another (the hypnotist) to respond to suggestions for changes in subjective experience, alterations in perception, sensation, emotion, thought or behaviour. -- If the subject responds to hypnotic suggestions, it is generally inferred that hypnosis has been induced. Many believe that hypnotic responses and experiences are characteristic of a hypnotic state. While some think that it is not necessary to use the word "hypnosis" as part of the hypnotic induction, others view it as essential."

This description of hypnosis introduces the concepts of *induction* and *suggestion*, which are the most important terms in the discourse over the nature of hypnosis. *Suggestions* or *suggestive communications* are statements, given to the subject, which can take the form of instructions, commands, questions or assertions in order to produce avolitional responses in the subject (Weitzenhoffer, 2000). *Induction* can be defined as merely a suggestion among others, a suggestion to enter hypnosis, usually imagined as the eye-fixation suggested sleep induction or some variations of it (Weitzenhoffer, 2000). Though in fact, induction has no such strict boundaries, and for example relaxation has been found as an unnecessary part of the induction regarding responsiveness to suggestions (Banyai & Hilgard, 1976; Kirsch, Mobayed, Council & Kenny, 1992). It has even been stated that any kind of procedure can be used as an induction as long as the subject recognizes that procedure as such (Kirsch, 2001). These broad boundaries of induction and suggestion will be followed here.

Suggestive communications play a special role in the phenomenon of hypnosis. *Hypnotic suggestion* is meant to affect performance during hypnosis and *posthypnotic* *suggestion* refers to the suggestion given during hypnosis in which the subject is instructed to show certain behaviour or have certain experiences after the termination of hypnosis. Particularly, the responding to posthypnotic suggestions is characterized by a lack of awareness of the reason for the behaviour and a feeling of compulsion to react in a certain way (Kihlstrom, 1985). As opposed to social request, posthypnotic suggestions are seen as operating at the level of experience, not merely behaviour (McConkey, 2008) and have been used in several studies (Raz et al., 2005; Raz et al., 2007; Raz et al., 2006; Raz et al., 2002; Kallio & Koivisto, in press). At the same time, it is good to remember that results obtained by the posthypnotic suggestions do not tell anything about the hypnotic state per se.

The soft-worded definition of hypnosis by APA concentrates on the hypnotic reaction and tries to overlook the definition of *the hypnotic state*. This is quite understandable, since while responding to hypnotic suggestions can be observed and even measured, there is so far no objective way to decipher whether a person is under hypnosis or not. Meanwhile, there are some uncertainties also in the definition of hypnotic responding. For instance, it has for a long time been studied as *hypnotisability*. However, by definition, hypnotisability is merely the increase in responsiveness due to hypnotic induction. Since most studies do not measure the baseline non-hypnotic responding, there is no way to evaluate this increase caused by hypnosis and the word hypnotisability is then used to refer to the total responsiveness during hypnosis (Kirsch, 1997). Here a clear distinction will be made between hypnotic or post-hypnotic *suggestibility*, as the total responsiveness due to the involvement of induction, and *hypnotisability*, as only the increase in suggestibility caused by hypnosis. Now that the key concepts are familiar an overview of the origin and the current condition of the state vs. non-state debate can be made.

1.2. Historical debate

Hypnotic phenomena have fascinated inquisitive human minds for centuries. The historical review is usually started with Franz Mesmer's (1734–1815) understanding of the nature of sudden curative incidents taking place after his suggestive procedures. He argued these phenomena to be caused by invisible animal magnetism, and quite soon was proven to be wrong. Later on, these occurrences were renamed to hypnotism by James Braid (1795–1860), who revived their reputation, tried to bring them closer to neurological conceptualization and developed his own view according to which the unique effect of hypnosis is psychophysiological by nature and caused by suggestions. He also recognized the history of hypnotic phenomena to reach far into centuries ago (Braid, 1846).

Over the years both scientific and public opinion about the nature of hypnosis underwent great transformations and the dispute evolved. In the 1900th century straightforward behavioural experiments conducted on impressionable individuals relying on a special state of hypnosis were confronted by the modern approach with more elaborated experimental paradigms and mass examination. This confrontation questioned all the previous results and observations and stripped hypnosis from its special status. Nonetheless, neither of these approaches fully satisfied all the scientific brethren and some have continued to search for the ‘real’ hypnosis.

Nowadays, hypnosis still is a highly controversial and debated matter. As Kihlstrom (1985) points out, the field is characterized by consensus over basic observations, but controversy over their interpretation. Roughly, opinions are often divided in two based on the question of state (Kallio & Revonsuo, 2003; Lynn & Green, 2011; Lynn et al., 2008). One side reckons hypnotic phenomena to be unique and bound to qualitative alterations in the mental state. The other side sees no need to go into this undefined area and instead tries to explain them only by already well-known psychological concepts, such as expectations and motivation. Thus, the first view is often referred to as the state view and the second one as the non-state view.

According to the state view, the hypnotic induction produces a shift − whether interpreted as trance, dissociation or otherwise an altered state of consciousness – which evokes extraordinary behaviour, abilities and experiences such as realistic hallucinations, naturally and regardless of whether the procedure is detected as hypnosis or not (Barabasz, Barabasz, Jensen, Calvin, Trevisan & Warner, 1999; Gruzelier, 1998; Orne, 1959; Hilgard, 1973; Spiegel & Spiegel, 2004). This perspective concentrates on the intrinsic neurophysiological processes following induction and being in hypnosis.

Non-state view theorists consider hypnosis merely as responding to imaginative suggestions independent of hypnotic induction (Barber, 1964; Kirsch & Braffman, 2001). This viewpoint does not deny the possible occurrence of shifts in mental processes or subjective feelings of such, but does not perceive them as the cause of hypnotic phenomena and rejects labelling them as the altered state of consciousness (Kirsch, 2001; Lynn et al., 2008). Hypnosis is defined in the sociopsychological context it is engaged in. The focus is on processes outside the individual such as interaction with the observer, and mostly preceding the induction such as rapport with the hypnotist, the expectations and beliefs attached to hypnosis. This basic division implies that the state and non-state view defenders use qualitatively different approaches when studying hypnosis, which quite naturally leads to differing results and often prevents comparison.

Some theorists present their own views on the nature of hypnosis, trying to accommodate both extremes. For instance, Lynn et al. (2008) introduce their stand as the response set theory. It stands that though both intended and unintended actions are affected by inner cognitive models, at the moment of execution they are all unconscious and automatic, and the sense of deliberation is always merely an illusion. Though this non-state theory is sociocognitive by nature, it has a shade of reverence towards the state view.

Meanwhile, Kallio and Revonsuo (2003) propose both state and non-state views to be equally right, but in different circumstances, and hypnosis to consist of two parts – the hypnotic state and the degree of responsiveness to imaginative suggestions which can be enhanced by the presence of the hypnotically induced state. According to the researchers, although many hypnotic experiences do not require the presence of an altered mental state and are fully explained by non-state views, in some cases clear qualitative shifts caused by induction do occur and should be distinguished.

There have also been a few optimistic attempts to bring opponents to an agreement by emphasizing their commonalities (Hilgard, 1973; Lynn & Green, 2011). Regardless of the base camp, both views recognize the importance of such factors as expectations, response motivation and rapport with the hypnotist for the outcome of hypnotic procedure (Lynn et al., 2008). In addition to that, there can be seen some sort of common acknowledgement that suggestions create altered experiences and the changes caused by suggestions resemble those produced by real-life experiences

(Kosslyn et al., 2000; Szechtman et al., 1998) indicating that subjects are not simply faking the altered perceptions.

As regards most of the other issues, counterparties remain firm to the extent that the state vs. non-state debate is occasionally recognized as unfruitful (Hilgard, 1973; Kihlstrom, 2005) or at least unresolvable with the current lack of common definitions, for example of an altered state, and solid research evidence (Kallio & Revonsuo, 2003; Lynn et al., 2008). Some want to call hypnosis an altered state, others as merely a feeling of an altered state, and devotees of both views manage to collect evidence in support of the theory they feel anchored in. As Hilgard (1973) notes, frequently the alternative views seem to accept the same facts under different labels and occasionally tend to emphasize some facts while ignoring others. Kihlstrom (1985) reminds of the importance of taking both views into consideration and discovering the laws of hypnotic behaviour and experience rather than enforcing them. In order to follow this rationale, both stances will be presented and their arguments and observations reviewed here with equal respect.

1.3. States of altered consciousness

The enigma of hypnosis can be approached from several directions. One way would be to start from the conceptual level by asking, what is an altered state of consciousness and how could it be defined and tested. Consciousness is seen to be comprised of two main components: awareness (i.e. the content of consciousness) and arousal (i.e. the level of consciousness), which are usually positively correlated (Boly et al., 2008). The decrease in these two is known as the state of reduced consciousness and is observed in for example sleep, anaesthesia, coma and somnambulism. Brain activity changes associated with states of reduced consciousness, such as sleep and somnambulism have been largely untangled (Poe, Walsh & Bjorness, 2010). However, it has been long known that the neurophysiology of hypnosis does not resemble that of sleep but rather wakefulness (Evans, 1977), and therefore hypnosis is usually not included in these states.

When it comes to other qualitative changes in consciousness, some definitions and attributes of an altered though not reduced state of consciousness have been proposed. Revonsuo et al. (2009) point out one more property of consciousness worth taking into account, which is its representativeness of the reality. The normal state is then defined as the processing of accurate information about the context. An altered state, on the contrary, is defined by internally or externally caused changes in the informational streams between the contents of consciousness and the context. The researchers propose this to lead to temporary and globally-emerging misrepresentations of the reality and to be combined with the alterations in the prefrontal cortex activity.

Dietrich (2003) also states the importance of prefrontal activity in alteration of consciousness. The researcher distinguishes six possible altered states: meditation, hypnosis, daydreaming, runner's high, drug-induced states and dreaming as a special part of sleep. Though these states are induced through various behaviours, they are seen to share a common neural mechanism − a transient decrease of activity in particular parts of the dorsolateral prefrontal cortex. Phenomenological uniqueness of each is stated to derive from the deregulation of different dorsolateral circuits and the degree of hypofunction. All in all, unlike in reduced mental states, in altered states the level of arousal can stay high, but the level of awareness is low or the contents are dramatically misrepresentative of the context.

Adding hypnosis to the set of altered mental states proposed by Dietrich (2003) could be viable, since focusing on specific dorsolateral circuits does not contradict the finding that hypnosis is not due to general inhibition of the frontal lobe activity (Kallio, Revonsuo, Hämäläinen, Markela & Gruzelier, 2001; Kallio, Revonsuo, Lauerma, Hämäläinen & Lang, 1999). In addition to that, currently many similarities have been found between for example hypnosis and meditation (Spiegel, White & Lynn, 2010). Dietrich (2003) suggests these two to resemble each other in causing a redirection of attentional resources and, together with daydreaming, to be characterised by toning-down of the external noise. As opposed to meditation, hypnosis has higher sense of self and lower cognitive flexibility and willed action. In hypnosis, suggestions do not pass on to the highest level of processing but are executed on the lower levels, creating the phenomenological experience of automatic behaviour.

Despite this fair pondering, it has been questioned whether hypnosis should be recognized as a distinct mental state in general. After all, if hypnosis causes alteration of such a researched phenomenon as consciousness, some clear inimitable biological markers independent of specific suggestions ought to emerge (Kallio & Revonsuo, 2003; Lynn et al., 2008). So far, no discrete neurophysiological profile of the hypnotic state per se has been reported (Oakley, 2008; Spiegel et al., 2010). This has been appraised to result from methodological differences among studies (Oakley, 2008) and not conducting enough research on the so called *neutral hypnosis*, where no additional suggestions are used except the one of entering and deepening hypnosis (Cardeña, Jönsson, Terhune & Marcusson-Clavertz, 2012). The latter is a relatively new field of interest made possible by the development of brain imaging techniques. It is believed to help separating the hypnotic state from the effects of specific suggestions, even those for relaxation and focus of attention, often included already in the traditional induction. The research on neutral hypnosis could also aid finding the desired neurophysiological markers of hypnosis.

There are also less optimistic opinions in the non-state camp regarding the search for the neural profile of hypnosis. According to them, most social behaviours cannot be well described in terms of brain activity (Willingham & Dunn, 2003). Even if the exact neural changes specific to hypnosis are found, the underlying meaning of these alterations is not clear, since all psychological processes have neurobiological patterns, and thus they are not enough to categorize hypnosis as a distinct mental state (Lynn & Green, 2011). Contrasting attitudes serve to further heat up the theoretical battle and the investigation of the nature of the altered state of hypnosis.

