Neuro-cognitive factors contributing to paranormal beliefs: core knowledge violations, cognitive inhibition, and the social brain

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Abstract

The present thesis consists of six studies that investigate different cognitive factors that contribute to believing and unbelieving in paranormal, superstitious, magical, and supernatural (commonly referred to as paranormal belief). Earlier studies have found several factors reaching from personality factors to cognitive factors to cultural factors that contribute to believing. However, the research has neglected the important factor of what sets paranormal beliefs apart from other beliefs. In addition, although we know a lot about demographical and personality features that contribute to differences in paranormal beliefs, neuro-cognitive differences are still not well known or empirically tested.

One explanation that takes into account the difference between paranormal beliefs and other beliefs is that paranormal beliefs stem from core knowledge confusions about the ontological properties of mental, physical, and biological phenomena. The first study of the thesis tried to gain insight into the neural basis of core knowledge confusions in an event-related electroencephalography study. The next two studies tested the possibility that cognitive inhibition, the ability to flexibly switch between thinking modes and if needed, to inhibit unwanted or irrelevant thoughts, could contribute to believing and unbelieving. In these two studies group differences between paranormal believers and skeptics were first compared by using tests of cognitive inhibition and secondly by using brain imaging. Brain imaging was done during a task that invoked paranormal interpretations. The last three studies of the thesis examined the role of the social information processing differences between paranormal believers and skeptics. Methods included brain imagining, behavioral experiments, and self-report measurements. In the first study, we tested how conceptions about the mind are related to beliefs and core knowledge confusions. In the second and third of these studies, we tested group differences between paranormal believers and skeptics by using brain imaging and a behavioral test. We investigated if the groups differ in attribution of intentions to randomly moving objects and in tendency for illusory face perception.

The results suggest that core knowledge confusions are based on intuitive world knowledge and that this intuitive world knowledge is less categorized among paranormal believers than among skeptics. Cognitive inhibition was also found to contribute to paranormal beliefs: strong cognitive inhibition downplays paranormal

beliefs. Social information processing was connected to paranormal beliefs in several ways. First, understanding mind and its properties in a Cartesian dualistic way was associated with paranormal beliefs and ontological confusions preceded them. Second, believers when compared to skeptics assigned more intentions to randomly moving objects. This was associated with activation of the mentalizing system at the brain level. Finally, we found out that paranormal believers were more prone to illusory face perception than skeptics were. The results underline that if one seeks to understand believing and especially unbelieving, which both are complex phenomena, individual differences in cognitive processing must be taken into account.

Tiivistelmä

Tämä väitöskirja koostuu kuudesta tutkimuksesta. Näissä tutkimuksissa tarkastellaan erilaisten kognitiivisten tekijöiden vaikutusta siihen, uskooko ihminen yliluonnolliseen ilmiöihin vai ei. Aiemmissa tutkimuksissa on löydetty useita tekijöitä, jotka vaikuttavat uskomiseen tai uskomattomuuteen. Uskomiseen ja uskomattomuuteen vaikuttavat esimerkiksi persoonallisuuden ominaisuudet, kulttuuriset tekijät ja tietyt kognitiiviset tekijät. Nämä tutkimukset eivät kuitenkaan yleensä ole ottaneet kantaa olennaiseen kysymykseen: mikä erottaa yliluonnolliset uskomukset muista uskomuksista? Lisäksi kokonaisuudessaan yliluonnollisten uskomusten kognitiivisista tekijöistä tiedetään edelleen melko vähän, vaikka erilaisia osaselittäjiä ilmiölle on löytynyt.

Yksi määritelmä, jolla yliluonnolliset ja taikauskoiset uskomukset eroavat muista uskomuksista on, että ne ovat erilaisia ydintiedon sekaannuksia. Toisin sanoen yliluonnollisissa uskomuksissa sekoitetaan keskenään psyykkisten, fysikaalisten ja biologisten olioiden perustavanlaatuisia ydinominaisuuksia ja juuri näiden ydinominaisuuksien sekoittaminen on määrittelevää yliluonnollisille uskomuksille suhteessa muihin uskomuksiin.

Väitöskirjan ensimmäisessä tutkimuksessa testattiin ydintiedon ominaisuuksien sekaannusten prosessoinnin aivokorrelaatteja aivosähkökäyrämittausta hyödyntäen. Seuraavissa kahdessa tutkimuksessa vertailtiin kognitiivisen inhibition vaikutusta taikauskoon skeptikkojen ja taikauskoisten välillä. Kognitiivinen inhibitio tarkoittaa kykyä muuttaa joustavasti ajattelutapoja ja ajattelun kohteita sekä kykyä työntää tarvittaessa asioita pois mielestä. Ryhmiä verrattiin ensin yleisesti käytetyillä kognitiivisen inhibition testeillä ja toisessa tutkimuksessa aivokuvantamista hyödyntäen tehtävässä, joka pyrki herättämään yliluonnollisia tulkintoja. Viimeisissä kolmessa tutkimuksessa tutkittiin sosiaalisen tiedonkäsittelyn eroja yliluonnolliseen uskovien ja skeptikkojen välillä kokeellisin menetelmin, aivokuvantamismenetelmin ja itse-arviointikyselyin. Näistä ensimmäisessä testattiin miten käsitys mielen (ja sen prosessien) ja ruumiin yhteydestä (niin sanottu "mieli-ruumis-ongelma") on yhteydessä yliluonnollisiin uskomuksiin ja ydintiedon sekaannuksiin. Toisessa tutkimuksessa testattiin ryhmäeroja yliluonnolliseen uskovien ja skeptikkojen välillä tehtävällä, joka tehtiin aivokuvantamisen aikana. Tehtävässä tutkittiin tavoitteellisen ja tarkoituksellisen toiminnan näkemisessä satunnaisesti ja tarkoituksellisesti liikkuvissa kuvioissa.

Kolmannessa tutkimuksessa tutkittiin ryhmäeroja skeptikkojen ja taikauskoisten välillä herkkyydessä nähdä kasvoja erilaisissa esineissä ja luonnon muodostelemissa.

Tulokset antavat tukea väitteelle, että ydintiedon sekaannukset perustuvat intuitiiviseen tietoon maailmasta ja että tähän liittyvä kategorinen tieto on heikommin rajautunutta taikauskoisilla kuin skeptikoilla. Kognitiivisen inhibition havaittiin olevan yhteydessä yliluonnollisiin ilmiöihin uskoviin siten, että tehokkaampi kognitiivinen inhibitio heikensi taikauskomuksia. Sosiaalisen tiedon käsittelyn osalta tulokset osoittivat, että taikauskoiset suhtautuvat mieleen ja sen ominaisuuksiin dualistisesti ja että tämä oli voimakkaasti yhteydessä taikauskoon. Dualistinen ajattelu voitiin myös tulosten valossa tulkita ydintiedon sekaannuksen muodoksi. Lisäksi taikauskoiset liittivät enemmän intentioita satunnaisesti liikkuviin kappaleisiin kuin skeptikot, ja tämä oli yhteydessä sosiaalista informaatiota käsittelevän aivoverkoston aktivaatioon aivotasolla. Taikauskoiset olivat myös alttiimpia huomaamaan kasvojen kaltaisia piirteitä erilaisissa esineissä ja luonnon muodostelemissa. Kokonaisuudessaan tulokset korostavat yksilöllisten kognitiivisten erojen huomioimista, kun monisyisiä ilmiöitä kuten yliluonnolliseen uskomista tai siihen uskomattomuutta yritetään selittää.

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List of original publications

This thesis is based on the following publications, referred to in the text by their Roman numerals.

I Lindeman, M., Cederström, S., Simola, P., Simula, A., Ollikainen, S., & Riekki, T. (2008). Sentences with core knowledge violations increase the size of N400 among paranormal believers. *Cortex*, *44*, 1307–1315. doi:10.1016/j.cortex.2007.07.010.

II Lindeman, M., Riekki, T., & Hood, B. M. (2011). Is weaker inhibition associated with supernatural beliefs? *Journal of Cognition and Culture*, *11*, 1–2. doi:10.1163/156853711x570038.

III Lindeman, M., Svedholm, A. M., Riekki, T., Raij, T., & Hari, R. (2013). Is it just a brick wall or a sign from the universe? An fMRI study of supernatural believers and skeptics. *Social Cognitive and Affective Neuroscience*, *8*, 943–949. doi:10.1093/scan/nss096.

IV Riekki, T., Lindeman, M., & Lipsanen, J. (2013). Conceptions about the mind-body problem and their relations to afterlife beliefs, paranormal beliefs, religiosity, and ontological confusions. *Advances in Cognitive Psychology*, *9*. doi:10.1111/j.2044-8295.2012.02118.x.

V Riekki, T., Lindeman, M., & Raij., T. T. (2014). Supernatural believers attribute more intentions to random movement than skeptics: an fMRI study. *Social Neuroscience*. doi:10.1080/17470919.2014.906366.

VI Riekki, T., Lindeman, M., Aleneff, M., Halme, A., & Nuortimo, A. (2013). Paranormal and religious believers are more prone to illusory face perception than skeptics and non-believers. *Applied Cognitive Psychology*, *27*, 150–155. doi:10.1002/acp.2874.