1.4. Results from the field of hypnosis

1.4.1. The role of components in hypnosis

Another way to approach the mystery of hypnosis would be from the point of view of empirical research. At the very fundamental level, an empirical study of hypnotic phenomena is governed by the conjecture over the nature and localization of hypnosis. The chosen stance then determines where the focus of attention is directed in research and what components of hypnotic procedure are targeted (Kallio & Revonsuo, 2003).

When studying the phenomenon of hypnosis, a rough distinction could be made between being in hypnosis and the effects of suggestion. Though both of these are included in the classical hypnotic process, they can also be examined independently as intrinsic and instrumental research, respectively (Oakley & Halligan, 2009). This division appears regularly in the state vs. non-state debate and is crucial for understanding it.

Perhaps casting an eye on the results of the effects of different components on hypnosis might help illustrate the presented empirical division. Suggestion and its effects are a good starting point for presenting the instrumental research. Suggestion is a broad term and not all of them are alike. In fact, it has been recognized as a domain itself, with sub-domains such as hypnosis, placebo, memory alteration and sensory suggestions (Kirsch et al., 2011). A successful responding to a suggestion means following the given instructions. As opposed to other kinds of suggestions, hypnotic ones are instructions for a change in experience independent of any alterations in stimulus conditions (Kirsch et al., 2011). Both sides of the state vs. non-state debate agree on the key role of suggestive communications in hypnosis. However, non-state theories view this to occur mostly through some level of cognition, even if the conscious experience feels involuntary, while state-viewers insist on a genuine automaticity of responding to suggestions.

When compared to other kinds of suggestions, such as placebos or leading questions, hypnotic suggestions seem to differ not only in the semantic nature (Kirsch & Braffman, 2001), but also in the caused brain activity patterns (Kirjanen, 2012). The suggestion for induction can, for instance, contain directions for muscular and mental relaxation, while suggestions following induction usually concern either motor productions (involuntary movements) or inhibitions (paralyses) or cognitive productions (positive obstructive hallucinations) or inhibitions (amnesia, analgesia, negative obliterating hallucinations) (Kirsch & Braffman, 2001; Barabasz et al., 1999). Even in the same hypnotic context different kinds of suggestions have been found to cause dissimilar neural activation (Barabasz et al., 1999; Jensen et al., 2001), which makes the exact verbal formulation of the suggestion a very important variable to control for. Kallio and Revonsuo (2003) propose that, for instance, true realistic hallucinations, as opposed to simple mental imagery, are brought about only by deceptive suggestions following a suggestion for induction and occur automatically and effortlessly.

The word *hypnosis* is also one part of the phenomenon and can be seen as a separate suggestion. Especially non-state researchers argue that there is no need to label the conducted procedure as hypnosis in order to create the hypnotic phenomena, and it is enough to present it as testing the ability to imagine, motivate subjects to perform well (Kirsch et al., 1992) and convince them in successful responding (Barber & Carverley, 1964; Barber & Carverley, 1965). Even more efficient is changing the expectations and attitudes towards hypnosis through direct experience rather than by mere verbal convincing (Wickless & Kirsch, 1989). Nonetheless, others' evidence clearly shows that the label of hypnosis as such has a powerful influence on the subsequent responsiveness to suggestions as compared to presenting the same procedure as relaxation (Gandhi & Oakley, 2005).

As regards being in hypnosis as the intrinsic phenomenon, induction as a special kind of suggestion is usually seen as an essential gate to that. It is a matter of current research whether hypnotic induction is necessary for the effects of further suggestions to manifest not only in subjective reports, but also in observed behavioural and brain activity changes. State view defenders insist that induction is essential for the effect of suggestion to occur in its full magnitude (Derbyshire, Whalley & Oakley, 2009; Kosslyn et al. 2000). Meanwhile, non-state view holders find induction to be unnecessary and to affect merely by increasing expectations, and proper suggestions to be enough for using normal psychological processes to their full extent (Kirsch, 2001, Mazzoni et al. 2009; Raz et al., 2006).

Not much is yet known about induced hypnosis as a state independent of specific suggestions, also referred to as neutral hypnosis. The studies conducted on the matter so far have had similar findings, which show that plain being in hypnosis is qualitatively different from relaxed but alert wakefulness based not only on self-reports but also brain activity alterations (Cardeña et al., 2012; Fingelkurts, Al., Fingelkurts, An., Kallio & Revonsuo, 2007; Fingelkurts, An., Fingelkurts, Al., Kallio & Revonsuo, 2007; Terhune, Cardeña & Lindgren, 2011a). These results fortify the position and necessity of induction as a catalyst for the qualitative shift in the mental state.

1.4.2. The role of individual differences in hypnosis

The tendency to respond to suggestions is called suggestibility. On the one hand, it is closely related to the impact of suggestion, but on the other hand, so far, it is also the only criteria to select subjects for study of being in hypnosis. Therefore, suggestibility forms a bridge between the two sides of the described empirical distinction.

The most widely applied mean to operationalize hypnotic responsiveness is by using the standardized behavioural scales on hypnotic suggestibility. The typically used suggestibility scales, such as Harvard Group Scale of Hypnotic Susceptibility, form A (HGSHS-A; Shor & Orne, 1962), Stanford Hypnotic Susceptibility Scale, form C (SHSS-C; Weitzenhoffer & Hilgard, 1962) and Waterloo-Stanford Group Scale of Hypnotic Susceptibility (WSGS; Bowers, 1998), a group adaptation of SHSS-C, include suggestions about motor and cognitive productions and inhibitions. The total score is derived from the number of suggestions the subject is indicated to respond to behaviourally and do not include any measure of various subjective experiences. The ability of suggestibility scales to measure hypnotic responsiveness and to define its relation to hypnotisability, hypnotic depth and non-hypnotic suggestibility has been criticized (Weitzenhoffer, 1980). Some view different types of suggestions to produce qualitatively different hypnotic phenomena, in which case the essential information might not be captured by the total score (Kallio & Revonsuo, 2003).

Responding to suggestions, as measured by the standardized scales, does not seem to be enhanced dramatically by induction (Braffman & Kirsch, 1999). In fact, Kirsch and Braffman (2001) review the results on the connection between hypnotic and non-hypnotic responsiveness and conclude that non-hypnotic imaginative suggestibility and subject’s expectations are enough to explain the major part of the hypnotic suggestibility. This means that hypnotisability at the level of population is negligible.

Supporting the non-state approach, most hypnotic phenomena are known to be produced by suggestions even without any use of the term hypnosis or the procedure of hypnotic induction. Kirsch and Braffman (2001) insist that hypnotic responsiveness is an ability similar to other cognitive abilities, but restricted to imaginative suggestions. This outlook has gained support by the evidence that the stability of hypnotic responsiveness is comparable to that of the IQ and greater than that of many personality traits (Piccione, Hilgard & Zimbardo, 1989). Hypnotic suggestibility can also be taught and moderately increased for a short time with the proactive cognitive-behavioural training (Bates, Miller, Cross & Brigham, 1988).

At the same time, hypnotic behaviour is not hard to imitate behaviourally. So far, no undisputed ways to differentiate between hypnotic responding and simulation have been found. Orne (1959) found that, as compared with simulators, the real subjects invariably describe a shift in state from normal waking experience: inability to resist the suggestion, subjectively real quality of hallucinations and tolerance of logical inconsistencies. Hypnotic behaviour of highly susceptible subjects has also been found to be independent of being observed (Evans & Orne, 1971; Kirsch, Silva, Carone, Johnston & Simon, 1989; Perugini et al., 1998). However, when interpreting these results, it is worth keeping in mind that when subjects know that they will go through both non-hypnotic and hypnotic condition they might simply not perform their best in the non-hypnotic one due to expectations and the hold back effect (Zamansky, Scharf & Brightbill, 1964). That is why in addition to self-reports, substantiation can be gathered in the form of reaction times and accuracy rates during different forced choice tasks (Kallio & Koivisto, in press; Raz et al., 2006; Raz et al., 2007; Raz et al., 2002; Terhune et al., 2011b), with the help of brain activity measurement (Barabasz et al., 1999; Cardeña et al., 2012; Fingelkurts, Al. et al., 2007; Fingelkurts, An. et al. 2007; Jensen et al., 2001; Kallio et al., 1999; Kosslyn et al., 2000; McGeown, Mazzoni, Venneri & Kirsch, 2009; McGeown et al., 2012; Perlini, Lorimer, Campbell & Spanos, 1992; Raz, et al., 2005; Terhune et al., 2011a) and eye-movement detectors (Kallio, Hyönä, Revonsuo, Sikka & Nummenmaa, 2011).

Usually studies exploit suggestibility scores to differentiate between those who get very high scores and those who do not seem to respond to suggestions at all, and compare the performance of these two extreme groups. Nevertheless, there are no systematically used limits for classifying the responders, and even susceptible subjects, who receive high scores on the suggestibility scales, differ in their hypnotic abilities and experiences as indicated by self-reports, task performance, physiological and neural activation. Among such detected factors of difference are the ability to hallucinate (Szechtman et al., 1998), dissociative tendencies (Terhune et al., 2011b) and the feeling of involuntariness in the posthypnotic condition (Howard & Coe, 1980; Schuyler &

Coe, 1981). These results force to question the practice of studying subjects as homogeneous groups based only on the suggestibility scores (Kallio & Revonsuo, 2003).

One way to avoid losing valuable information from the individual performance and examine the full depth of hypnotic phenomena would be concentrating on the extremely highly suggestible subjects, often referred to as *hypnotic virtuosos*, in the form of case studies. Though there are some opposing opinions (Wagstaff & Cole, 2005), the case study approach is seen as useful, because it allows to pay more attention to individual differences amid effective hypnotic responders (Kallio & Revonsuo, 2005; McConkey et al., 1989; Raz et al., 2007; Weitzenhoffer, 2000). It could furthermore be seen as a form of the grounded theory method, particularly appropriate in new topic areas, when the theory can be inductively built, revised or extended through the analysis of obtained empirical data (Eisenhardt & Graebner, 2007).

Having gone through the dispute over the meaningful components of and individual differences in hypnotic responding the focus of attention will next be directed to the empirically observed and measured effects of hypnosis significant for the present study.

1.4.3. The perceptual and neural effects of hypnosis

The exact effects of hypnosis on perception and behaviour as well as the underlying neural routes are studied vigorously. In the field of perception, the effect of hypnosis is often studied by *hallucinations*. According to Merriam-Webster medical dictionary hallucination is a perception of something with no external cause. Hypnotic hallucination could be defined as a spontaneous replacement of some content of consciousness with the suggested content (Kallio & Revonsuo, 2003). It shares with the imaginary perception the property of being self-generated and with the real perception the experience of the stimulus being externally originated (Szechtman et al., 1998).

In particular, visual hallucinations have lately attracted new research interest. A wealth of studies on the suggestive modulation of Stroop effect has been generated by Raz and his associates (Raz et al., 2005; Raz et al., 2006; Raz et al., 2007; Raz et al., 2002). In these studies the posthypnotic suggestion was given to perceive letters in colour words as meaningless symbols after which the classic Stroop test was conducted. Results were somewhat inconsistent since inhibition of the Stroop effect was found in highly suggestible subjects both after hypnotic induction only (Raz et al., 2002) and also without it (Raz et al., 2006). Nonetheless, these findings established the power of suggestion to overcome even such automatic processes as word recognition in proficient readers.

Other studies on visual hallucinations have used pictures of graphical coloured rectangles separated by black lines, such as in Mondrian patterns, in colour and grey scale when giving the hypnotic suggestion to perceive the first ones in grey scale and the second ones in colour (Kosslyn et al., 2000; Mazzoni et al., 2009; McGeown et al., 2012). Also here researchers obtained slightly different results concerning the necessity of induction for the suggested changes to occur. Kosslyn et al. (2000) found only hypnotic suggestions to change the activity in the colour areas of the left hemisphere and to create altered experiences. However, Mazzoni et al. (2009) and McGeown et al. (2012) showed that although hypnotic induction enhances the efficacy of suggestion in highly suggestible subjects, it is not necessary for the alteration of colour perception. Those researchers saw the difference between their results and that of Kosslyn et al. (2000) to be due to the use of slightly dissimilar suggestions in different conditions by the latter, questioned the validity of these opposing results, and gave their support to the non-state view of hypnotic responding as a goal-directed activity independent of induction. However, behavioural changes in the visual perception only after induction have been observed recently also by using simple coloured shapes and a posthypnotic suggestion to see some of these shapes in a different colour (Kallio & Koivisto, in press). The researchers specified that shorter presentation times could not have offered the opportunity to use goal-directed approach and the hypnotic responding was automatic.

Despite the differences, neurophysiological findings of hypnotic responsiveness have shown certain common directions. For instance, changes in the *default mode* activation during hypnosis have been found to be a way to identify it (McGeown et al., 2009; McGeown et al., 2012; Rainville, Hofbauer, Paus, Duncan, Bushnell & Price, 1999; Raz et al., 2005). Default mode network is a common name for those brain areas that are systematically active when there can be seen no particular goal-directed activity that is when the individual is awake and alert, but yet not actively engaged in an attention-demanding task (Raichle et al., 2001). This network involves the posterior cingulate, precuneus and the medial prefrontal cortex. Deactivation of this network implies presence of goal-directed occupation. Such deactivation was detected in highly suggestible subjects after hypnotic induction even before performing the task (McGeown et al., 2009). The researchers considered that, combined with the found activation in the attentional system during hypnosis (Rainville, Hofbauer, Bushnell, Duncan & Price, 2002), these results suggest that the induction works by helping the subject focus attention on suggestions and use imaginative skills to the full extent.

Other promising studies have detected changes in the functional connectivity of the brain of the highly suggestible subjects during hypnosis (Cardeña et al., 2012; Fingelkurts, An. et al., 2007; Terhune et al., 2011a). Neural functional connectivity is the association between the coordination of activity of different cortical regions (Friston, 1994). In a recent study by Terhune et al. (2011a) self-reports and brain electrical activity data were collected from highly and low suggestible individuals during normal condition and neutral hypnosis. Lower connectivity was found in highly suggestible individuals between frontal and parietal regions after induction. These results were confirmed by Cardeña et al. (2012) when using neutral hypnosis. Once in a while subjects were prompted to report their experiences and advised to go deeper into hypnosis. Reported spontaneous hypnotic experiences were associated with lower global functional connectivity. Similar results were previously shown in a study of a hypnotic virtuoso (Fingelkurts, An. et al., 2007). Additionally, Hoeft et al. (2012) found elevated local functional connectivity between the dorsal anterior cingulate cortex and the dorsolateral prefrontal cortex at rest in highly suggestible individuals and proposed this to be the neural basis of suggestibility.

The decrease in functional connectivity has been proposed to indicate the temporary inability of some cognitive subsystems to communicate with each other after hypnotic induction (Fingelkurts, An. et al., 2007) while enhanced communication between others might take place (Hoeft et al., 2012). The neural changes then result in alterations in the phenomenal unity of consciousness (Terhune et al., 2011b) and are consistent with the theoretical view presented by Dietrich (2003), according to which altered states of consciousness are accompanied by deregulation of different dorsolateral prefrontal circuits. Connecting the presented results to the deactivation of the default mode network, Terhune et al. (2011a) proposed that the reduced neural coordination in highly suggestible individuals may mediate reduced activity in the default mode network during hypnosis. As a result, during hypnosis the disrupted phenomenal unity of consciousness is combined with greatly focused attention.

Regarding other empirical results, a couple of studies on the hypnotic state of a hypnotic virtuoso indicated inimitable changes in brain oscillation patterns (Fingelkurts, Al. et al., 2007), automatic and volitional eye movements (Kallio et al., 2011) and a larger negativity to unattended deviant audiostimuli presented among identical audiostimuli (Kallio et al., 1999) after a hypnotic induction. Further findings and clarifications are needed and contemporary brain activity recording techniques are anticipated to answer many of the questions piled up over the years.

1.5. Electroencephalography

So far, one of the most used measurement tools in the research on hypnosis is electroencephalography (EEG) (Barabasz et al., 1999; Cardeña et al., 2012; Jensen et al., 2001; Kallio et al., 1999; Perlini et al., 1991). EEG is a non-invasive method of recording the temporal proceeding of the electrical synchronous post-synaptic potentials of groups of cortical pyramidal cells (Luck, 2005). Electrodes attached to the surface of the scalp capture the difference in the voltage between a pair of electrodes.

When compared with behavioural measurements, continuous EEG recording merits by showing processing activity without requiring a behavioural response, though the functional meaning of this signal might not be as clearly interpreted as in case of behavioural response (Luck, 2005). The main strengths of EEG, as compared to hemodynamic brain imaging techniques, are the fine-grained temporal resolution of milliseconds, the low cost and relative mobility. However, its limitations are poor spatial detection and weak signal-to-noise ratio, so that muscle activity and surrounding electrical fields cause large artefacts which manage to cover the studied signal changes. Manual data cleaning, artefact correction and averaging of EEG across a large number of trials are only the briefest description of the procedures necessary to increase the quality of the recorded signals.

Event-related potentials (ERPs) are averaged EEG epochs that are time-locked to a specific event, usually the stimulus onset. When background brain activity and non-neuronal electrical noise are averaged out from the event-locked epochs of data, what is left is called an ERP with its characteristic positive and negative deflections. ERPs are further analysed in terms of their positive and negative peaks which are named according to their polarity and order of occurrence or latency (e.g. the first negative peak as N1 or N100). Early peaks are mainly influenced by external factors, such as the physical properties of the stimulus, and depict sensory processing independent of the task the subject is committed to, while changes in the later peaks are due to higher cognitive processes and are more affected by internal factors (Luck, 2005).

1.5.1. Visual attention in ERPs

ERP technique has emerged to be a suitable way to study, among others, the temporal structure of neural activity of attentional processes. It is thus of interest in the research on hypnosis which is thought to include highly focused receptive concentration and diminution of peripheral awareness (Dietrich, 2003; Spiegel & Spiegel, 2004). Top-down directed attention requires voluntary effort and can be seen as distinct changes in the ERP waves. Attention can be further divided into sustained and transient attention, and regarding visual features into spatial and non-spatial visual attention, all of which cause specific alterations in ERP profiles. Additionally, ERP waveforms elicited when attending to stimuli that combine several features provide information on the time course with which individual features and their conjunctions are selected and processed (Hillyard & Anllo-Vento, 1998).

Sustained attending to non-spatial visual attributes, such as colour, orientation, shape and frequency of stimuli, has been found to affect ERP waves at longer latencies, as compared with attending to spatial features (Luck, 2005). Particularly N2 and P3 peaks seem to be affected by visual attention. In tasks that require responding to some stimuli and not responding to others, inhibiting the response has been found to increase N2 and P3 peaks (Bekker, Kenemans & Verbaten, 2004; Smith, Johnstone & Barry, 2008). The increase in N2 has also been detected when the stimuli are simply infrequent (Nieuwenhuis, Yeung, van den Wildenberg & Ridderinkhof, 2003), the subject must unexpectedly produce a response with higher than normal force (Donkers & van Boxtel, 2004) or receives a false cue to respond (Band, Ridderinkhof & van der Molen, 2003). Some proposed that N2 is connected to the non-motoric stage of inhibition and P3 is connected to motor inhibition (Smith et al., 2008). Others viewed increase in those to reflect conflict-monitoring and choosing between two responses rather than mere inhibition (Band et al., 2003; Donkers & van Boxtel, 2004; Nieuwenhuis et al., 2003). Third managed to find all these operation peaks to exist, but to be generated in different parts of the brain (Kropotov, Ponomarev, Hollup & Mueller, 2011). Recent reviews seem to support this latter view. Frontocentral N2 is proposed to be connected both to cognitive control, such as regulation of strategy, cancelling a prepared response, as well as the detection of novel stimuli and posterior N2 to orienting of visual attention (Folstein & Van Petten, 2008). At the same time, P3 peak is connected to stimulus probability and task relevance, the orienting of attention to unexpected or significant events in the environment and the updating of working memory (Linden, 2005).

Moreover, contrasting to unattended stimuli, visual attending is often associated with a prolonged increased negativity at 150−350 ms after the stimulus onset (Anllo-Vento, Luck & Hillyard, 1998; Eimer, 1997; Smid, Jakob & Heinze, 1999; Wijers, Mulder, Okita & Mulder, 1989). This attention-related negative shift is referred to as selection negativity and seems to have a posterior scalp distribution (Folstein & Van Petten, 2008). Such negative deflection represents the orienting towards the task-relevant properties of the stimulus. Another way to view it would be as rather a cognitive process initiated after selection is finished allowing selective analysis of the visual percept, such as perceptual analysis in the short-term memory or feature integration (Smid et al., 1999).

In the research on hypnosis, N2 and P3 wave amplitudes of attenuated stimuli have been found to diminish with the increase in efficacy of positive obstructive hallucinations in highly suggestible subjects (Barabasz et al., 1999; Jensen et al., 2001; Perlini et al., 1992; Spiegel et al., 1985). This might indicate that positive hallucinations make the subject focus away from the presented stimulus, which leads to a decrease in the perception of that stimulus and reduced electrical responses (Jensen et al., 2001). No ERP studies on posthypnotic suggestion are known to be reported of.

The introduced outlines from the fields of hypnosis and EEG form the foundation of the research presented here. They also serve to guide the choice of objectives and methodology and lead into the question of research.

1.6. Aims of the present study

In the present study, the effect of posthypnotic suggestion on the perception of visual stimuli of different colour and shape is examined. The used suggestion for visual hallucination instructs seeing stimuli of a particular shape in the opposite colour after which the task is to respond to stimuli of a particular colour. The aim is to find out whether this suggestion used posthypnotically would produce the suggested responses as detected by both the behavioural performance, measured in reaction times and accuracy rates, and electrical brain activity. Another aim is to see whether the same effect could be obtained when the instruction is given outside hypnosis in the simulation condition.

The case study approach is taken and the focus is set on two highly suggestible individuals. This is done in order to detect the individual variability which can be found even among highly suggestible subjects. Three age- and gender-matched control subjects are asked to simulate the suggested perception and behaviour and use their imagination without inferring that they should try to mimic the exact hypnotic state. Additionally, at the end of the experiment case subjects who had gone through hypnosis were asked to report their subjective experiences during the posthypnotic condition.

If hypnotic induction leads to a profound shift in the brain state which allows receiving the suggestion in a more efficient way, it would be expected that the effect of the posthypnotic suggestion on behavioural performance and ERPs would not resemble that of either control subjects or the virtuoso herself when asked to merely use her imagination. Changes that are not specific to the effect of posthypnotic suggestion should be found in both conditions and among several subjects, whereas changes specific to the effect of posthypnotic suggestion would be expected to occur only in the posthypnotic condition.

The research field is full of controversial results thus making the setting of well-grounded hypotheses which would not be biased a challenging procedure. In order to avoid taking a side in the state vs. non-state debate, the study was conducted to address the following questions: Can the posthypnotic suggestion for visual hallucination produce the suggested behaviour and affect electrical brain activity? Is the highly experienced hypnotic virtuoso capable of performing equally good without the posthypnotic suggestion merely by using imagination or is induction necessary for the suggested behaviour to appear? Are these effects restricted to highly suggestible subjects, and are there differences among them?

2. Methods

Methodological issues form an essential part of the state vs. non-state debate and are key concern for the research on hypnosis. This chapter will show, how the methodological questions were answered in this study. It will introduce the used variables, measures, the actual procedure, as well as the means and parameters of pre-processing and analysing of the data

2.1. Subjects

Five paid volunteers participated in this experiment. The main focus of interest was set on one extremely highly suggestible subject TS-H (scored the maximum of 12 points on both SHSS-C (Weitzenhoffer & Hilgard, 1962) and HGSHS-A (Shor & Orne, 1962)). This hypnotic virtuoso has a long history of successful hypnotic responding in experimental studies (Fingelkurts, Al. et al., 2007; Fingelkurts, An. et al., 2007; Kallio & Koivisto, in press; Kallio et al., 2011; Kallio et al., 1999), a psychometrically normal profile and no history of neurological or psychiatric illnesses (see details in Kallio et al., 2011). Additionally, there was one not yet as well examined, but also highly suggestible subject RM (scored 9 points on SHSS-C and 12 points on HGSHS-A) and three control subjects (CS1, CS2 and CS3) whose suggestibility was not assessed. Subjects TS-H and RM also served as their own controls performing the task both posthypnotically and by using plain mental imagery. The posthypnotic suggestions were chosen because the main case subject TS-H is known from the previous research (Kallio et al., 2011) to be motorically stagnant while being in hypnosis, which would make the behavioural measurements impossible.

All subjects were women, whose age ranged between 39 and 49 years (mean 44.2 years, SD 4.0 years). All of them were right-handed and had normal or corrected-to-normal vision. Informed consent was obtained according to institutional procedures prior to participation in the experiment. The experiment was conducted according to the ethical standards of the American Psychological Association (APA) and approved by the Ethics Committee of the University of Turku, Finland (statement 18/2011).