Abbreviations

ANOVA	Analysis of variance
β	Beta, regression coefficient
C	Criterion value reflecting answering bias derived from signal detection analysis
d'	Perceptual sensitivity derived from signal detection analysis
EEG	Electroencephalography
ERP	Event-related potential
ESP	Extra-sensory perception
F	ANOVA test statistic
fMRI	Functional magnetic resonance imaging
FWE	Familywise error
IFG	Inferior frontal gyrus
MNI	Montreal Neurological Institute
mPFC	medial prefrontal cortex
ms	millisecond
p	Probability of test statistic assuming null hypothesis is true
PCC	Posterior cingulate cortex
r	Pearson's product-moment correlation coefficient
ROI	Region of interest
SD	Standard deviation
STG	Superior temporal gyrus
t	t-test statistic
ToM	Theory of mind
TPJ	Temporoparietal junction
vmPFC	ventral medial prefrontal cortex
Z	z-test statistic
WSCT	Wisconsin Card Sorting Test
α	Cronbach's alpha (measure of internal consistency of a scale)
η2	Eta squared (estimate of effect size)

1. Introduction

Imagine that someone close to you is sick and you are driven by worry. You are thinking about how the person is and wondering if you should call the person. Suddenly, the phone rings and it is the person you were thinking about on the phone. This is good, but was there a link between the thought and the phone call? Maybe for some, the idea that "Yes, there was a connection" came immediately, *intuitively.* And maybe for some, the idea came, but was instantly dismissed or *inhibited,* as it did not *rationally* or *analytically* make any sense.

Most of us have experienced or at least heard about these kinds of situations. However, the explanations of what happens in these situations differ significantly among people. Some would say that the call was merely an odd coincidence. There was nothing special or unnatural in it because it is simply impossible that thoughts, a mental process, could have had an effect on the calling because mental processes can be only shared via physical mediators, such as vibrating air that the senses can interpret as speech, or by physical signs. On the contrary, some could say that this was not a coincidence. There was some sort of a link between the thought and the intention of the caller because sometimes thoughts can directly affect other people's thoughts. We just do not understand how this happens yet. In some sense, there could have been even something *supernatural* or *paranormal* in it. Maybe it was *extra sensory perception*. From a scientific point of view, belief in extra sensory perception or similar beliefs are not plausible and yet they are relatively common; for example, 41% of Americans believe in extrasensory perception (Gallup, 2005). In Finland, belief in extrasensory perception has slowly been declining: while in 2004 more than every third (36%) person believed in it, in 2013 every fourth (25%) believed in it (Tieteen tiedotus ry, 2013). As another example of the commonness of paranormal beliefs, in Europe only 18% of people agree with a statement that, "I don't believe there is any sort of spirit, God, or life force" in contrast to 52% who believe in God and 27% who believe in some sort of spirit or life force (European Commission, 2005).

Cultural evolution and cultural learning are suggested to have important effects on commonality of religious supernatural beliefs (Gervais, Willard, Norenzayan, & Henrich, 2011). Historically, belief in the supernatural has been common, close to a norm, and although disbelief is nowadays more common than potentially any other time

of history, belief remains common. Thus, although there may have been a cultural transition, especially in the Western countries, that has made disbelief more culturally accessible than before, there is still large variation in the numbers of people who believe or do not believe.

While cultural influences have effects on adopting beliefs, situational and contextual factors, such as stress or primed thoughts related to death, also modify the strength of supernatural beliefs (Keinan, 2002; Norenzayan & Hanse, 2006). People may also react differently in the same context and culture, showing that not only culture or situation, but also the subjective properties, such as information processing differences, interact with the context and culture. In other words, even though the macro cultural and situational effects are important in supernatural and paranormal beliefs, some people may have individual properties that make them more skeptical than others or contrary stronger believers than others. Thus, even though the cultural zeitgeist may explain general shifts in the number of believers and non-believers, it does not explain the existence of individual differences between believers and unbelievers who live in the same culture or act in the same contexts. Briefly, to fully understand why some people believe and others do not, we also have to understand how individual differences contribute to maintaining paranormal beliefs or rejecting them. This study focuses on some of the individual neuro-cognitive factors that may contribute to disbelief and believing in the supernatural and paranormal.

Earlier studies have recognized several factors, such as demographics, education and personality factors that contribute to believing and unbelieving (see Irwin, 2009; Vyse, 2014). Although several factors have been found, the found effect sizes have been modest and the results have sometimes been inconsistent. This hints that the phenomenon derives from multiple factors or that the questions asked to explain the phenomena have not been accurate enough.

Cognitive factors associated with beliefs have also been studied. For example, the connection of general intelligence and paranormal beliefs is only weak and some studies have failed to find it (reviews: Wisemann & Watt, 2006; Vyse, 2014). It has also been tested to determine if paranormal beliefs stem from an inability to critically evaluate the beliefs (French & Wilson, 2007), but there is little empirical support for the claim. However, there is consistent evidence that paranormal believers perform worse than skeptics do in deductive reasoning (French & Wilson, 2007; Wisemann & Watt, 2006). There is also some, but inconsistent, evidence that paranormal beliefs are associated

with difficulty in engaging in probabilistic reasoning (review: Rogers, Davis, & Fisk, 2009). Another cognitive factor that has been convincingly associated with paranormal beliefs is overactive pattern detection (French & Wilson, 2007; Wiseman & Watt, 2006). For example, paranormal believers favor false alarms over misses when searching for meaningful stimuli among noise (Krummenacher, Mohr, Haker, & Brugger, 2009). Thus, there have been some cognitive factors that have been connected to paranormal beliefs, but the overall picture is still not clear. For example, the domain specificity or generality of the pattern detection is not clear and the underlying cognitive factors leading to weak performance in deductive reasoning are not clear. In addition, little is known about the neural basis of these cognitive factors.

Another cognitive factor that has been suggested to be important, especially in religious supernatural beliefs, is the way of understanding other minds and the way the social brain develops (e.g., Bloom, 2004). It has been suggested that the development of the social brain, by default, leads to some supernatural beliefs such as belief in a soul (Bering, 2006). However, these claims have been mostly theoretical and the few empirical studies have focused on such beliefs as believing in gods (e.g., Norenzayan, Gervais, & Trzesniewski, 2012) or believing in souls (Bering & Bjorklund, 2004). Thus, these studies have commented little on the diverse paranormal beliefs outside religious beliefs and the empirical testing of factors contributing to belief and disbelief regarding the role of processing of social information has been scant.

The present study explores cognitive and neural foundations that contribute to individual differences in why some believe in the paranormal and others do not. This thesis focuses on three aspects of individual differences. First, how are intuitive differences in world knowledge about mental, physical, and biological phenomena related to paranormal beliefs and are they measurable using brain research methods? Second, how does the monitoring and regulating of raising intuitions contribute to or hold back paranormal beliefs, and third, how do the individual differences in the social information processing, for example ability to understand abstract intentional minds, contribute to paranormal beliefs?

1.1 Paranormal, supernatural, magical, religious and superstitious beliefs are forms of ontological confusions

Paranormal belief is a complicated concept to define and sometimes exactly the same beliefs have been studied under different names; for example, under the title of paranormal, superstitious, magical, or supernatural beliefs (reviews Irwin, 2009; Vyse, 2014; for the conceptual basis for the present set of studies, see Lindeman & Svedholm, 2012). This lack of clear definition of the topic of the research has led to miscellaneous operationalization and unnecessary heterogeneity in the concepts. Paranormal, superstitious, magical, or supernatural beliefs have often been categorized vaguely and been conceptualized simply as erroneous or scientifically impossible beliefs (e.g., Tobacyk & Milford, 1983; Beck & Forstmeier, 2007; Sharps, Matthews, & Asten, 2006), magical beliefs (e.g., Rozin, Millman, & Nemeroff, 1986), overactive pattern perception (e.g., Wiseman & Watt, 2006), and associative or covariation biases (e.g., Gianotti, Mohr, Pizzagalli, Lehmann, & Brugger, 2001; Nemeroff & Rozin, 2000).

Although these conceptualizations fit with paranormal beliefs, they also fit with beliefs that are not usually considered as paranormal or only cover specific types of paranormal beliefs. These conceptualizations are thus unable to answer the crucial question of what, if anything, separates paranormal beliefs from other beliefs. In other words, these conceptualizations do not answer what makes a paranormal belief in a ghost conceptually different from an erroneous non-paranormal belief that all birds can fly or why both, voodoo and ESP are considered as paranormal beliefs. The inability to conceptually separate paranormal beliefs from other beliefs questions the rationale to study them separately. Thus, when trying to explain what especially leads to supernatural, superstitious, paranormal, magical, and religious beliefs, a conceptualization that sets these beliefs apart from other non-paranormal, unfounded beliefs is needed.

There is one common denominator that almost all beliefs considered paranormal, supernatural, superstitious, magical, and religious share and which sets them apart from other beliefs: they all include confusions regarding core ontological properties of mental phenomena, material objects, living, and animate organisms (Lindeman & Svedholm, 2012; Lindeman & Aarnio, 2007). Core ontological properties refers to fundamental attributes of evolutionary important phenomena that children learn universally and

easily such as independent existence and force for physical phenomena and living for biological phenomena (Hirschfeld & Gelman, 1994; Inagi & Hatano, 2004; Spelke & Kinzler, 2007; Wellman & Gelman, 1998). Another example of fundamental attributes that children learn to understand is that intentional acts are functions of animate beings and that physical events happen because of unintentional force. In addition, at the crux regarding ontological properties important for paranormal beliefs is the understanding that people have minds and inner mental states in forms of beliefs, desires, and intentions.

In paranormal, supernatural, superstitious, magical, and religious beliefs these core ontological properties are often confused. For example, belief in psychokinesis means that a person can directly manipulate physical entities with mental thoughts. This would mean that a mental thought would have a physical property of mechanical force. Similarly, in out-of-body experiences the mental thoughts and consciousness would have a physical property of independent existence and ability to move in space. In addition, a similar belief in an immortal soul would mean that a mental process of consciousness would have in itself a biological quality of living and a physical quality of independent existence and an ability to move in time and space. In other words, mental phenomena would not be interdependent on any physical or biological processes. A similar, but less strict conceptualization than the one used in this thesis has emerged in the field of cognitive science of religion where religious supernatural beliefs are considered to be any kinds of ontological confusions, not limited to core ontological properties (e.g., Boyer, 2001; Atran & Norenzayan, 2004; for discussion of the relation of these conceptualizations, see Lindeman & Svedholm, 2012). Taken together, the common unifying theme at the heart of the content of paranormal, supernatural, superstitious, and magical beliefs are core ontological confusions. In other words, although the appearance or the phenotype of these beliefs are cultural dependent and may prominently vary, they all share the similarity of being different forms of ontological confusions.