2.2. Stimuli and apparatus

Visual stimuli consisted of two-dimensional images of three different shapes − triangle, square and circle − in one out of two different equiluminant (12.9 cd/m^2) colours − red or blue. Monochromatic stimuli were shown one at a time at the centre of a black (0.2 cd/m^2) screen and were 6.5 cm wide and 6.5 cm high (visual angle of 2.5° × 2.5°). Subjects were seated in a dimly lit sound-attenuated room in front of a high resolution 19’’ CRT computer monitor (1024 × 768 pixel, refresh rate of 85 Hz) which was positioned at eye level 150 cm in front of the subject. Stimuli were presented with E-Prime 2.0 software.

The six different stimuli (3 shapes × 2 colours) were presented in random order and with equal probability across trials so that each stimulus was presented 36 times in a block. Altogether each block consisted of 216 stimuli. Stimuli were presented for 24 ms and followed by 800−1200 ms of blank black screen so that the speed of presentation was on average 60 stimuli per minute and block duration did not exceed four minutes. Each session consisted of twelve blocks and did not last for more than an hour and a half excluding the electrode attachment period in EEG sessions which did not last for more than half an hour.

2.3. Procedure

The study of each subject consisted of three sessions conducted on different days: first one behavioural and afterwards two EEG sessions. Behavioural and EEG sessions were separated to prevent the movement artefacts from disrupting the EEG data. Preceding the experiment, all subjects were informed that the purpose of the study is to examine hypnosis, but control subjects were also told that they will not be hypnotized.

The experiment was started with overall instructions which in EEG sessions were followed by affixing the electrode cap and establishing the signal quality. In the beginning of each block, the subject was told that either red or blue was the targeted colour. After that the suggestion was given followed by the task to press the key on a pad held in one's lap with the dominant hand whenever the stimulus of the targeted colour was shown. Both colours were used as targets an equal amount of times. The tasks on behavioural and EEG sessions were otherwise the same, except that during EEG recordings subjects were asked to reply only to each tenth targeted stimulus while counting all the targeted stimuli in their mind without moving their lips or tongue. Also this was done to prevent the movement artefacts from disrupting the EEG data. Speed and accuracy were emphasized equally during the behavioural sessions. To reduce muscle artefacts in the EEG signal, subjects were instructed to avoid any kind of unnecessary movements during EEG sessions.

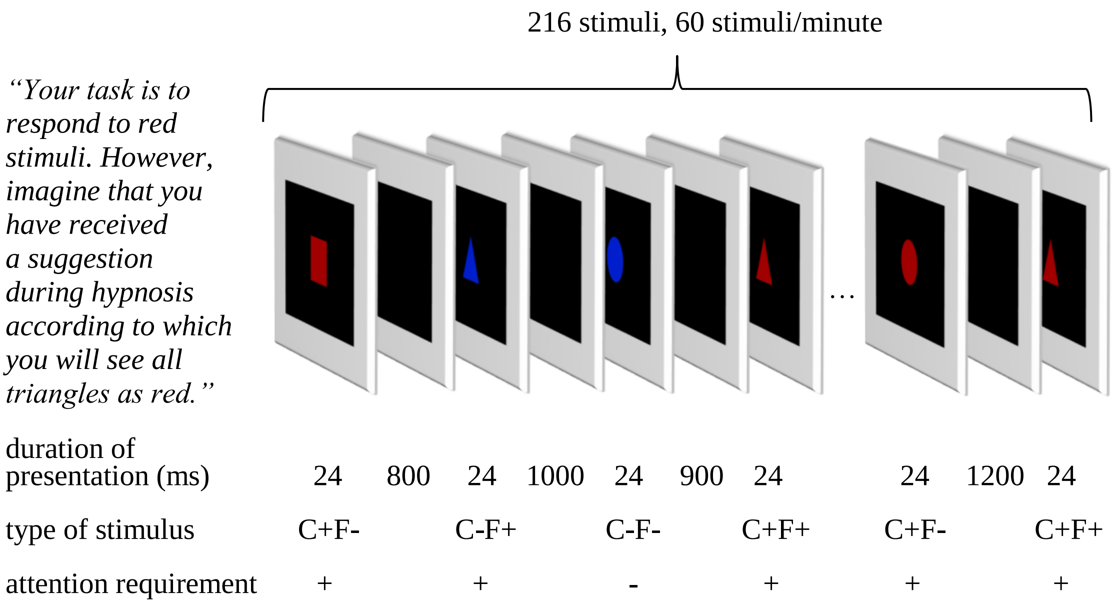

Fig 1. An example of the procedure in a simulation block with the task to respond to all red stimuli. The time of presentation of each type of stimulus and the blank screen, the type of the stimulus and the requirement of attention according to the given suggestion are shown below. In the behavioural sessions subjects were requested to respond to every targeted stimulus, while during the EEG sessions they were told to respond only to every tenth targeted stimulus. Instructions were given in Finnish and the text shown here is the approximate translation.

Three types of blocks were used: normal, posthypnotic and simulation blocks. Highly suggestible subjects went through posthypnotic and simulation blocks, while control subjects went through normal and simulation blocks. In the normal blocks, subjects were requested to react only to stimuli of the targeted colour. In the posthypnotic blocks hypnosis was induced with one word by an experienced hypnotist S. Kallio (see the video in Kallio et al., 2011) and subjects were given a deceptive suggestion according to which they would see, for example, all triangles as red (all shape × colour combinations were used in turns). After that they were awoken not remembering the given suggestion and the task of responding, in this case to red stimuli, was given. Suggestion was cancelled after each block.

In the simulation blocks, subjects were told to *imagine* as if they had received a suggestion according to which they see, for instance, all triangles as red. Therefore, in this example, in the posthypnotic and simulation blocks during the task of responding to red stimuli they had to monitor and respond to all red shapes and blue triangles imagined to be red (Fig. 1) All shape × colour combinations were used as targeted stimuli in separate blocks.

Functionally stimuli were divided in the posthypnotic and simulation blocks in four types: stimuli combining both the targeted colour and suggestion-relevant shape (C+F+, where C stands for colour and F for shape), other stimuli of the same colour, but suggestion-irrelevant in shape (C+F-), stimuli of the opposite colour and suggestion-relevant shape (C-F+) which were targeted by the suggestion in the posthypnotic and simulation blocks, and non-target stimuli of untargeted colour and suggestion-irrelevant shape (C-F-) which were to be ignored. In the normal condition of control subjects responses were grouped based solely on the colour of stimulus − targeted (C+) or untargeted (C-). Later on this division was used when analysing the results.

Each session consisted of two types of blocks standing for two different conditions. Highly susceptible subjects underwent posthypnotic and simulation blocks, so that the blocks targeting the same shape followed each other, but the order inside these couples was changed based on the condition (e.g. PHC(=posthypnotic)-T(=triangle), SIM(=simulation)-T; SIM-S(=square), PHC-S; etc.). Sessions of the control subjects consisted of normal and simulation blocks which were alternated in the same way. The order of blocks was counterbalanced across subjects so that every second subject went through the blocks in a reversed order. The highly suggestible subjects had their blocks in a reversed order also during the second EEG session. This shuffling was used to avoid any kind of influence of the order of tasks on performance.

Each session was divided in two halves based on the targeted colour – first red and then blue or the other way around − and a break in between. A short practice period preceded each half of the session in order for the subject to familiarize herself with the specific task requirements. After all the sessions both highly suggestible case subjects were inquired about their subjective experiences during the posthypnotic condition.

2.4. Measurements

Data from the behavioural sessions – response times and accuracy rates − were gathered with E-Prime 2.0 software. Continuous EEG was DC-recorded with the NeuroScan 4.3 acquisition system using a band pass of 0.05−100 Hz with a 50 Hz notch filter and a sampling rate of 1000 Hz. Signals were recorded from 19 Ag–AgCl electrodes mounted in an elastic cap according to the extended International 10–20 System of electrode placement at Fp1, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1 and O2. The nose tip was used as an on-line reference. Two EOG electrodes, one below the right eye and one in the right eye corner, were used for eye movement detection. All electrode impedances were kept below 5 kΩ.

2.5. Data analysis

Behavioural results were averaged with E-Prime 2.0 software according to the type of stimulus. Response time medians and Error rates were grouped in the posthypnotic and simulation blocks based on the previously presented division. Responses which did not follow the block-specific suggestion, such as not responding to C+F+, C+F- or C-F+ stimuli, and responding to C-F- stimuli, were counted as erroneous. In the normal blocks errors were detected when the key was not pressed to C+ stimuli or when it was pressed to C- stimuli. Response times were obtained only on the stimuli that were responded accurately to. Response time medians were used instead of means because they are less affected by the possible outliers. In order to compare the behavioural data of control subjects between the simulation and normal condition new variables were formed by summing up the values across all stimuli and forming averaged individual response times and error rates in each condition.

Response times and error rates were further analysed with SPSS/PASW Statistics 18. Statistical analyses were carried out using repeated measures analysis of variance (ANOVA) in a similar way to Kallio and Koivisto (in press). In order to do this, analysis were done one subject at a time using separate blocks as individual cases placed on rows so that every analysis of each condition was conducted on the data from 6 (3 shapes × 2 colours) blocks. When analysing error rates, colour (colour: targeted, untargeted) and shape of the stimulus (shape: suggestion-relevant, suggestion-irrelevant) and, when dealing with response time medians, the stimulus as such (stimulus: C+F+, C+F-, C-F+), were used as within-subject factors. The displayed within-subjects effects were Greenhouse-Geisser corrected. In case of the data of highly suggestible subjects, condition (condition: posthypnotic, simulation) was used as an additional factor.

The continuous EEG was segmented into ERP waves from 100 ms prior to 400 ms after the onset of the visual display using Brain Vision Analyzer 2.0. Data from the first two channels, FC1 and FC2, were disabled because of its high level of noise. A band pass of 0.1−20 Hz and a notch filter of 50 Hz were used. Baseline correction was made on the time interval from 100 ms until the onset of the stimulus. Trials with eyeblinks (VEOG exceeding ±70 μV) and trials with response given in the time interval of 200 ms prior and 800 ms after the onset of the visual display were eliminated from further analyses. The lowest allowed activity in successive 100 ms intervals was set to 0.5 μV. On the basis of the literature and visual inspection of the data, peaks were manually found in the averaged stimulus by block waveforms of each subject. The information on peak latencies and their amplitudes was then exported to SPSS/PASW Statistics 18 for further statistical analysis.

Based on the visual inspection the only noticeable differences of ERP wave peak amplitudes of different stimuli were located in the electrode channels attached to the posterior parietal (P3 and P4), occipital (O1 and O2) and posterior temporal (T5 and T6) cortical areas, so the statistical analyses were carried out only on the data from these electrodes. The peak amplitudes and latencies of the averaged ERP waveforms were compared. Since the sustained visual attention to non-spatial features might be expected to have a greater effect on the later electrical activity, especially the later ERP peaks formed a matter of interest in this study. All peaks were analysed, but statistically significant differences were found only in the amplitudes of the second negative peak (N2 peak; time window 200−290 ms) and the third positive peak (P3 peak; time window 260−360 ms).

Statistical analyses of the case study EEG data were also carried out by repeated measures ANOVA, using the same method as in a previous case study by Kallio et al. (1999) when treating blocks as distinct subjects. The block data were placed on rows and 12 (3 shapes × 2 colours × 2 sessions) blocks were used to represent each condition. First, peak amplitudes were examined. Thereafter, also the differences in peak latencies were inspected. Within-subject factors were cortical area (area: P, O, T) and hemisphere of the electrode (hemisphere: left, right), colour (colour: targeted, untargeted) and shape of the stimulus (shape: suggestion-relevant, suggestion-irrelevant). It is worth noticing that the effect of shape here is connected to suggestion and not mere physical properties of the stimulus or attending preferences, since three kinds of shapes were used with only one being targeted each time by the suggestion. Additionally, C-F+ stimuli peaks were compared between the conditions. Analysis of the data of control subjects included only these four factors, but in case of highly suggestible subjects condition (condition: posthypnotic, simulation) was used as one more factor. The results were Greenhouse-Geisser corrected.

3. Results

Behavioural and EEG measurements were obtained on separate sessions, not connected when analysing and also here they will be presented separately. This chapter will introduce the results of statistical analysis and go through the significant findings. The results concerning particular electrode sites are not presented since the data were quite small, the statistical results were not systematic and the localization of the changes in activity was not the aim of this study. Case subjects' self-reports from the posthypnotic condition are presented at the end.