Though most of the beliefs share this common denominator of core ontological confusions, some beliefs often studied under paranormal beliefs do not. For example, belief in extraterrestrial life or UFOs is a plausible belief as long as the postulated aliens do not possess abilities or properties that violate core ontological categories. Thus, focusing on the common denominator, ontological violations allow an articulated conceptualization that specifies what makes a paranormal belief different from other

beliefs and what connects these different beliefs under a common label. This conceptualization also suggests that the trajectory and explanations for these beliefs may be different from other beliefs, such as common mistaken beliefs (e.g., dolphins are fishes) because these beliefs are related to core knowledge. Basing on this conceptualization, paranormal, supernatural, superstitious, and magical beliefs are together here after referred as paranormal beliefs.

Although in the present thesis, the conceptualization of paranormal beliefs covers supernatural religious beliefs, it should be noted that even though religious beliefs such as belief in a god or gods, are also ontological confusions, these beliefs are not the same as religion or religiousness. Religion and religiousness are broader phenomena than supernatural religious beliefs alone. They also cover social, ritual, and institutional aspects outside mere beliefs. In addition, not all religious beliefs, for example a belief that you should not do harm or that you should respect your parents, are necessarily supernatural or paranormal. Thus, explaining religion or religious behavior covers features outside of explaining belief in paranormal beliefs: for example, how motivation affects participation in ritual behavior or how belonging to a religious institution affects wellbeing or behavior. These themes are left outside the scope of the current thesis. In this thesis, the focus is on individual neuro-cognitive factors that contribute to believing and unbelieving in the paranormal.

1.2 Paranormal believers are prone to core knowledge confusions

In childhood the domain-specific knowledge about psychological, physical, and biological is not fine-tuned and category mistakes are common, as already observed by Piaget (1929/1951)**.** For example, children's intuitive way of explaining physical phenomena in terms of psychological terms such as intentionality, has led to a suggestion that children are intuitively theists and bound to teleological reasoning that contributes to creationistic thinking and believing in a *primus motor*, creator god (Kelemen, 1999; 2004). In addition, because children treat the mind as independent from the body in a Cartesian, dualistic way, beliefs in spirits and souls without physical bodies are sensible (Bloom, 2004; 2007; Bering, 2006; Bering & Bjorklund, 2004). These children's tendencies to fuse the categorical information have led to conclusions

that these universal intuitive biases function as a base for various paranormal beliefs. These studies link paranormal belief with early emerging intuitive biases, but they focus only on specific beliefs and do not comment on what separates the intuitively rising paranormal beliefs from other non-paranormal intuitive beliefs. They also do not comment on what leads to individual differences in adulthood.

There is some empirical evidence that among adult paranormal believers ontological confusions are more common than among skeptics (Lindeman & Aarnio, 2007; Lindeman & Saher, 2007). In these studies, the believers agreed more than skeptics did that sentences with core knowledge violations were literally true. Thus, more than skeptics, paranormal believers agree that a river literally wants to flow or that a thought can heal or physically damage. However, it is not clear why supernatural believers approve sentences with core knowledge violations more than skeptics do.

According to dual-process theories, we have two reasoning systems or types of thinking, intuitive and analytic (for review see Evans, 2008). Intuitive processing is considered to be autonomous, fast, and not dependent on working memory while analytic thinking is considered to be slow, deliberate and dependent on working memory (Evans, 2012; Stanovich, & Toplak, 2012). These two processing types may produce conflicting results or be prone to different conceptions. For example, understanding the contagiousness of diseases may be done in both magical and biological terms (Legare & Gelman, 2008). Thus, although in adulthood explicit knowledge may challenge paranormal beliefs, intuitive knowledge may align with it in the form of confused core knowledge. It has even been proposed that paranormal beliefs may be latent and can re-emerge in adulthood if cognitive control of intuitive thinking is hindered (Hood, 2009), but so far it is not clear why the beliefs are more latent for some and less latent for others.

It is possible that there are simply developmental differences that lead to differences in the intuitive categorical knowledge regarding psychological, psychic, and biological phenomena, which leads to looser categorical boundaries for paranormal believers than for skeptics. However, paranormal believers have also been found to rely more on intuitive thinking than skeptics (Epstein, 2010; King, Burton, Hicks, & Drigotas, 2007; Lindeman & Aarnio, 2007; Sadler-Smith, 2011). Thus, because paranormal believers trust their intuitions more than skeptics do, it is possible that the potentially confused intuitions affect believers' more than unbelievers' reasoning. For example, in the case of telekinesis, if believers' intuitive knowledge about mental processes does not strictly

rule out the possibility that a mental process could possess physical power, the belief is alluring and deciding whether telekinesis is possible or not would be laborious. Adversely, if skeptics' intuitive core knowledge about mental processes is stricter and trust in, sometimes confused, intuitions less than believers, skeptics may effortlessly exclude the entire possibility of telekinesis. This would not mean that the paranormal believers would claim that paranormal phenomena such as telekinesis occur all the time in everyday life because the explicit knowledge about life is against this claim. Rather, differences in intuitive core knowledge could keep the door open for such beliefs or would not exclude such beliefs categorically. On the other hand, for skeptics the door would be shut or almost shut and categories constricted. Thus, metaphorically speaking, closing the door during reasoning of what is possible and what is not would require more work for believers than for skeptics.

1.3 Neural foundations of core knowledge confusions: intuitive world knowledge and N400

Intuitive mental presentations, such as core knowledge, are challenging to study. One possible way to tap the intuitive world knowledge is by using electroencephalography (EEG) to measure brain's event-related potential (ERP) N400 (Osterhout et al., 1997). The N400 is measurable in situations in which a word is anomalous in the context of the presented sentence (e.g., I take tea with sugar, milk, and *a cat*). Presentation of these kinds of anomalies elicits a negative ERP that is measurable from the scalp approximately 400ms after the anomalous word. The N400 is associated with processing of meaning and it is sensitive to expectations and contextual effects; furthermore, it can be elicited with various stimuli including not only written, spoken, and signed words, but also with pictures or objects (for review, see Kutas & Federmeier, 2011).

The N400 was traditionally only connected to language processing, but nowadays it is considered to be related to a general understanding of meaning and it can be effectively used to examine understanding of the meaning in language processing and semantic memory (Kutas & Federmeier, 2011). The suggestions that the N400 reflects meaning processing outside the literal meaning of language is supported by the findings that the N400 is sensitive to non-literal language processing such as metaphors that

capture meaning outside the semantic rules (for review, see Coulson, 2011). Generally, the more negative the N400 is, the less coherently the target word fits with the expectation and context that is created by the whole sentence and earlier knowledge.

In paper I, we used an N400 ERP paradigm to test processing differences between paranormal believers and skeptics while they were deciding if sentences with core knowledge confusions were literally true or not. The aim of the study was to verify a conceptual definition of paranormal beliefs and to gain insight into the neural correlates of knowledge confusions. The possible benefit of using the N400 to measure core knowledge confusions is that, when subjects process language, they process not only semantic meaning, but also the meaning of the stimuli in relation to real world knowledge. Because the N400 has been found to reflect expectations that are based on the long-term memory regarding the phenomena that occur and what objects there are in real life, independent of semantic rules (Chwilla & Kolk, 2005; Federmeier, Kluender, & Kutas, 2002), it could also reflect differences in core knowledge. The effect of world knowledge has been shown in a study in which semantic anomalies and context anomalies were compared. When the N400 responses were compared in a context of "Dutch trains are ____ and very crowded," the semantic anomaly "sour" elicited the same size N400 effect as the world knowledge violation "white," which contrasts with the real world knowledge of Dutch people that Dutch trains are "yellow" (Haagort et al., 2004). In these tasks, the more negative N400 effect is suggested to reflect longer retrieval of information from long-term memory. In the context of core knowledge confusions, this would mean that in deciding the literal truth of sentences with ontological confusions, less coherent core knowledge would lead to more laborious reasoning and to longer long-term memory retrieval times. Thus, in Paper I, we expected that when compared to skeptics, paranormal believers would exhibit more negative N400 to sentences with core knowledge confusions.

1.4 Does cognitive inhibition suppress paranormal beliefs?

Although the simplest explanation for the differences in processing sentences with core knowledge confusions between paranormal believers and skeptics might only be their qualitative difference in the coherence of the core knowledge, there may be other sources for the differences as well. One possible explanation, complementary or

independent, for the differences could be the ability to suppress intuitions that contradict analytic, explicit interpretations. In other words, if the intuitive word knowledge differs from explicit learned knowledge, there may be processes that suppress and diminish the intuitive interpretation.

Analytic thinking is shown to diminish paranormal beliefs, at least to some extent (Gervais & Norenzayan, 2012; Lindeman & Aarnio, 2006; Pennycook et al., 2012). However, how exactly the discrepancies between analytic and intuitive interpretations in reasoning interact, is currently under debate (see for example Bonner & Newell, 2010; De Neys, 2012; Evans, 2008; Stanovich, 2009a, 2009b). The main questions under debate are whether the intuitive and analytic processes simply compete with each other in a sense of "the stronger wins," or does a special mechanism regulate these thinking processes. One possible mechanism that could function as a suppressor of intuitive thinking, and hence intuitions contributing to paranormal beliefs is cognitive inhibition.

Cognitive inhibition is a general term that refers to conscious or unconscious cognitive control involving suppressing, stopping or overriding cognitive processes. Cognitive inhibition has a high heuristic value as it is used in several fields of psychology, although the explanations and definitions of its nature differ. Generally, it is considered to be resource-dependent. In cognitive psychology and neuropsychology, cognitive inhibition may refer to an ability to inhibit responses and distractors or to inhibit irrelevant or unwanted thoughts (Friedman & Miyake, 2004; Nigg, 2000; Redick, Heitz, & Engle, 2007; Macleod, 2007). In social psychology the idea of controlling dominant responses and biases comes close to conceptions of cognitive inhibition although the research does not always comment on inhibition research in cognitive psychology (for a review, see Hagger, Wood, & Stiff, 2010).

Neuroanatomically, brain imaging studies and lesion studies have associated inhibitory processing to the right inferior frontal gyrus (IFG). In tasks that require response inhibition, set shifting, or inhibiting thoughts, this area is usually activated and lesions in this area compromise success in these tasks (Andersson et al., 2004; Andersson & Levy, 2009; Aron, Robbins, & Poldrack, 2004; Aron, 2007; Munakata et al., 2011). There is also some *in vivo* neuro-cognitive evidence that disrupting normal right IFG functioning with repetitive transcranial magnetic stimulation enhances intuitive biases in syllogistic reasoning (Tsujii, Masuda, Akiyama, & Watanabe, 2010). All these lines of research suggest that cognitive inhibition could be involved in paranormal beliefs because it tunes reasoning and contributes to the interplay of

intuitive and analytic processing. Importantly for the individual differences point of view of the current set of studies, the right IFG activations are also shown to be a source of individual differences in cognitive tasks that involve conflict adaptation and resolution (Egner, 2011).

Hood (2009) has suggested that without the ability to adequately inhibit rising intuitions, people might be overwhelmed by a sense of the supernatural. In line with this argument, weaker inhibitory control has been associated with teleological biases (Kelemen & Rosset, 2009) and a tendency to make core knowledge confusions (Svedholm & Lindeman, 2013a). Interestingly, paranormal beliefs and cognitive inhibition also share other correlates. They are both associated with intuitive biases in logical reasoning, altered states of consciousness, creativity, and intuitive thinking (references in Papers II and III). In addition, during adulthood when cognitive inhibition is most efficient, supernatural beliefs are less common, and inversely, during childhood and old age when cognitive inhibition is least efficient, paranormal beliefs are more common (references in Paper II and III). To clarify the role of cognitive inhibition in paranormal beliefs, we compared cognitive inhibition between believers and skeptics in Paper II and Paper III.

In Paper II, we used the Stroop color-word test (MacLeod, 1991; 2005) and Wisconsin Card Sorting Test (WSCT) (Demakis, 2003) to directly test whether paranormal believers have weaker inhibitory processing than skeptics have. We hypothesized that paranormal believers have weaker performance in the inhibition tests than skeptics. The Stroop test is mostly considered to reflect relatively low-level automatic perceptual and response stage processing when subjects try to inhibit automatic responses (Friendman & Miyake, 2004; Nigg, 2000; Redick, Heitz, & Engel, 2007). The Wisconsin Card Sorting Test (Demakis, 2003), in turn, measures the ability to shift mental sets flexibly and avoid perseverative errors. The tendency to make perseverative errors is especially suggested to be connected to inhibitory problems.

In Paper III, inhibition was assessed indirectly by measuring right IFG activation with functional magnetic resonance imagining (fMRI) during a task that evokes paranormal interpretations. We expected that when compared to skeptics, believers would have weaker activation of right IFG. This activation difference could reflect weak engagement in cognitive inhibition in the situation that allures paranormal interpretations.

1.5 Paranormal beliefs and the social brain: Understanding minds and paranormal agents

During the last ten years, many cognitive scientists of religion have suggested that belief in supernatural, particularly religiosity, is a cognitive default and a by-product of the human evolution of cognition (e.g., Guthrie, 1993; Kelemen, 2004; Barret, 2000; Boyer, 2001; Bering, 2006; Bloom, 2007). The idea could be summarized as follows: because humans are able to form representations of immaterial minds and psychological processes and tend to treat their own minds as separate from their bodily functions, they are also able and prone to form representations of gods, spirits, and an afterlife. Human's ability to understand minds could contribute to paranormal beliefs on several levels; for example, this ability could enable the formation of representations of supernatural beings and by seeing physical processes as intentionally caused by an agent. Thus, in these terms, a tsunami could be seen as a deliberate expression of anger towards the people who have disputed and angered a supernatural being. This intuitive ability to understand minds could make believing in paranormal concepts comprehensible and alluring.

In the field of developmental psychology and neurosciences, human understanding of other minds, that other people act goal-directed and intentionally based on their wishes and beliefs is called theory of mind (ToM). The ToM begins to develop from birth and some social related habits and bases for later developing skills are innate (Farroni et al., 2005; for reviews of ToM development, see Blakemore, 2008; Saxe, Carey, & Kanwisher, 2004; Wellman, Cross, & Watson, 2001). The ToM is not one process but a bundle of processes. For example, perception of goal-direct movement does not necessarily involve further mentalizing, meaning that people do not necessarily form higher level presentations of inner mental states, such as beliefs or wishes, that potentially guide or are related to the goal-directed action. Thus, understanding that an agent tries to reach a goal does not necessitate understanding of the beliefs that underpin the goal reaching. This gradualness of ToM processing is also reflected as gradual development. By the first year, infants can ascribe agency to an entity and understand that an agent acts towards a goal. By 18 months, an infant's joint attention skills and "pretend play" begin and serve as a base for more refined mentalizing skills such as

understanding false-beliefs and inner mental motives. A child usually masters these abilities around four to five years of age.

Although mentalizing develops and becomes refined gradually towards adulthood, mentalizing and other ToM skills are on a continuum that stems from both heritable variation and environmental inputs (Baron-Cohen, Knickmeyer, & Belmonte, 2005; Crespi & Badcock, 2008; Kanazawa, 2010; Tooby & Cosmides, 1990); even healthy adults may fail in tasks that require mentalizing of higher level intentions or perspective taking (Keysar, Lin, & Barr, 2003). Individuals who have serious disorders in these skills, that is, individuals with autism spectrum disorders, even more drastically evidence the variety and importance of the ToM skills. In autism spectrum disorders the problems with ToM skills are sometimes even characterized by the term "mind-blindness" (Baron-Cohen, 1999; Frith, 2001). Thus, in adulthood, there seems to be individual differences in ToM processing and some of the differences are present in the general population.

Even though ToM processing may serve as a base for paranormal beliefs as suggested by many researchers, these researchers have not usually commented on the individual differences in ToM processing and paranormal beliefs. For example the question of why skeptics with normal ToM processing do not believe in paranormal has not been fully addressed. One possible explanation that aligns with the present definition of paranormal beliefs could be that what separates believers and skeptics who both have normal ToM is how the properties of mind are understood at the core level. In other words, how is the input from the ToM system intuitively and explicitly understood and interpreted? The last three studies of the present study explored this and other differences between the believers and skeptics in ToM-related information processing.

1.6 Paranormal beliefs and the social brain: Dualism and the mind without the body

Bloom (2004) argues that because of human's intuitive understanding of physical and mental phenomena is based on different rules and systems, they are prone to treat mind and body as separate entities. This in turn leads to dualistic thinking about how mind and body are associated, or to put it in scientific terms, to a dualistic view about *the mind-body problem*. However, even though dualistic beliefs are dominant in childhood

(e.g., Bjorklund & Bering, 2004) and remain relatively common in adulthood (Demertzi, et al., 2009; Fahrenberg & Cheetham, 2000; 2007; Stanovic; 1989), there are still many people who do consider the mind as either interdependent or the same as the body (i.e., brain and its functions). One possible explanation for the different views of mind-body relations could be that skeptics' core conception of physical and mental phenomena is different from that of paranormal believers. In other words, believers' core knowledge is looser and remains closer to the developmentally initial idea of mind-body dualism, that the mind is fully independent or materially different from physical matter and the body.

In terms of core knowledge confusions, this would mean that a mental phenomenon would have biological and physical properties of living and physical existence in space. In contrast, a skeptics' view could be that mental phenomena are either the same or at least interdependent on the physical brain and not living *per se.* Thus, even if mental processes may feel as if they are independent, they are, at the core, interdependent on the brain and body. Therefore, the different conceptions about the mind-body problem between the groups could be related or could stem from paranormal believers' general tendency to make core knowledge confusions about mental, physical, and biological phenomena. This tendency could also explain why dualistic beliefs are related to paranormal beliefs that have nothing to do with mind-body relations such as faith healing and psychokinesis (Stanovich, 1989; Thalbourne, 1996).

We used two different studies in Paper IV to test the relations of conceptions about the mind-body relations, paranormal beliefs, and core knowledge confusions. Our hypothesis was that both implicit (i.e., believing in an immortal soul) and explicit (i.e., explicit definitions of mind-body relations) dualistic perceptions about the mind-body relationship are related to paranormal beliefs and ontological confusions. In turn, we expected that non-dualistic perceptions such as that the mind is dependent on the brain functions (emergentism) or that the mind is the same as the brain functions (monism) are unrelated or negatively related to paranormal beliefs and ontological confusions. We also tested the role of ontological confusions as a preceding factor that explains differences in mind-body conceptions and which functions as a unifying background variable for the paranormal beliefs. This could explain why paranormal beliefs that have nothing to do with mind-body relations are still associated with them (e.g., belief in horoscopes and belief in an immortal soul).

1.7 Paranormal beliefs and the social brain: Oversensitive social information processing?

Another source of individual differences in paranormal beliefs that could be related to social information processing, could be the differences in the amount of representations the ToM-system generates during spontaneous or deliberate processing. Baron-Cohen (1999) has suggested that it may be impossible to understand the idea of paranormal agency without properly functioning ToM and in support, Norenzayan, Gervais, and Trzesniewski (2012) found out that people with autistic spectrum disorders that have mentalizing deficits have fewer beliefs in religious agency such as gods than control subjects did. This suggests that at the extreme end of the ToM continuum, that is characterized by "mind-blindness," paranormal beliefs in agency are diminished and a well-functioning ToM maybe a prerequisite for some paranormal beliefs. However, these results do not address the individual differences along the continuum but only the extreme. Thus, the question remains, does a scarce or a strong mentalizing tendency lead to scarce or strong paranormal beliefs in general population?