3.1. Behavioural results

3.1.1. Error rates

First, the effect of posthypnotic suggestion on the accuracy of TS-H was examined in a colour × shape × condition ANOVA. All main effects and interactions were found to be significant. The highest significant interaction was that of colour × shape × condition ($F(1,10)=70.28$, $p<.001$). Further analyses of this revealed that the colour × shape interaction was significant only in the simulation condition ($F(1,5)=162.52$, $p<.001$), with most erroneous reactions caused by C-F+ stimuli targeted by the suggestion. When compared between conditions, TS-H had higher error rates in the simulation condition ($F(1,10)=247.30$, $p<.001$) particularly to C-F+ stimuli (PHC: 3.8%, SIM: 55.8%, $p<.001$; Fig. 2a). Therefore, for her especially the responding to the target stimuli of suggestion was considerably less accurate in the simulation condition.

RM's error rates were also affected by all the factors and their interaction (colour × shape × condition: $F(1,10)=75.59$, $p<.001$). Analysis of the latter showed that the colour × shape interaction was significant only in the posthypnotic condition ($F(1,5)=85.46$, $p<.001$). Alike TS-H, RM had the highest error rates in response to the C-F+ stimuli, responding to which was meant to show the efficiency of given suggestion, but she, unlike TS-H, was more precise with her responses in the simulation as compared to the posthypnotic condition ($F(1,10)=88.24$, $p<.001$; PHC: 68.7%, SIM: 4.8%, $p<.001$; Fig. 2b).

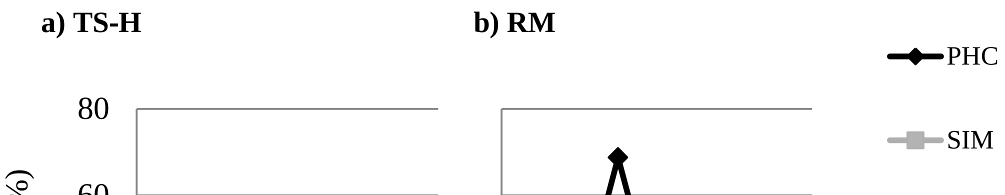

Figure 2. Error rates (% of all the responses to those stimuli) for each type of stimulus as a function of condition (posthypnotic; PHC, and simulation; SIM) for (a) TS-H and (b) RM.

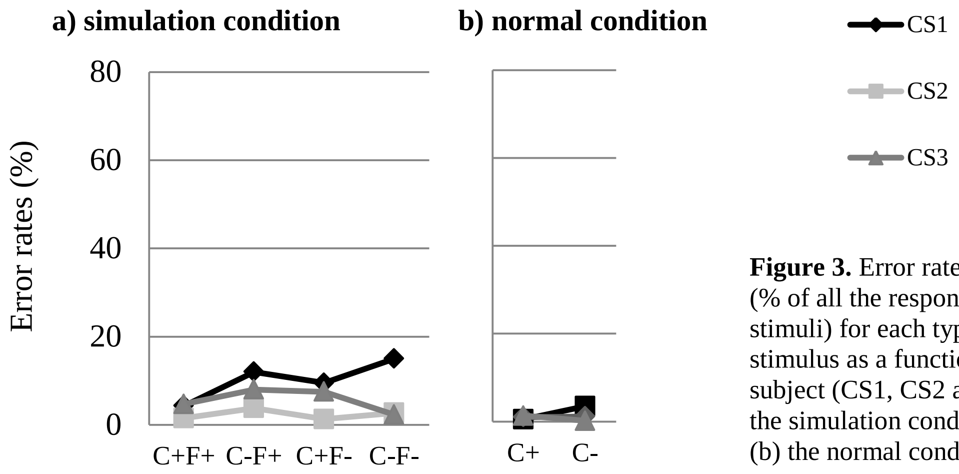

Figure 3. Error rates (% of all the responses to those stimuli) for each type of stimulus as a function of control subject (CS1, CS2 and CS3) in (a) the simulation condition and (b) the normal condition.

Individual analyses of control subjects' data from the simulation condition did not show any significant effects (Fig. 3). When compared with normal condition only the error rates of CS1 were increased when shape was introduced as an additional attended feature in the simulation condition (*F*(1,10)=23.56, *p*<.005). This means that attending to conjunction of visual features did not decrease accuracy systematically.

3.1.2. Response times

Response times were analysed with a stimulus × condition design of ANOVA. Only stimulus had an effect on the reaction times of TS-H (*F*(1,13)=24.72, *p*<.001). She responded faster to the C+F+ stimuli and slower to the C-F+ stimuli targeted by the suggestion (*p*s<.01; Fig. 4a).

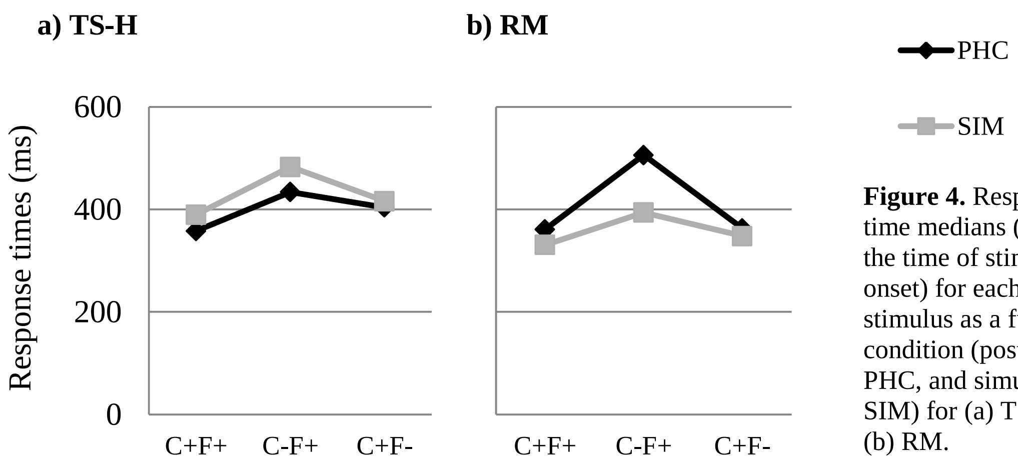

Figure 4. Response time medians (ms from the time of stimulus onset) for each type of stimulus as a function of condition (posthypnotic; PHC, and simulation; SIM) for (a) TS-H and (b) RM.

For RM, also the stimulus × condition interaction was significant ($F(1,12)=7.72$, $p<.05$). During the simulation task, her response rates to C-F+ stimuli were faster as compared to the posthypnotic condition (SIM: 394 ms, PHC: 506 ms; $p<.05$; Fig. 4b). These results indicate that implementing the suggestion, classifying the stimuli targeted by the suggestion and responding correctly to them caused a significant delay in responding of both case subjects. However, between the conditions, the performance of TS-H was more even and did not depend on whether she had received the suggestion for simulation or the posthypnotic suggestion, while RM had to decide for a longer time when responding to the stimuli targeted by the suggestion in the posthypnotic condition. As in case of error rates, for RM conscious simulating was noticeably more efficient than following the posthypnotic suggestion.

Analysing the individual data of the control subjects and comparing them with the normal condition revealed that reaction times were generally increased in the simulation condition for all control subjects (CS1: $F(1,10)=25.41$, $p<.005$; CS2: $F(1,10)=36.42$, $p<.001$; CS3: $F(1,10)=6.06$, $p<.05$; Fig. 5). This means that adding attention to shape of the stimulus prolonged the mean time of responding for all controls. Overall, the behavioural results imply dissimilarities in processing of stimuli between posthypnotic and simulation conditions and also differences even among highly suggestible subjects.

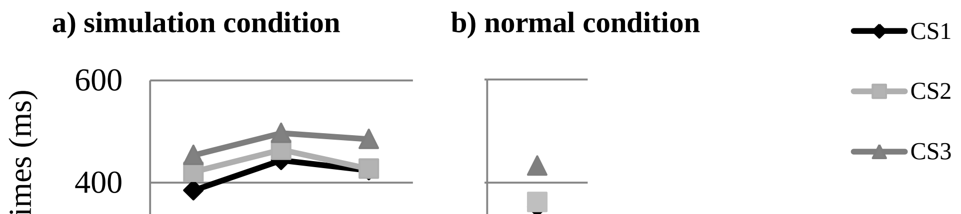

Figure 5. Response time medians (ms from the time of stimulus onset) for each type of stimulus as a function of control subject (CS1, CS2 and CS3) in (a) the simulation condition and (b) the normal condition.

3.2. ERP results

3.2.1. N2 peak

The data of TS-H were analysed first with a colour × shape × area × hemisphere × condition ANOVA. N2 peak amplitudes were significantly affected by the colour × condition interaction ($F(1,22)=7.30$, $p<.05$) so that colour had an opposite effect on N2 waves in the two conditions (Fig. 6 and Fig. 8a). In the posthypnotic condition more negative amplitudes were associated with C- stimuli ($F(1,11)=3.36$, $p<.10$), while in the simulation task C+ stimuli caused more negative amplitudes ($F(1,11)=4.05$, $p<.07$), although both effects were only marginally significant. The effect of shape was also significant ($F(1,22)=5.78$, $p<.05$), and N2 amplitudes were increased to F+ stimuli. This means that, irrespective of the condition, shape was a significant feature, which caused an effect in the visual processing of TS-H.

The results of RM from the similar analysis showed also a condition × colour interaction. However, at a closer look the effect of colour was only relatively more significant in the simulation ($F(1,11)=92.99$, $p<.001$) as compared to the posthypnotic condition ($F(1,11)=10.73$, $p<.01$). Higher negative amplitudes in both were due to C- stimuli (Fig. 7 and Fig. 8b), the same way as in the data of TS-H from the posthypnotic condition. All in all, condition did not seem to have a crucial effect on processing of RM. The effect of shape was significant as well ($F(1,22)=3.96$, $p<.06$), with more negative amplitudes to F+ stimuli. The colour × shape interaction was also found to be significant ($F(2,35)=3.64$, $p<.05$). The C-F+ stimuli targeted by the suggestion caused more negativity than C-F- stimuli. Therefore, stimuli of the same colour with the shape of different suggestion-relevancy were processed dissimilarly. Regarding latencies, C- stimuli had slightly later peak times ($F(1,22)=55.34$, $p<.001$).

The data of control subjects were analysed individually and separately for the normal and simulation condition. The effect of attending only to a specific colour, derived from the normal condition, was seen as more negative amplitudes in response to C+ stimuli (CS1: $F(2,17)=7.02$, $p<.05$; CS2: $F(1,15)=6.30$, $p<.05$; CS3: $F(2,22)=7.42$, $p<.005$; Fig. 9) as it did in the data of TS-H from the simulation condition.

Averaged ERPs of TS-H from six electrodes

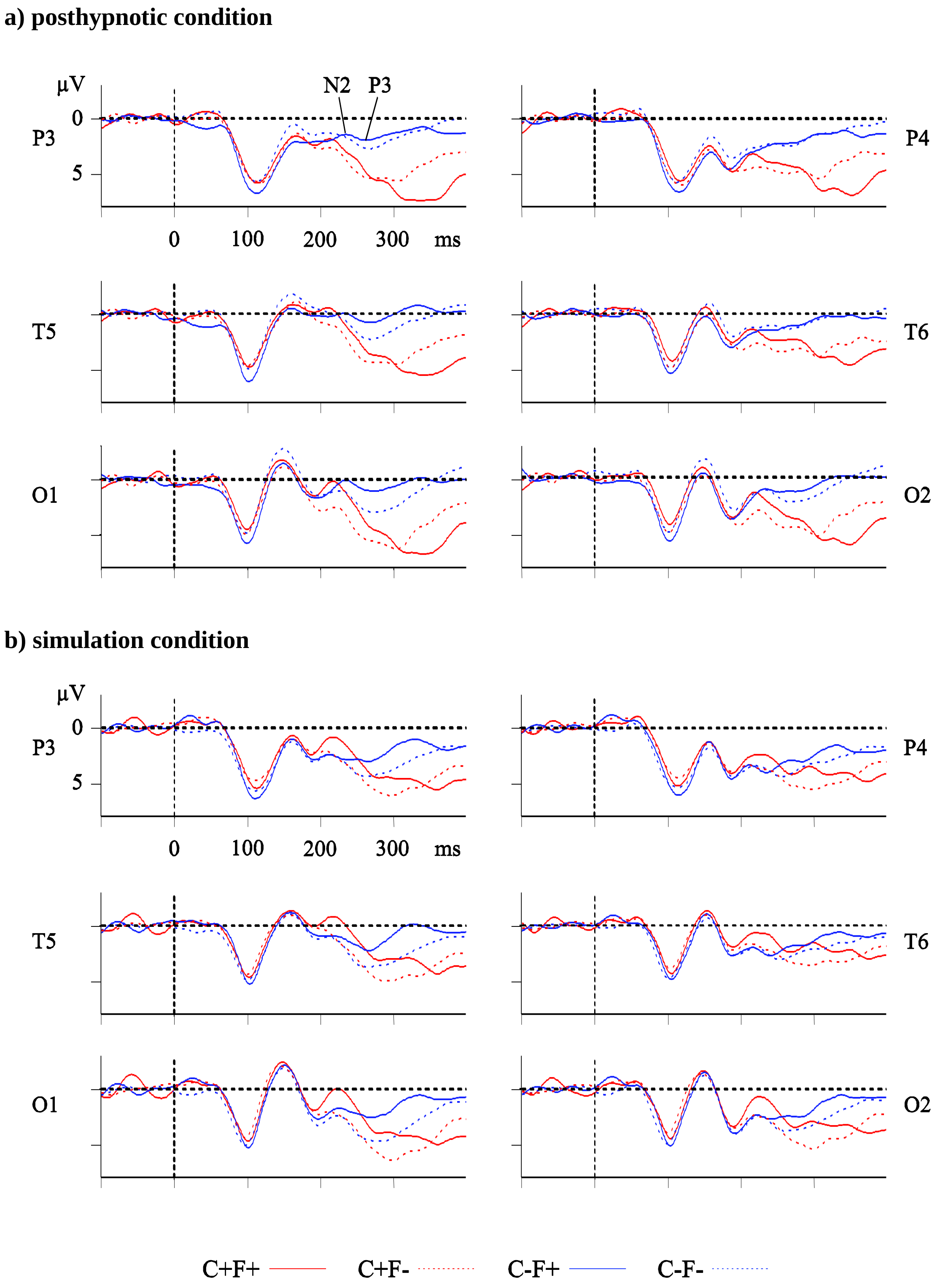

Figure 6. Grand average ERP waveforms of TS-H from the posterior parietal (P3 and P4) and occipito-temporal (O1, O2, T5 and T6) electrode sites for each type of stimulus in (a) the posthypnotic condition and (b) the simulation condition.