Although the ToM is considered to be a domain-specific system dedicated to understanding intentionally acting agents, people tend to interpret surrounding world's events in mental terms, whether they are intentional, random, or mechanical. Usually, this is done only in a metaphorical sense without a genuine belief. For example, a storm could be observed to be an exceptionally *angry* storm or a malfunctioning computer can be described as *being stupid* and having maybe even *a grudge* against the user. In cognitive psychology, this tendency to anthropomorphism, treating nature and the physical world as human-like or with psychological terms, has been proposed to serve as an inductive base of reasoning (Epley, Wayatz, & Cacioppo, 2007; Guthrie, 1993). A similar idea, that ToM processing is a "default mode of cognizing," has also been suggested in the field of neurosciences based on a different line of research (Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008). However, this suggestion does not comment on mentalizing non-mental phenomena. Although treating the non-human phenomena as human is a common everyday phenomena, it has been suggested that this tendency is associated with paranormal beliefs (Guthrie, 1993; Barret, 2000) and indeed,

it has been found that paranormal believers believe that a storm has a purpose explicitly planned by a supernatural agent (Svedholm, Lindeman, & Lipsanen, 2010).

In Paper V we tested whether paranormal believers engage more in ToM processing when they process randomly moving objects than skeptics do. We utilized fMRI during a viewing task of animations with randomly and intentionally moving geometric shapes and asked the participants to judge the randomness and intentionality of the animations. At the brain level, areas related to interpreting intentional animations and mentalizing in general are based on a large network that is functionally specialized to some extent (Amodio & Frith, 2006; Frith & Frith, 2003; Gallagher & Frith, 2003; Van Overwalle & Baetens, 2009). The network includes superior temporal sulcus (STS) that is activated by observing faces and biological motion, temporoparietal junction (TPJ), posterior cingulate cortex (PCC), and the ventral medial prefrontal cortex (vmPFC). The right TPJ, PCC and vmPFC are specially connected to higher level mentalizing about inner mental states (see paper V for references). We hypothesized that during the random animations, paranormal believers' mentalizing network is more active than that of skeptics.

The question of specificity of the association of ToM processing, that is, mentalizing non-mental, and paranormal beliefs is interesting because earlier studies have found that, in general, paranormal believers find more patterns in ambiguous semantic and visual stimuli (Brugger et al., 1993; Giannotti, Mohr, Pizzagalli, Lehman, & Brugger, 2001; Fyfe, Williams, Mason, Graham, & Pickup 2008; Elk, 2013). Thus, it might be that because paranormal believers are generally prone to see patterns-in-noise, this also affects their tendency to find meaningful patterns in ambiguous situations whether the stimuli is social or not. In social situations it then would not be sensitivity to social information per se, but a general tendency to interpret patterns as meaningful even from scarce information which then can be interpret in mental terms. However, it could also be possible that a general pattern-detection tendency and social cognition enhance each other. For example, the bottom-up tendency to find meaningful patterns could lead to further mentalizing them with the top-down processes, in a sense that the constantly detected patterns call for explanation that tends to be mental among the believers. Alternatively, the lower level processing of social related information could be even more sensitive than general sensitivity to patterns in any stimuli.

To further test the association of paranormal beliefs, sensitivity to social information, and patter-detection, we used pictures of artifacts and scenery with and without face-

like patterns in a detection and a rating task in Paper VI. In the study, paranormal believers and skeptics were asked to identify and to point to the face-like areas in the pictures. Afterwards, they also rated the face-likeness and emotionality of the possible face-like areas. We expected that paranormal believers would be more prone to illusory face perception (i.e., reporting seeing face-like areas when none exists) and that paranormal believers would rate the artifact faces more face-like and emotional than skeptics would.

2. Aims of the study

This thesis consists of six studies conducted with various methods ranging from self-report online questionnaires to fMRI imagining. Three different research questions (1-3 below) were addressed with the studies. The research questions and types of studies of each research paper are listed in Table 1. The exact hypothesis of each study can be found in the original papers.

The three main research questions and expectations were:

1) What are the neural correlations of ontological confusions that are highly related to paranormal beliefs? We expected that ontological confusions are manifestations of intuitive world knowledge and that to determine the literal truth of sentences with ontological violations is more difficult for paranormal believers than for skeptics, which in turn, is reflected as a more negative N400 effect in an EEG among paranormal believers. (Paper I).
2) Does effective cognitive inhibition downplay paranormal beliefs? We expected that good performance in inhibition tests is associated with unbelieving and compromised performance with believing. We also expected that in skeptics, processing of information that could be interpreted in paranormal terms elicits activation in the right IFG that is associated with cognitive inhibition. (Papers II and III)
3) How is the social brain related to paranormal beliefs and is an oversensitive theory of mind related to paranormal beliefs? Three different expectations were set. First, 3a) we expected that the way people understand the mind-body problem contributes to believing and unbelieving. Both implicit and explicit dualistic stands were expected to be related to paranormal beliefs. Dualistic stands were also expected to mediate the relationship between ontological confusions and paranormal beliefs. Second, 3b) we expected that paranormal believers, in contrast to skeptics, assign more intentions to random moving objects and that this is reflected at the brain level as activation of the mentalizing network. Third, 3c) we expected that in contrast to skeptics, paranormal believers are more prone to illusory face perception. (Papers IV, V, and VI)

Table 1. Overview of the studies and research questions

Paper	Research question	Participants	Methods
I	1	10 paranormal believers and 10 skeptics	EEG, N400 ERP study
II	2	12 Skeptics and 14 paranormal believers	Performance in inhibition tests
III	2	Pilot study: 119 volunteers	Online self-report
		Main study: 11 paranormal believers and 12 skeptics	fMRI and a self-report
IV	3a	Study 1: 850 volunteers	Online self-report
		Study 2: 74 volunteers	Speeded conditions of self-report scales
V	3b	11 paranormal believers and 12 skeptics	fMRI and a rating task
VI	3c	47 volunteers	Perceptual detection task and a rating task

3. Methods

3.1 Participants

The studies consisted of experimental, electrophysiological, neuroimaging and correlational studies with a total of 1,182 participants with various educational, occupational, and belief backgrounds. Detailed descriptions of each study are presented next.

Paper I was an experimental EEG study conducted with 10 paranormal believers (three males, mean age=26 years, range 23-31 years) and 10 skeptics (three males, mean age=26 years, range=23-49 years). All participants were right-handed, healthy, and native Finnish speakers recruited from an earlier study with 3,261 participants (Lindeman & Aarnio, 2006). Participants were recruited depending on their degree of self-reported paranormal beliefs. Participants whose results placed them in the upper- or lower 10% of the Revised Paranormal Belief Scale (Tobacyk, 2004) scores were contacted and invited to participate in the follow-up study concerning information processing and brain responses. From the people willing to participate, 20 participants were randomly selected. The range of paranormal beliefs scores was on a scale 1-5 (1=strongly disagree, 5=strongly agree): 1.0-1.1 for the skeptics and 3.1-3.9 for the paranormal believers. The study was conducted in an EEG laboratory with the approval of the Research Ethics Committee in the Department of Psychology, University of Helsinki.

The study of paper II was conducted with 26 participants recruited from the same participant pool as the participants of Paper I. Twelve skeptics (5 females, mean age=32.2 years) and 14 paranormal believers (11 females, mean age=34.6 years) took part in the study. All participants scored on the highest or lowest 25th percentile on the Revised Paranormal Belief Scale (Tobacyk, 2004) measured in the earlier study. Eleven of the believers were full-time students, two were employed, and one did not report an occupational status. All skeptics were university students and ten of them had completed upper-secondary school, one had attended vocational school, and one had graduated with a Master's degree. From the believers, 12 had finished upper-secondary school, one had attended a polytechnic school, and one had graduated with a Bachelor's

degree. The basic education level or years of study for the university students did not differ between the skeptics and believers.

The pilot study of Paper III was used to prepare the stimulus material and its participants consisted of 119 volunteers (99 female, 20 male, mean age 27 years, range 19-48 years) recruited via Internet mailing lists. The pilot study was an online self-report questionnaire.

The main study of Paper III and the study of Paper V were fMRI experiments conducted with 23 volunteers recruited from an earlier study of representative sample of 15 to 56-year-old Finns (Lindeman, 2011). Participants were recruited based on their paranormal beliefs scores (highest and lowest 10%) on the Revised Paranormal Belief Scale (Tobacyk, 2004). Eleven of the participants were paranormal believers (6 female, average age=38, range=23-53 years) and 12 were skeptics (6 female, 5 male, average age=34 years, range 21–49 years). All participants were healthy and fulfilled the safety requirements for fMRI imagining. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the studies.

Paper IV's study 1 was done as an online self-report with 850 volunteers (59% women, 41% men, mean age=30 years, range=16-66 years). Thirty-four percent of the participants were university students and 7.3% were other students. Ten percent of the university students were psychology students and the second largest group (6%) were students of mathematics, while the rest had 20 different subject areas of study. Of the participants who were not currently studying, 32.5% were working in 95 different occupations, 12.9% were otherwise occupied, and 12.7% were without specified occupational status. Educational levels varied from basic education (17.7%) to upper-secondary level (38.1%) to higher education (32.9%) and not specified (11.3%). Religious affiliations of the participants were, Evangelical Lutheran (46.2%), some other church (3.2%), no conviction (38.4%), and no answer (12.2%). Various Internet mailing lists and message boards were used to recruit the participants.

Study 2 of Paper IV was an experimental study conducted with 74 participants (41 women, 33 men, mean age=32 years, range 20-53). Twenty-one of the participants were currently university students while 53 were currently working in 34 different occupations. Participants were recruited from Internet mailing lists, discussion forums, notice boards, and with the snowball method. To obtain participants from both ends of the paranormal belief continuum, two different advertisements were used during

recruiting: one emphasizing believing in the paranormal and the other, expressing skepticism towards the paranormal.

The study of paper VI was conducted with 47 healthy volunteers with normal or corrected to normal vision (26 female, mean age=31 years, range=20-50 years). Participants were recruited from the participant group of Study 2 of Paper V if they were in the upper or lower quartiles (25%) of scores on the Paranormal Beliefs Scale (Tobacyk, 2004).

3.2 Procedures, measurements and stimuli

3.2.1 Paper I

The study of Paper I was an experimental EEG study. The stimuli of the study consisted of 210 three-word sentences. Three different types of sentences were used: normal sentences ("stars shine on the sky"), anomalous sentences ("stars rust in the sky"), and core knowledge violations ("stars live in the sky"). Each group consisted of 70 sentences and all sentences across the sentence groups had the same structure (first subject then predicate). For a more detailed description of the stimulus material, see paper I.

Subjects evaluated each presented sentence ("Is the sentence literally correct?"; "yes", "no") during EEG measurement in a sound-attenuated room. Each sentence was presented in random order, word-by-word. Every word was on the screen for 400ms followed by a blank screen for 400ms before the next word was shown. Answers given to the question were saved as an explicit measurement of the *core knowledge violations* if they were given in a 1500 ms time window starting after the last word had appeared on the screen. Response times for the answers were calculated from the trigger word to the subject's response.

The EEG was recorded with silver/silver chloride electrodes placed at six standard recording sites (Fz, F3, F4, Cz, C3, C4, Pz, left and right mastoid) and two EOG-Channels (HEOG and VEOG). Midline electrodes (Cz and Pz) were chosen for statistical analysis, the placement of the ground electrode, and the use of off-line re-reference of the data to the arithmetic average of the left and right mastoids was done

according to the widely used methods of N400 studies (see paper I for references). Data were sampled at a rate of 500 Hz and amplified with a .01-40-Hz bandpass filter.

To test the between-group differences in the EEG signals, the trials were segmented into 800ms epochs: 100ms before the target to 700ms after the target onset. The target was the predicate in the middle of the sentence. The data were averaged across trials. The resulting ERPs were digitally filtered (.5-10-Hz bandbass filter), baseline corrected using the average of the 100ms pre-stimulus epoch, computationally re-referenced to the average of the mastoids, and cleaned from artifacts (larger than +-75 μV). To investigate the N400 effect, the highest negative peak amplitude between 300 and 500ms of each sentence type were determined from the individuals' ERPs.

3.2.2 Paper II

In the study of Paper II, subjects were tested with the Stroop Color-Word test (Macleod, 1991, 2005) followed by the Wisconsin Card Sorting Test (Demakis, 2003). Two trials of the Stroop test were used for statistical analysis: color naming from non-word letters (XXXX, that were red, green, yellow or blue) and an incongruent trial where the participants had to name the words that were written in different colors (e.g., "red" printed in blue ink). The time difference between the color naming from non-word trials and from incongruent trials was used as a score for the *Stroop inhibition* that reflects the relative slowing down of processing between the tasks.

The WCST was administered with standard instructions with four stimulus cards and 128 response cards. The cards depict figures with varying numbers and colors. The participants' task is to sort randomly presented cards from a deck to the stimulus cards' three possible dimensions (figure, color, number). The goal of the sorting is to discover the unrevealed rule on the basis of feedback given after every try (was the sorting done "right" or "wrong"). After ten consecutive right answers the sorting rule changes without informing the participant. Thus, the participant has to sort out the new rule again by trial and error. The following measures were used for analysis: *total errors* (all wrong answers); *non-perseverative errors* (random non-perseverative errors); *correct categories* (how many rule-categories out of six were finished), and *perseverative errors* (perseveration tendency).

3.2.3 Paper III

Paper III consisted of a pilot study and an fMRI experiment. The pilot study was used to test and develop the stimulus material for the main fMRI study. In the pilot study participants rated 24 short story-picture pairs. Short stories described critical life situations and were paired with sharp color photos of lifeless objects and scenery containing no letters, numbers, animals, or people. Participants were given the following instruction: ”Imagine you are walking down the street. You are deep in thought, thinking about the situation described in the story. Suddenly, you see a picture on a large poster right in front of you. Try to think about what thoughts the picture might raise in you in that situation”. For example, a participant would first read an example: "You have been unemployed and have finally gotten a job interview. After the interview, you are unsure about how it went and anxiously await the employer’s decision," followed by a picture of a business suit. Examples of the stimuli can be found in Paper III.

First, the story-picture pairs were rated, regarding how much belief in *seeing sign* there was on a scale from 1-5, where 1=completely disagree to 5=completely agree, "If I saw that poster in that situation, I would think that the picture contained a sign or a message about how this situation was going to turn out." Second, the subjects rated what emotions the pairs elicited on a three-point scale for *positive emotions* ("Yes, very positive" to "Does not raise emotions") and on a corresponding three-point scale for *negative emotions*.

The results of the pilot study showed that the distribution of the ratings were for most pictures bimodal peaking at ‘completely disagree’ and ‘somewhat agree.’ Seeing pictures as signs correlated strongly with believing in the supernatural (r=.50, $p < 0.001$) measured with the Revised Paranormal Beliefs Scale (Tobacyk, 2004). In addition, seeing the pictures as signs was related to both positive (r=.51, $P < 0.001$) and negative (r=.55, $P < 0.001$) emotions.

In the main study, 30 story-picture pairs were used. These were selected and developed based on the pilot study and balanced with respect to emotional valence. The study setting was similar to the pilot study, except that it was conducted during fMRI scanning. Furthermore the presenting time of the stories and the pictures was controlled, and answering to the *belief in sign* and *emotionality* was submitted after the imaging.

The stories were shown for 7s, the pictures for 5s followed by an 8s pause showing a blank screen.

The fMRI imaging was done using a Signa VH/i 3.0 T scanner (GE Healthcare, Chalfont St Giles, UK) with the following parameters: echo time 32 ms, repetition time 2.0 s, flip angle 758, field of view 22 cm, 34 slices aligned with the line connecting the anterior and posterior commissures, slice thickness 4.0 mm and matrix size 64 x 64. In the pre-processing state, the functional pictures were realigned, normalized to a Montreal Neurological Institute template, and smoothed to enable intersubject comparison and to account individual variation in functional anatomy (see paper III for details).

Next, time series were analyzed with a general linear model and box-car functions for *story, picture,* and *rest* blocks were modeled and convolved with a hemodynamic response function. The fMRI data were fitted to the model. Contrast images for each participant in each condition (*story > rest, picture > rest, and story > picture*) were calculated to show differences in parameter estimates in each voxel. Individual contrast images were then used for group-level analysis.

The overall activation of the task (*picture > rest*) was tested with one sample t-test with believers and skeptics pooled using family wise error (FWE) correction for multiple comparisons to the entire brain volume. Group differences were tested with two-sample t-tests. Group differences were tested in two a priori anatomical regions of interest (ROI): right inferior frontal gyrus (IFG) based on the cognitive inhibition literature (Aron, Robbins, & Poldrack, 2004), and the left IFG ROI based on the earlier study regarding interpreting messages (Tylén et al., 2009). The activation in the right IFG ROI was used also in the multiple regression analysis with pooled groups to test the association of picture > rest contrasts activations and a self-reported variable of *seeing signs*. The results of the ROI analysis were FWE corrected in the volume of ROI.

3.2.4 Paper IV

Study I of Paper IV was conducted as an online self-report. The following measures were used. To measure explicit conceptions about the mind-body relationship, a modification of Stanovich's (1989) 27-item Dualism scale was used. The original scale was simplified, ambiguous items were excluded, and items concerning monism and emergentism were added. The new scale had 25 items that were evaluated with a five-

point scale (1=strongly disagree, 5=strongly agree). Three factors were identified with a factor analysis with a Varimax rotation. Based on the analysis, these factors were named *reflective dualism* (mind and body are qualitatively distinct), *emergentism* (mind and brain are qualitatively different, but interdependent), and *monism* (mind and body are the same or fundamentally united), with reliability estimates (Tarkkonen & Vehkalahti, 2005) of .87, .82, and .75, respectively.

Afterlife beliefs, beliefs concerning properties of an immortal soul, in other words beliefs about which biological and psychological processes may continue after death, were assessed with a scale modified after Bering and Bjorklund (2004, Experiment 3). The questions were answered in dichotomous form. For example, "When a person is dead, is she or he still able to X" ("yes", "no"). The scale consisted of 22 items regarding biological processes (e.g., When a person is dead, is she or he still able to *eat?*); psychobiological processes (e.g., be hungry); perceptual processes (e.g., see); desire (e.g., want); emotions (e.g., feel sad), and epistemic processes (e.g., know). The *afterlife belief* variable was the average score of the items (Cronbach's α=.94).

Paranormal beliefs were measured using a Revised Paranormal Beliefs Scale (Tobacyk, 2004, Cronbach's α=0.92). The scale included 26 five-point items (1=completely disagree, 5=completely agree). The scale had seven subscales: witchcraft; psi; traditional religious beliefs; superstition; spiritualism; extraordinary life forms, and precognition. Example statements used were, "Some psychics can accurately predict the future" and "Some individuals are able to levitate (lift) objects through mental forces,"

Thirty statements of the Core Knowledge Confusions scale (Lindeman & Aarnio, 2007) were used to measure *ontological confusions*. In the scale, first, six practice sentences were presented and participants were asked to determine if the sentences were metaphorically or literally true. The sentences were either clearly literal sentences (e.g., "Sibelius was a composer") or metaphorical (e.g., "A surprising piece of news is a bombshell") to highlight the difference between metaphorical and literal sentences. The scale was dichotomous (1=only metaphorically true, 2=literally true) unlike the original 5-point scale. The actual 30-item scale consisted of sentences with ontological confusions such as "the house knows its history," "a force lives in nature," and "a foot wants to move"; four metaphorical and four literal statements were also used to disguise the purpose of the scale. The average score of all items was used as an *ontological confusions* variable (Cronbach's α=.88).