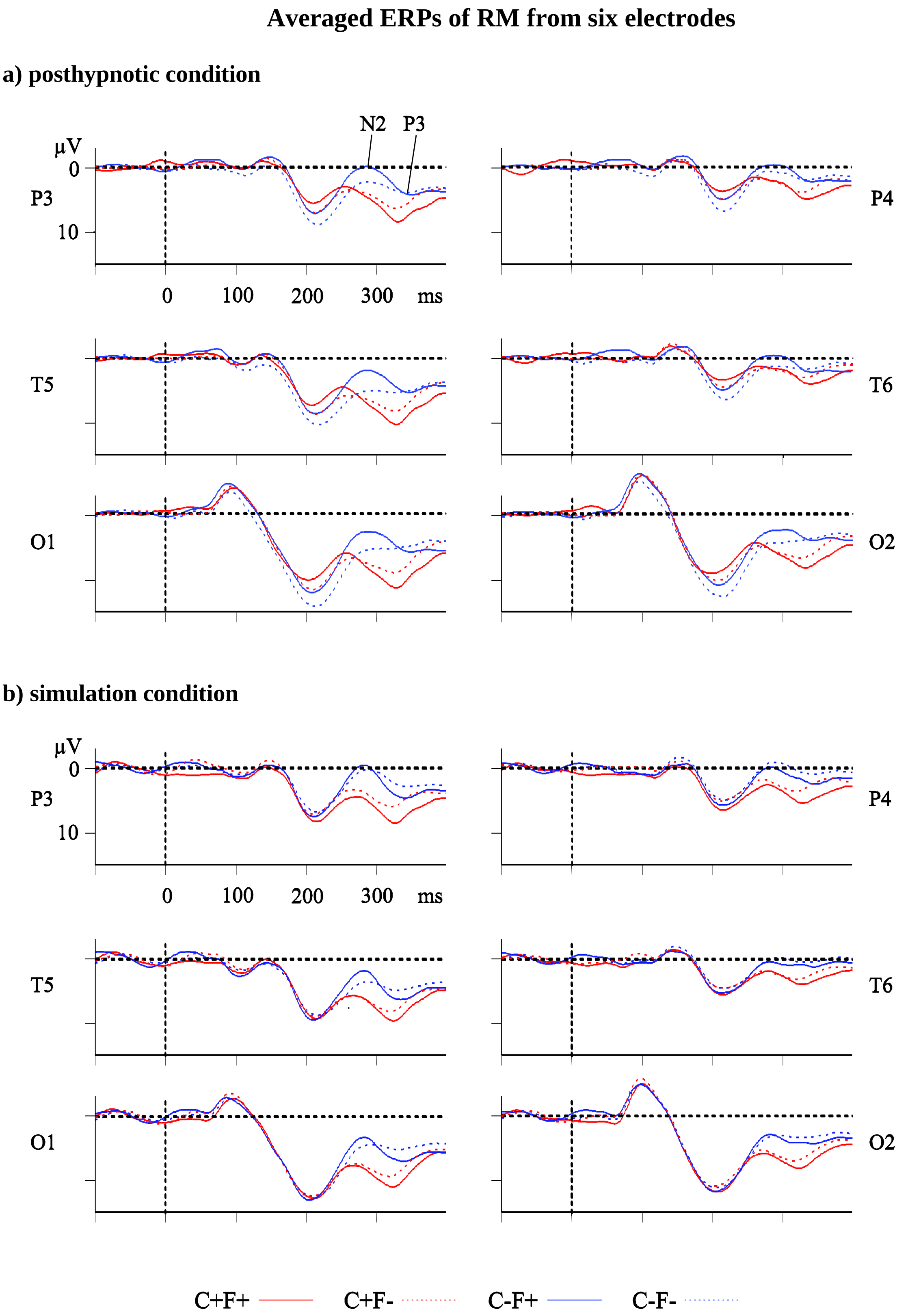

Figure 7. Averaged ERP waveforms of RM from the posterior parietal (P3 and P4) and occipito-temporal (O1, O2, T5 and T6) electrode sites for each type of stimulus in (a) the posthypnotic condition and (b) the simulation condition.

Averaged ERPs from T5 for each type of stimuli

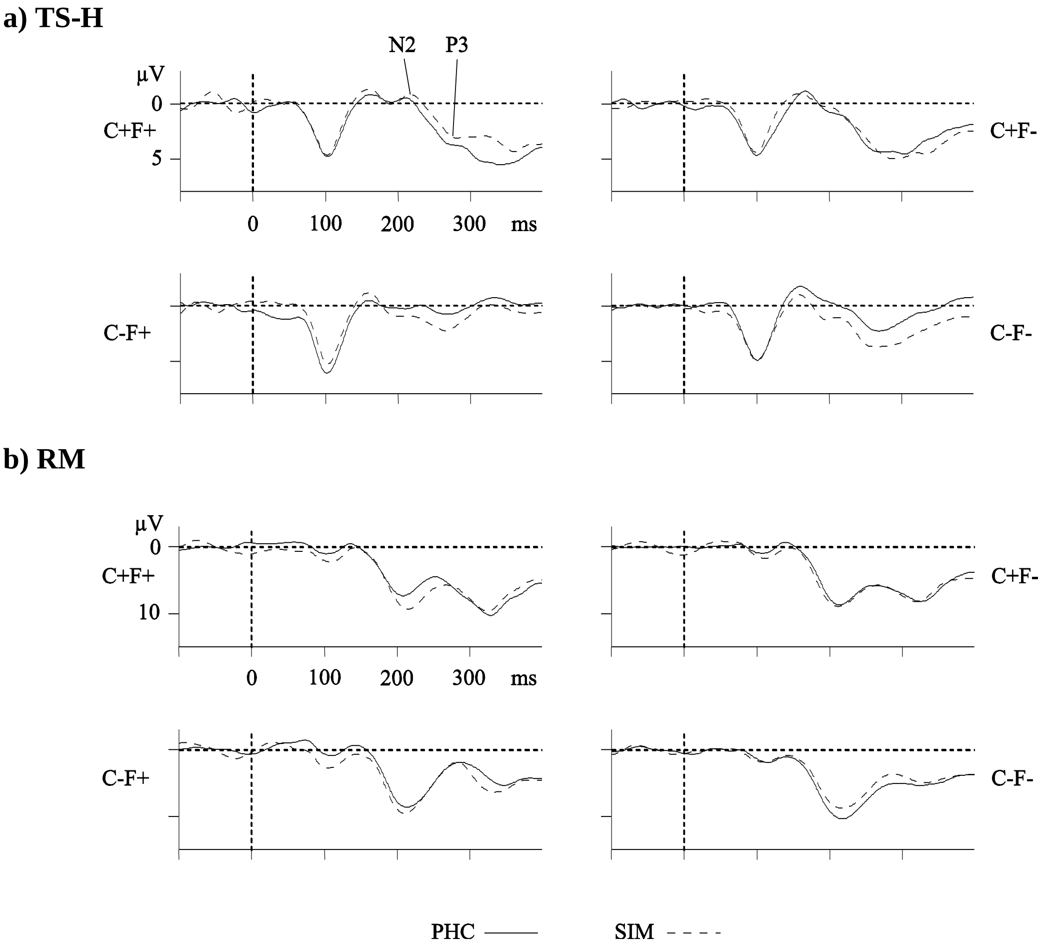

Figure 8. Averaged ERP waveforms from the posterior temporal (T5) electrode site for each type of stimulus in the posthypnotic condition (PHC) and the simulation condition (SIM) of (a) TS-H and (b) RM. No significant differences between the conditions were found when comparing case subject's N2 and P3 peaks of C-F+ stimuli.

When attending to shape was added in the simulation condition of control subjects, the effect of colour remained significant only for CS2, though it was reversed with more negative amplitudes to C- stimuli ($F(1,11)=7.18$, $p<.05$; Fig. 10). Concerning the effect of shape in the simulation condition, control subjects were quite uniform in their results (CS1: $F(1,11)=11.48$, $p<.01$; CS2: $F(1,11)=14.50$, $p<.005$; CS3: $F(1,11)=3.50$, $p<.09$) with more negative amplitudes to F+ stimuli, in line with the results of both RM and TS-H. The results of controls indicate that adding attention to shape in the colour selection task affected and redirected the resources allocated to performing the task, at least of those processes that are seen in the N2 time interval.

Averaged ERPs from six electrodes in the normal condition

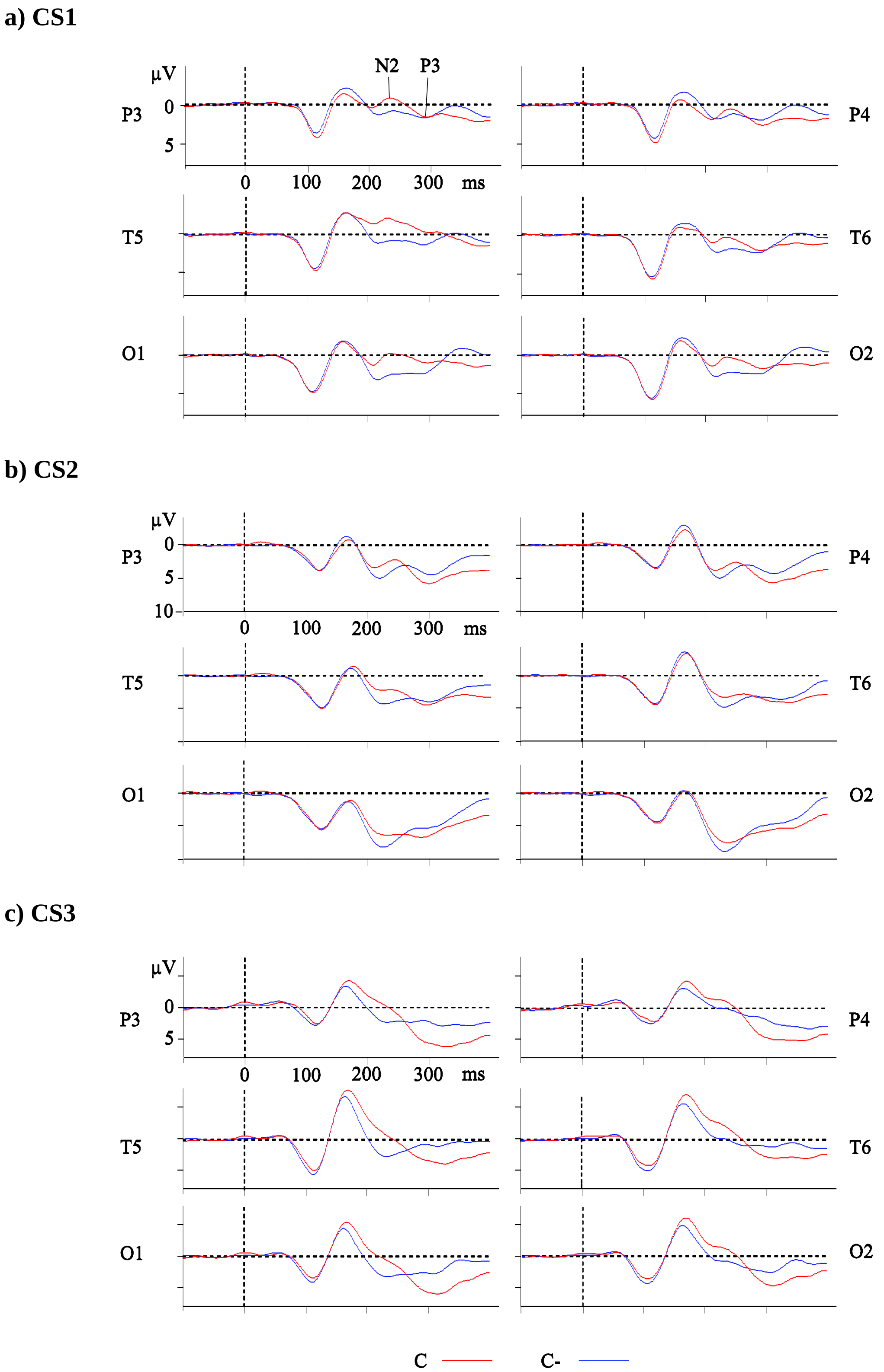

Figure 9. Averaged ERP waveforms from the posterior parietal (P3 and P4) and occipito-temporal (O1, O2, T5 and T6) electrode sites for each type of stimulus in the normal condition of control subjects (a) CS1, (b) CS2 and (c) CS3.