In Study 2 of Paper IV, participants made speeded versions (answering time was restricted to 4s) of the Core Knowledge Confusions scale and afterlife beliefs scale in a laboratory setting. Speeded conditions were used to eliminate the possibility of engaging in effortful processing so that the subject would instead produce intuitive, default responses (Bargh, 1989; Kelemen & Rosset, 2009; Wilkowski & Robinson, 2007). *Afterlife beliefs* were measured with the same protocol as in Study I except that the answering time was not restricted and answers were entered with a joystick. The core knowledge confusions scale was slightly modified from Study 1 and there was a different answering method.

Instead of answering whether the *ontological confusions* were literally true or metaphorical as in Study 1, participants were asked to simply answer whether the sentences were literally true or not. This answering method was used to highlight the importance of the literal truth. In Study 1, it could have been possible that rather than answering about literal truth, the participants were judging whether the sentences were more metaphorically or literally true. Paranormal beliefs were measured with the Revised Paranormal Beliefs Scale (Tobacyk, 2004).

3.2.5 Paper V

Paper V consisted of an fMRI study in which participants watched and rated animation videos with four intentionally and four randomly moving animated shapes. Four intentional animations depicted short, story-like narratives such as "four children playing a tag game." The movement of the shapes was independent; they moved with changing speed, were goal-directed, and interacted with others. The shapes also "communicated" with reciprocal small, shaking movements. In the four random animations, the shapes' movement was unsystematic, not goal-directed, and there was no reciprocal action between the objects. All animations lasted 30 seconds.

One trial consisted of an animation, five questions, and a 20 second rest. Each animation was presented twice with two different kinds of instructions. Participants were asked to either watch the animations freely or calculate how many times the shapes in the animations touched each other or the edges of the screen. Different instructions were used as a control task to control the allocation of attention during the animations. After each animation, participants were presented three questions about the intentionality (e.g., "How intentional was the movement?"), one about the randomness

of the movement ("How random was the movement of the shapes?"), and if a control task was used, one about the control task ("Did the objects touch each other and the walls more than X times?"). If a control task was not present, there was a second question concerning randomness. Participants answered with a continuous visual-analog scale. Average rating scores for *intentionality* and *randomness* were calculated.

The fMRI acquisition and pre-processing was similar to the main study of Paper III and similarly, functional time series were analyzed with a general linear model. Box-car functions that were convolved with hemodynamic response functions were calculated for the following: intentional animations (IA); intentional animations with the control task (IAC); random animations (RA); random animations with the control task (RAC); answering intentional questions; answering random questions, and rest blocks. For each subject, the following individual contrasts were calculated to test the effects of the animation type and control task: intentional > random (IA + IAC - RA - RAC); animations with the control-task > animations without the control-task (-IA + IAC - RA + RAC); the interaction effect of animation type and control task (+IA -IAC - RA + RAC); intentional animations > rest (IA + IAC - rest), and random animations > rest (RA + RAC - rest). These first-level contrasts were then used in a second level analysis. One sample t-tests were used for a group level analysis and two-sample t-tests were used for between-group analyses. All results were FWE-corrected for multiple comparisons after random field theory either to the whole brain volume or to the volume of an ROI.

ROIs were chosen a priori and were based on a meta-analysis of the mentalizing network (Overwalle & Baetens, 2009). The ROIs were: TPJ, mPFC, and PCC. We also used a functionally determined ROI of mPFC based on the rating task (intentional ratings > random ratings) to identify the areas associated with intention evaluation. The rating tasks were orthogonal to the animations activations in the model; thus, they were statistically independent, which enabled avoiding "double dipping" (Kriegeskorte, Simmons, Bellgowan, & Baker, 2009). "Double dipping" refers to an error of using statistically dependent measures when determining ROIs and then testing the activations within the same ROIs. Double dipping biases the statistical strength of the activations.

3.2.6 Paper VI

Paper VI describes a study with two different tasks. In both tasks, the same stimuli material was used: 98 artifact face pictures that had an area that could be interpreted as face-like and 87 non-face pictures that had no face-like areas. The stimuli pictures were chosen after a pilot study in which the stimulus material was tested on 10 participants (see Paper VI for details). Pictures depicted such items and objects as furniture, and such places as rooms, buildings, and landscapes. No people or animals were in the pictures. Some of the pictures were staged; some were natural. Pictures were kept as natural as possible and only their size was altered so that they were all 640 x 640 pixels.

In task one, the detection task, participants tried to identify face-like areas from the 185 pictures. The task was performed in a laboratory with a computer. One trial consisted of a fixation cross (1000ms), a picture (1000ms), and a response phase (4000ms). The response was entered with a mouse on an empty area that was the same size as the presented picture. If participants saw a face-like area on the picture, they were instructed to point and click the left mouse button on the blank area at the approximate place where the face-like area was seen. If no face-like area was detected, participants were instructed to press the right mouse button. After the answer or if no answer was given during the answering window, the next trial was presented. Variables for hit and miss rates for both, artifact and non-artifact faces were calculated. For the artifact faces, all left mouse clicks ("Yes, there is a face-like area in the picture") were coded as *hits* if the answer was given in an area that was in the pilot study defined as the face-like area. If the area clicked when answering "yes" was outside the previously defined face-like area, the answer was coded as *yes-miss*. All right clicks ("No, there is no face-like area") were coded as *misses*. For the non-face pictures, left mouse clicks ("yes") were coded as *false alarms* and right mouse clicks ("yes") as *correct rejections*. For both picture types, non-responses were coded as *non-responses* (no group differences were found in *non-responses*). The test had good internal consistency: for artifact faces, Cronbach's α=.93, and for non-face pictures, Cronbach's α=.98.

The second task, the rating task, was completed after the detection task. All artifact face pictures were presented a second time one by one and the participants were asked to rate the *face-likeness* (Cronbach's α=.98) and *emotionality* (Cronbach's α=.95) of them. Responses were recorded using a visual analog scale presented below the picture. The answering time was unrestricted. If participants did not see any face-like area in the

picture, they were instructed to press the right mouse button and the answer was coded as 0 (not at all face-like or not emotional).

4. Results

4.1 Neural foundations of core knowledge confusions

The study of Paper I investigated the neural correlates of ontological violations by measuring N400 ERPs during a semantic judgment task of normal sentences, anomalous sentences, and sentences with ontological violations. A multivariate analysis of variance showed that there was a main effect of group (F (1,18)=2.16, p <.032, $\eta 2$=.231), sentence (F (2,17)=26.02, p <.001, $\eta 2$=.754) and electrode (F (2,18)=14.56, p <.01, $\eta 2$=.447). There was also an interaction effect between the group and the sentence (F (2,17)=4.10, p < .035, $\eta 2$=.325). Regarding the interaction, comparisons showed that for core knowledge sentences a more negative N400 effect was found among the believers than among the skeptics (p<.05).When comparing the other two sentence types, the N400 elicited by the anomalous sentences was more negative than that elicited by the normal sentences (p < .001), or the core knowledge sentences (p <.001). Between-group differences for anomalies (p=.481) or normal sentences (p = .213) were non-significant. The results showed that, as expected, paranormal believers had a stronger (more negative) N400 response to the sentences with ontological violations than skeptics did.

The behavioral data showed that there were no group differences in reaction times to different sentences. There were also no group differences in the judgment of whether the ontological sentences were literally correct or not.

4.2 Cognitive inhibition and paranormal beliefs

In Paper II, the WCST and Stroop test were used to assess inhibition in skeptics and paranormal believers. A multivariate analysis of variance was used to test the group differences in the four subscales of WCST. The univariate F was significant, F(5,20)=3.47, p=0.02, and the results showed that paranormal believers' performance was poorer than skeptics in each of the four scores: *total errors, non-perseverative errors, perseverative errors,* and *categories correc*t. A one way ANOVA was used to test the difference between paranormal believers' *(*M=307, SD=155) and skeptics'

(M=293ms, SD=142) performance in the *Stroop inhibition* task. The performance did not differ between the groups (p=0.81).

In Paper III, cognitive inhibition was tested indirectly in an fMRI study and a self-repot rating task of the story-picture pairs after the imaging. The behavioral results showed that interpreting that the picture shown after the story could be interpreted as s*eeing a sign* was more common for paranormal believers (M=3.49) than for skeptics (M=1.79), $F(1,21)=25.92$, $p < .001$, $\eta 2=.564$. This replicated the finding of the pilot study.

The fMRI analysis showed that the main effect of viewing the pictures (picture > rest) with subject groups pooled, elicit activations in the left IFG, middle frontal gyrus, fusiform gyrus, middle occipital gyrus, and hippocampus. There was no statistically significant activity in the reverse contrast (rest > picture). No group differences were found at the whole brain level analysis or at the a priori chosen left IFG ROI. However, there was a group difference in the right IFG activation in the picture > rest contrast. Skeptics had a stronger activation than supernatural believers in an area covering pars orbitalis and pars triangularis ($t=5.34$, $p=< 0.05$, FWE corrected, coordinates of the peak activation: X=52, Y=22, Z=0). This cluster of activation also overlapped with an activation cluster of picture > rest contrast when the ratings of *seeing signs* was used as a covariate in the analysis ($t=4.73$, $p < .05$, FWE corrected; coordinates of the peak activation x=36, y=18, z=-10). To sum up, on average, skeptics had a stronger activation in the right IFG than paranormal believers did and when groups were combined, the more there was right IFG activation, the fewer were the self-reports of *seeing signs* in the pictures.