Averaged ERPs from six electrodes in the simulation condition

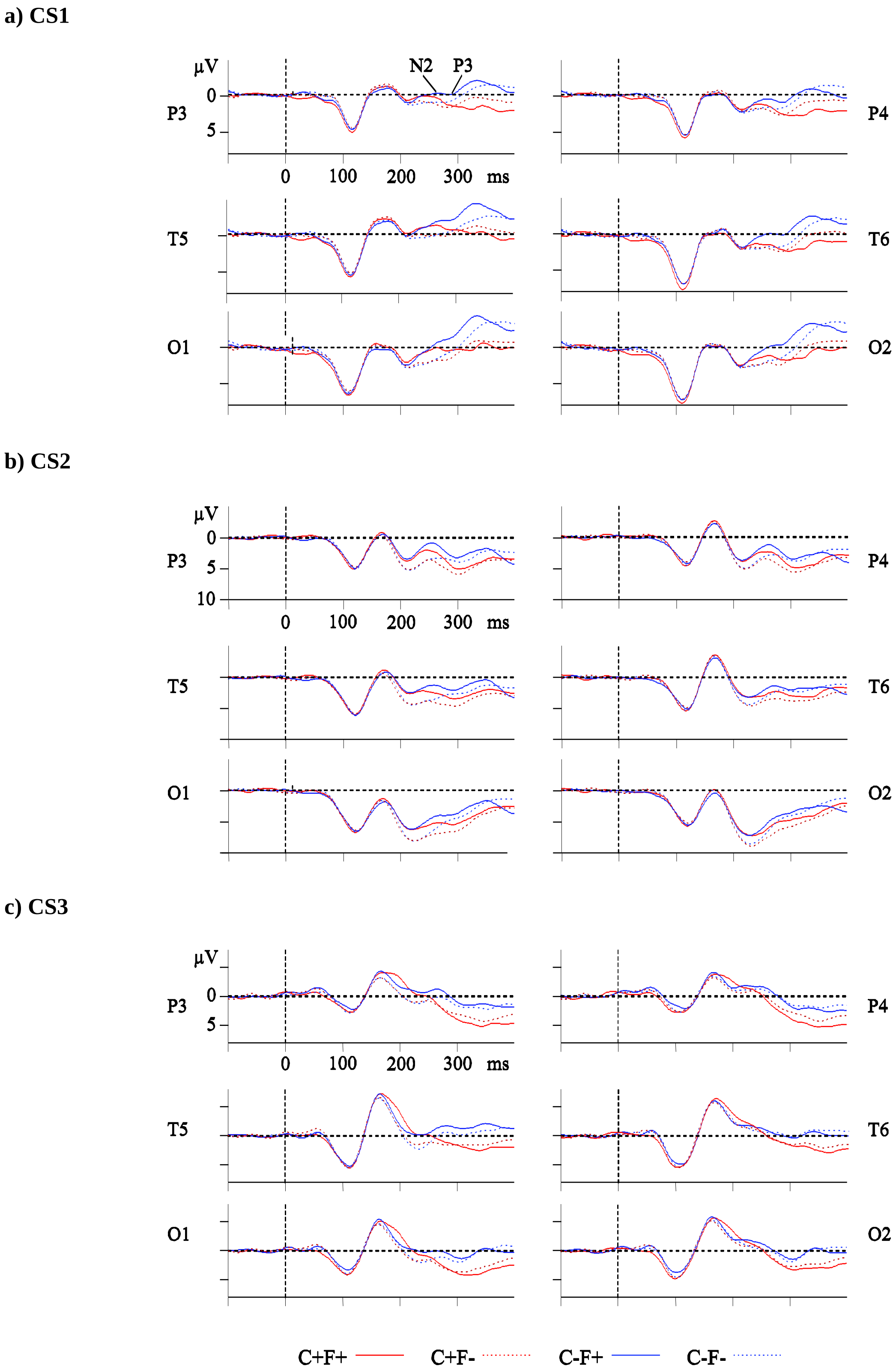

Figure 10. Averaged ERP waveforms from the posterior parietal (P3 and P4) and occipito-temporal (O1, O2, T5 and T6) electrode sites for each type of stimulus in the simulation condition of control subjects (a) CS1, (b) CS2 and (c) CS3.

In the normal condition C- stimuli produced later N2 peak latencies among all control subjects (CS1: $F(1,11)=25.00$, $p<.001$; CS2: $F(1,11)=71.86$, $p<$ 001; CS3: $F(1,11)=11.67$, $p<.01$). In case of CS2 this was so also during the simulation condition ($F(1,11)=5.16$, $p<.05$).

3.2.2. P3 peak

P3 peak analysis was also started with the data of case subjects and a colour × shape × area × hemisphere × condition ANOVA. For TS-H the interaction of colour × condition was significant ($F(1,22)=12.86$, $p<.005$), but at a closer look the colour had merely a relatively stronger effect in the posthypnotic condition ($F(1,11)=67.06$, $p<.001$) as compared to simulation ($F(1,11)=22.91$, $p<.002$). In both conditions less positive values were combined with C- stimuli, but the difference between P3 amplitudes in response to C- and C+ stimuli was slightly greater in the posthypnotic condition (Fig. 8a). The interaction of colour × shape was also significant ($F(1,22)=10.10$, $p<.005$). The C-F+ stimuli targeted by the suggestion caused less positivity than C-F- stimuli (Fig. 6). This implied differences in the information processing of stimuli with similar colour but dissimilar suggestion-relevancy of shape. A significant difference in latencies was found only in the simulation condition ($F(2,18)=11.08$, $p<.005$), where those of C- stimuli were clearly delayed as compared to C+ stimuli.

RM's P3 amplitudes were not affected by condition (Fig. 7 and Fig. 8b). Once again, these results showed that for RM the condition did not cause a profound alteration that would be seen in ERPs, but seemed to have merely a tuning effect. Latencies were found to be affected by colour ($F(1,22)=24.37$, $p<.001$) with later peak times to C- stimuli.

Analysis of the data of control subjects was done separately for the normal and the simulation condition. The effect of attention directed to colour alone was significant in the data of all control subjects (CS1: $F(2,18)=26.64$, $p<.001$; CS2: $F(2,19)=13.15$, $p<.001$; CS3: $F(2,17)=7.07$, $p<.05$; Fig. 9). However, for CS1 less positive values were attached to C+ stimuli, while for CS2 and CS3 less positivity was evoked by C- stimuli. The results from the simulation task indicated also the main effect of colour with less positive peaks to C- stimuli (CS1: $F(1,11)=5.05$, $p<.05$; CS2: $F(1,11)=29.84$, $p<.001$;

CS3: $F(1,11)=13.96$, $p<.005$; Fig. 10). Therefore, attending to the combination of colour and shape did not produce a clear change on the ERP waves of control subjects in the P3 time range.

The differences in the N2 and P3 peak amplitudes of C-F+ stimuli targeted by the suggestion between the posthypnotic and simulation condition of case subjects were compared in a pairwise analysis. No significant differences were found (Fig. 8) indicating that the processing of these stimuli was similar across the conditions.

3.3. Self-reports

TS-H and RM's reports of their subjective experiences from the posthypnotic condition were quite opposite. TS-H told that she did not notice any difference between the stimuli in perception, and experienced the suggested hallucinations as real without making an effort. RM admitted that during the posthypnotic condition she felt awkward because of the contradiction when "eyes say one thing and the brain says another thing" and did not see the stimuli targeted by the suggestion in the suggested colour.

4. Discussion

In the present study, the combination of behavioural and EEG data was obtained and analysed for the purpose of studying the effect of posthypnotic suggestion for visual hallucination on two highly suggestible individuals, TS-H and RM. For the sake of comparison, they went through the same task in the simulation condition encouraged to use goal-directed imagination. Data were also obtained from age- and gender-matched set of control subjects, who however performed only in the simulation task and additionally went through the normal comparative condition. In this chapter, the obtained results are reviewed, discussed in the context of previous empirical evidence on and theories of hypnosis and critically evaluated.

4.1. Summary and relation to the field of research

First of all, the posthypnotic suggestion was seen to produce the suggested behaviour in both case subjects. Though they reported not remembering the suggestion given under hypnosis, both responded in agreement with it not only to the explicitly demanded stimuli of a particular colour, but also to stimuli combining the opposite colour and the suggestion-relevant shape. This implies that, at least on the rough behavioural level, the posthypnotic suggestion had the desired effect on performance.

Closer analysis of the behavioural measurements confirmed the effect of the posthypnotic suggestion, but showed that TS-H was more efficient in responding to it, while RM had better results when using mere imagination. TS-H and RM did not outperform at their best, but at their worst did significantly differ from controls. For TS-H this was seen in the simulation condition as high error rates and for RM in the posthypnotic condition as both high error rates and long response times. Therefore, hypnosis did not enhance performance of TS-H giving her extraordinary abilities, but using plain imagination in the simulation condition made her inefficient. RM seemed to benefit well from her imaginary abilities and was somewhat confused by the posthypnotic nature of the suggestion. These behavioural results indicate that the highly suggestible case subjects had clear dissimilarities in performance both between conditions and among themselves.

Previously, undeniable dissimilarities in self-reports, task performance, physiological and neural activation have been found even among those, who get equally high scores on the suggestibility scales (Howard & Coe, 1980; Schuyler & Coe, 1981; Szechtman et al., 1998; Terhune et al., 2011b). The obvious differences in performance and self-reports of TS-H and RM is a good example of this. It confirms that highly suggestible individuals are not a uniform group. Therefore, grouping according to suggestibility rates only and studying subjects as masses might conceal this heterogeneity. First, this conclusion supports the need to search for other measures of hypnotic responsiveness (Weitzenhoffer, 1980), since the suggestibility score is not sensitive enough. Second, it adds to the view according to which conducting case studies is a useful method for revealing the unique individual qualities and patterns (Kallio & Revonsuo, 2005; McConkey et al., 1989; Raz et al., 2007; Weitzenhoffer, 2000). Third, it forces to question the validity of most opinionated results obtained from the studies that examined subjects as large homogeneous groups, since their outcomes might not be descriptive of the hypnotic phenomena.

In order to clarify further the nature and origin of the observed behavioural patterns the ERP results were analysed. Significant differences in ERPs were found among later peaks and had a posterior scalp distribution. This went along the lines of previous knowledge about the effects of visual non-spatial selective attention on ERP waves (Folstein & Van Petten, 2008) and the supposed connection of hypnosis and attention (Dietrich, 2003; Spiegel & Spiegel, 2004). Stimuli seemed to affect electrical brain activity by all features – colour, shape and their combination. The latter two demonstrated the effect of suggestion, which required shape-based responding, and attending to the conjunction of features.

The combined effect of colour and shape, meant to clarify the influence of the suggestion, was significant only in the data of both highly suggestible individuals. The shape-based discrimination was seen among stimuli of the untargeted colour with lower amplitudes to stimuli of the suggestion-relevant shape, as opposed to those of the suggestion-irrelevant shape. In the data of RM this was seen as higher negativity of N2 peak amplitudes, while for TS-H it emerged a bit later, as lower positivity in P3 time range. More negative amplitudes in N2 of RM might stand for greater orienting of visual attention towards the task-relevant stimuli targeted by the suggestion as opposed to stimuli that were to be ignored (Folstein & Van Petten, 2008), regulation of strategic behaviour (Band et al., 2003; Donkers & van Boxtel, 2004; Nieuwenhuis et al., 2003) or non-motoric stage of inhibition (Smith et al., 2008). More positive amplitudes in P3 of TS-H to unattended stimuli as opposed to those targeted by the suggestion might depict for instance clearer motor inhibition to those stimuli (Smith et al., 2008). Since the effect of shape was seen already in N2 time frame of both subjects, the different timing of the effect of colour and shape interaction might also denote simply individual temporal differences in the neural processing of the conjunction of features, with RM being slightly faster than TS-H, rather than qualitatively different processes.

The effect of colour in the ERP data was the only one to accord with the differences in the behavioural results among highly suggestible case subjects since it was different between the conditions. Generally, stimuli of the untargeted colour caused greater negativity in N2 and lower positivity in P3 time frames. However, this kind of negative shift did not occur in TS-H during the simulation condition and in RM was of slightly lower amplitude in the posthypnotic condition, according with their less accurate performance during these conditions. This could be interpreted as a later change in the orienting towards the more demanding group of stimuli the response to which required combining the features and discriminating based on the shape of the stimulus (Folstein & Van Petten, 2008; Linden, 2005). The examination of whether these trends represent changes in the more general SN which indicates rather a cognitive process initiated after selection is finished, such as perceptual analysis in the short-term memory or feature integration (Smid et al., 1999), would require further analysis.

Control subjects managed to reach similar level of performance as highly suggestible subjects when using only goal-directed imagination. This finding compels to question whether TS-H could have simulated during the posthypnotic condition or held back in the simulation condition (Zamansky et al, 1964). An overview of the results shows that her behavioural performance in the simulation condition did not resemble that of simple responding to colour, but ERP results did show a pattern similar to that obtained in the normal condition of the control subjects with a shift of negativity from stimuli of the targeted colour to those of the untargeted colour. Nevertheless, since ERPs show no significant difference in attention to shape or colour-shape conjunction between conditions, she did pay attention also to shape. This could mean that in the simulation condition TS-H was not able to maintain focus on the whole task and her attention slipped more to the colour which was targeted. Her performance was deteriorated by this attentional slide, and combining the features of stimuli of the untargeted colour was delayed, which resulted in the omission of the response or a late response and thus higher error rates.

If TS-H did not fake her performance, it seems that in the used experimental conditions she was just an inefficient simulator. During the simulation condition her attentional means were not well distributed and she tended to orient mostly to the colour. This might illustrate a need for her to deploy more resources to inhibit the real-life perceptual signals when using mere imagination, and designate that hypnosis alters her background neural activity in a way which makes this process easier, as it is seen from the posthypnotic performance. When she received the suggestion under hypnosis, execution of it with focusing attention on the demanding group of stimuli was effortless even though it had to be done already posthypnotically and the whole performance was enhanced. Another explanation would be that this result was due to some sort of carry-over effect caused by the rapid alternation of posthypnotic and simulation condition.

The performance of RM did not seem to be qualitatively affected by the way suggestion was presented, but was relatively more efficient when she was allowed to use conscious imagination. Fast to respond to suggestion for simulation, RM was confused when experiencing the influence of the posthypnotic suggestion – although her orienting worked in the same direction, processing and implementation were delayed. This might imply that for her the required processing was of the same kind in different conditions, involved the use of cognition even after hypnosis and thus did not resemble the assumed true visual hallucination (Kallio & Revonsuo, 2003).

The dispute over the necessity of the induction procedure for the effects of suggestion to occur in their full extent has gathered firm arguments on both sides (Mazzoni et al. 2009; Raz et al., 2006 vs. Derbyshire et al., 2009; Kosslyn et al. 2000). In the present study, suggestion given after induction resulted in the most optimal performance for the hypnotic virtuoso TS-H. This shows the importance of induction in receiving and processing of suggestions at least for some highly suggestible individuals. This can be due to the qualitatively different nature of the post-induction wakefulness as opposed to the general relaxed but alert wakefulness (Cardeña et al., 2012; Fingelkurts, Al. et al., 2007; Fingelkurts, An. et al., 2007; Terhune et al., 2011a). In the former, suggestion seemed to have the space to be processed and affect in another, more profound way, with efficient recruiting of volitional top-down attention and effortful control.

In the case of TS-H, there seems to be a huge gap between the non-hypnotic and hypnotic suggestibility. This interval is known as hypnotisability, and at the general level is thought to be negligible (Kirsch & Braffman, 2001). Present results imply that if the focus is set at the individual level, this rule might not apply and the difference between the non-hypnotic and hypnotic suggestibility can be quite dramatic. Thus, in some cases the hypnotic responding cannot be well explained by the non-hypnotic suggestibility.

The verbalisation of the suggestion has proven to be crucial for the neural processes (Barabasz et al., 1999; Jensen et al., 2001). In the posthypnotic condition of the present study, a deceptive suggestion was used to ensure the subjectively convincing quality of possible visual hallucinations (Kallio & Revonsuo, 2003). However, remembering the critique which obliterated the study of Kosslyn et al. (2000), who used dissimilar suggestions in alternative conditions, here the only addition made to the suggestion given during the simulation task was that of words "*Imagine that you have received a suggestion during hypnosis according to which* --". Therefore, this factor is not considered to be responsible for the observed dissimilarities between the conditions.

One more issue to keep in mind is that there is no proof that the posthypnotic suggestion would have evoked an actual visual hallucination. There is no direct evidence, excluding self-report, that even TS-H would have seen stimuli of a particular shape in the opposite colour right away, since the ERP waves of the stimuli targeted by the suggestion did not resemble those of the opposite colour. Nevertheless, later ERP peaks of these stimuli did differ significantly from those of the same colour, but suggestion-irrelevant shape. That is, the perception of shape did modify the processing of stimuli of the same colour in the later phase and could have had the effect on the level of conscious experience such as increasing the orienting of attention (Linden, 2005). If this interpretation holds, current results could add to the previous findings of the power of suggestion to interfere with automatic perceptual processing (Kosslyn et al., 2000; Mazzoni et al., 2009; McGeown et al., 2012; Raz et al., 2005; Raz et al., 2006; Raz et al., 2007; Raz et al., 2002), in this case the colour perception.

4.2. Limitations, strengths and future perspectives

The results of the present study were not all straightforward − some of them raised propositions for enhancement and some evoked more questions than they answered. First is the concern about the validity of the statistical analysis of behavioural and ERP data following the previous examples (Kallio & Koivisto, in press; Kallio et al., 1999). Treating individual's blocks as cases has the disadvantage of violating the assumption of independence of observations in ANOVA and suggests the results be viewed with caution. The used approach was considered to be sufficient for the requirements of the present study given the similarity with the previous works (Kallio & Koivisto, in press; Kallio et al., 1999). However, in the future it could be worth further analysis for example using the generalized estimating equations which allow relaxation of some of the assumptions of traditional methods (Liang & Zeger, 1986).

Second, the fact that the colour-shape conjunction showed merely dissimilar trends in ERP deflections in the two alternative conditions of highly suggestible subjects sets a question of whether these stimuli went through any different processing, which could be expected if true colour hallucinations are expected to occur and considered to be automatic as opposed to conscious mental imagery (Kallio & Revonsuo, 2003). Nonetheless, it is possible that the spatially limited nature of EEG recording and confining analysis to six posterior electrode sites could have concealed some influential neural processes especially those originating from the frontal parts. Consequently, this matter will require further investigation.

Though methodological details of the present experiment were carefully chosen, some of them restricted taking a position as regards to possible neural correlates of hypnosis found recently. The main of such specialties was focusing on the posthypnotic instead of hypnotic performance. This allowed to take interpretations of the results to the level of experience, not only behaviour (McConkey, 2008), but hindered making any inferences about hypnosis as a state. In addition to that, the default mode network (McGeown et al., 2009; McGeown et al., 2012; Rainville et al., 1999; Raz et al., 2005) was outside the coverage area of EEG measurement and the changes in the prefrontal activity (Dietrich, 2003) were not examined. To benefit from the methodological choices of the present study, further analysis of the data could be done for example on the alterations in functional connectivity (Cardeña et al., 2012; Fingelkurts, An. et al., 2007; Terhune et al., 2011a) and brain oscillations (Fingelkurts, Al. et al., 2007) during the performance in different conditions.

RM and TS-H are not equally experienced hypnotic responders. Thus, one more question evoked by the results was whether the observed dissimilarities between the two case subjects could be explained by the relative inexperience of RM as a hypnotic responder, or could they actually be due to some profound individual features and innate differences of neural processing. This issue remains to be studied in the future also on other highly suggestible hypnotic responders.

Although induction played an important role in the performance of case subjects TS-H and RM, the control subjects were able to mimic the effect of posthypnotic suggestion quite successfully. Supposing that true hallucinations can be brought only by deceptive suggestions following an induction (Kallio & Revonsuo, 2003), these results might mean that the used measurements were not sensitive enough to distinguish true realistic visual hallucinations from the mere use of one's imagination. Another explanation would be that the powerful effect of suggestion was not restricted to highly suggestible subjects, which would devour the whole idea of hypnotic virtuosos. Also this topic will require more precise examination in the future.

The research on posthypnotic suggestions for visual hallucinations is yet quite scarce. Therefore, each step, such as the present study, is valuable. The main strengths of it were the combination of both behavioural and EEG measurements, inclusion of several highly suggestible individuals and the gathered control evidence from the naïve matched subjects. In addition to the theoretical bearing, any research that scrapes the topic of visual hallucinations has the potential to become not only phenomenologically, but also clinically significant, as hallucinations often occur in neurodegenerative disorders, brain injuries and psychosis. The overall ability to respond to imaginative suggestions is a normal human capacity and important as a possible tool in such areas as pain management (Kirsch and Braffman, 2001). Understanding the physiological and cognitive effects of hypnosis might also be significant for its therapeutic implementation. All these possible benefits make solving the mystery of hypnosis more and more attractive, and the new research is hoped to build up a solid ground in the field of hypnosis and a firm base for its use.

4.3. Conclusions

Whether the posthypnotic suggestion can change the actual visual experiences, such as the perception of colour in a stimulus of a specific form, cannot be firmly concluded based on these data. Induction seemed to help the hypnotic virtuoso follow the given suggestion, and she was not able to simulate her posthypnotic performance. However, it did not have a clear influence on the performance of another highly suggestible subject and the control subjects were able to perform equally well with mere imagination.

Therefore, the main well-founded conclusions brought about by the present results are that there are obvious dissimilarities in attentional directing between the posthypnotic and simulation conditions and also variance even among the highly suggestible subjects which must be taken into account.

The obtained evidence supports the possibility that something extraordinary happens to the hypnotic virtuoso TS-H when she is introduced with hypnosis. Present results in combination with the previous knowledge of the changes that take place in her volitional eye-movements (Kallio et al., 2011) and neural functional synchronicity (Fingelkurts, An. et al., 2007), accompanied by the remained frontal activity (Fingelkurts, Al. et al., 2007; Kallio et al., 1999), fortify the idea of a profound shift in her mental processes during hypnosis. Redirecting attentional resources or toning down the external noise together with changes in the recorded neural activity are compatible with the idea of functional changes in different frontal circuits as a source of the altered states of consciousness (Dietrich, 2003) and fortify the connection between hypnosis and the proposed altered brain states.

There is no reason to doubt the reality of hypnotic phenomena as the research shows they resemble those produced by real-life experiences (Kosslyn et al., 2000; Szechtman et al., 1998). On the other hand, there is no need to classify them as incomprehensible and being beyond the reach of a common man since many of them can occur also without the involvement of hypnosis (Kirsch, 2001). Within these loose boundaries of universal endorsement the contemporary controversy over the definition and interpretation of hypnosis is continued in a restless state vs. non-state debate.

Though hypnosis is an ancient discovery, defining, parsing and investigating the fascinating phenomena of altered consciousness began relatively recently. Nonetheless, many in the field of hypnosis research have already hurried to choose their stance, as indicated by the clear distinction of sides in the state vs. non-state debate (Kallio & Revonsuo, 2003; Lynn & Green, 2011; Lynn et al., 2008). Tender reassurances that defining hypnosis as a state does not explain it as a phenomenon but only aids the categorizing (Kallio & Revonsuo, 2003), do not help bring the opponents together. In the promised age of neuroscience opinion is qualified only when it is made of bulletproof empirical evidence. In that sense, the present results offer a fruitful ground for the revision of current theories and background information.

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