4.3 Social brain and paranormal beliefs

4.3.1 Mind-body conceptions, ontological confusions, and paranormal beliefs

Paper IV's Studies 1 and 2 tested the association of implicit and explicit mind-body conceptions, ontological confusions, and paranormal beliefs. The self-report Study 1 found that *emergentism* ($M=3.34$) was the most preferred stance on the mind-body problem, followed by *monism* ($M=3.09$, $t(761)=3.74$, $p < .001$) and *reflective dualism*

(M=2.61, $t(762)$=-22.68, $p < .001$). Reflective dualism was positively associated and monism negatively associated with afterlife beliefs (r=.50, p < .001; r=-.32, $p < .001$, respectively), with paranormal beliefs (r=.70, p < .001; r=-.33, $p < .001$, respectively), and with ontological confusions (r=.54, $p < .001$; r=-.14, $p < .001$, respectively). Emergentism was only slightly associated with afterlife beliefs (r=.15, p=< .01) and paranormal beliefs (r=.17, p=< .001), and not with ontological confusions (r=.06, non-significant).

Multiple regression analysis was conducted to test whether reflective dualism and afterlife beliefs mediate the relationship between ontological confusions and religiosity and paranormal beliefs. The claim received support regarding partial mediation that was tested with Sobel's (1982) test. The effect was significant (p=.001) in both analysis: ontological confusion–reflective dualism–paranormal beliefs, Z=12.92, and ontological confusion–afterlife beliefs–paranormal beliefs, Z=8.95.

We tried also to replicate the findings of Study 1 in Study 2 using implicit measures of ontological confusions and afterlife beliefs. The findings of Study 1 were replicated: a significant indirect effect of implicit ontological confusions via afterlife beliefs to paranormal beliefs was found (β=1.57, with a bias corrected confidence interval [0.88, 2.20]). There was also a direct effect from implicit ontological confusions to paranormal beliefs. The tested model explained 77.8% of the variance of paranormal beliefs, $F(2, 69)$=120.88, $p < .001$. Because the sample size in Study 2 was small and the distribution of paranormal beliefs was skewed, the regression analysis was done with 1,500 bootstrapped resamples (Bollen & Stine, 1990; Shrout & Bolger, 2002) to achieve reliable estimates for the mediation effects.

4.3.2 Attribution of intention to randomly moving objects

In Paper V, we used fMRI to measure brain activations of paranormal believers while they watched randomly and intentionally moving animations. Groups were analyzed separately and then compared with each other. Watching the intentional animations in contrast to rest (intentional animations > rest) revealed typical activations related to watching animations with intentional content. For both groups, there were activations of TPJ, STG, and occipital visual areas together with parietal areas and middle temporal gyrus. For skeptics, there was also activation in the middle and inferior frontal gyri. The random animations > rest contrast revealed similar activations as when watching

intentional animations except that the activation of TPJ, typically associated with intentional animations, was missing. There were no group differences in either contrast when groups were compared. No interaction effects between the animation type and control task were found.

For skeptics, the intentional animations > random animations contrast produced activations in bilateral TPJs, ventral mPFC (vmPFC), and the post-central gyrus/inferior parietal lobule. In paranormal believers, activation differences were found bilaterally in the middle and inferior occipital gyri and in the left TPJ. Thus, the typical activation of right TPJ and mPFC to intentional animations was missing in believers but this was due the similarity of the activations to the random and intentional animations. No group differences were found in the direct comparison (intentional animations > random animations). However, in the reverse contrast (random animation > intentional animation) paranormal believers had stronger activation in vmPFC than skeptics. This activation difference was significant corrected for the multiple comparisons to the whole brain volume, to the a priori ROI and to the functional ROI. Thus, the area that was more strongly activated in paranormal believers than in skeptics while they watched random animations was the same area associated in literature to mentalizing and that was activated during the rating task of how intentionally behaving the animations were in contrast to how randomly moving the animations were.

4.2.3 Illusory face-perception

The results from Paper VI were analyzed using signal detection analysis (Green & Swets, 1966; Macmillan & Creelman, 2005) that enabled correction of the hit-rate with the false-alarm rate, revealing actual detection sensitivity. Two variables were calculated: perceptual sensitivity (d') and bias towards answering "yes" in both conditions (criterion C). Paranormal believers had more false alarms in non-face pictures, F (1,36)=7.95, p=.008, $\eta 2$=.181, and more hits in the predetermined face-areas, F(1,36)=9.99, p=.003, $\eta 2$=.217, than skeptics. The perceptual sensitivity d' did not differ between the groups but the criterion C differed. Skeptics (M=0.67, SD=0.39) had a higher criterion C than paranormal believers (M=0.43, SD=0.34), F(1, 36)=11.02, p=.002, $\eta 2$=.234). Thus, the believers both found more face-like areas, but also had more false alarms.

We also tested whether the paranormal believers found the predetermined face-like areas better than the skeptics. Analysis of covariance was conducted with the number of correct location identifications divided by the sum of correct and incorrect location identifications for all trials where participants had reported a face-like area as a dependent variable. Paranormal believers found more face-like areas (M=90) than skeptics did (M=87), $F(1,36)=6.01$, $p=.019$, $\eta 2=.143$. In the rating task, paranormal believers (M=110 SD=50) rated the face-like pictures more face-like than skeptics (M=72, *SD*=44), $F(1,37)=6.25$, $p=0.17$, $\eta 2=.145$) and more emotional than skeptics (believers: M=54, SD=18, skeptics M=42, SD=14), $F(1,37)=4.70$, $p=.037$, $\eta 2=.113$.

5. Discussion

5.1 Core knowledge confusions reflect intuitive differences in world knowledge

In Paper 1, we sought verification of the conceptual definition that paranormal beliefs stem from looseness of intuitive core knowledge and tried to gain insight into their neural basis. The results showed that when compared to skeptics, paranormal believers had a more negative N400 effect on sentences with ontological confusions. There were no differences between the groups in normal or anomalous sentences. This implies that what differentiated the believers from the skeptics was not the way they understood literally true sentences or anomalous sentences, but that they had difficulty in determining the literal truth of sentences with core knowledge violations. The N400 effect has been proposed to reflect long-term memory retrieval of world knowledge (Chwilla & Kolk, 2005; Federmeier et al., 2002; Hagoort et al., 2004; Kutas & Federmeier, 2011). Hence, the results suggest that for paranormal believers, the intuitive core knowledge is less categorized than for skeptics. Core knowledge confusions are common in childhood (e.g., Kelemen, 1999; 2004; Bloom & Weisberg, 2007) and may decline with age. The results suggest that if the categories remain loose later in life, paranormal beliefs that hold violations of core knowledge are readily comprehensible in adulthood. These results support the conceptualization of paranormal, superstitious, magical, and supernatural beliefs as similar phenomena stemming from core knowledge violations (Lindeman & Svedholm, 2012).

The number of corrects answers in the task did not differ between paranormal believers and skeptics. In other words, both groups were able to decide correctly, which sentences were literally true and which were not. Other studies, including paper IV of this thesis, that have been conducted with significantly larger participant groups have found differences in the correct answers between skeptics and paranormal believers (Lindeman & Aarnio, 2007; Lindeman & Saher, 2007; Svedholm, Lindeman, & Lipsanen, 2010; Svedholm & Lindeman, 2013). One possible explanation for this contradicting result is the small sample size. Another is that other studies have been primarily conducted as internet questionnaires, while the current study was done in a

psychology departments' EEG laboratory. The EEG laboratory setting may have propped up a scientific way of answering.

The N400 effect is considered to reflect unconscious processing of semantic information and a host of studies show that intuitive conceptions, including core knowledge confusions, often co-exist with later learned scientific conceptions (e.g., Kelemen & Rosset, 2009; Shtulman & Valcarcel, 2012, Svedholm & Lindeman, 2013b). If the discrepancy of the explicit answering and the N400 effect are further contrasted, the results can also be interpreted in a way that paranormal believers possess the same explicit knowledge as skeptics, reflected in right answers, but due to their loose categorical distinctions of core knowledge, the N400 was more negative. This interpretation also augments the understanding of the robust findings that trust in intuition and intuitive thinking in general is associated with paranormal beliefs (e.g., Epstein et al., 1996; King et al., 2007; Lindeman & Aarnio, 2006). Because paranormal believers' intuitive world knowledge is less strict, and if they trust more in their intuitions than skeptics, they are prone to accept ontological confusions rather than rely on learned knowledge that challenges the confused intuitions.

5.2 Strong cognitive inhibition dilutes paranormal beliefs

Paper II addressed the relation of cognitive inhibition and paranormal beliefs by measuring cognitive inhibition with two tests. The results supported the idea that if cognitive inhibition is weaker, paranormal beliefs are more common. When their responses were measured with WSCT, paranormal believers and skeptics differed in all types of errors, including perseverative errors that have most often been associated with inhibition problems (Demakis, 2003). This suggests that well-functioning inhibition contributes to disbelief. Because paranormal believers had generally worse success in the WSCT, the result may hint about other possible differences in other executive functions as well, for example regarding the ability to shift mental sets, an ability also needed in WSCT (Greve et al., 2005). However, because the specificity and factorial structure of WSCT is unclear (Dillon & Pizzagalli, 2007; Friedman & Miyake, 2004; Greve et al., 2005; Miyake et al., 2000; Nigg, 2000; Ray, 2004), diverse methods should be used to assess possible associations of cognitive inhibition, executive functions, and paranormal beliefs in the future. For example, better analysis of the relation of conflict

detection and cognitive inhibition could be fruitful because they are both associated with paranormal beliefs (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2013).

We also measured group differences using the Stroop test (Macleod, 2001, 2005) and found no differences between paranormal believers and skeptics. Earlier studies have found that weaker performance in the Stroop is related to teleological biases (Kelemen & Rosset, 2009) and ontological confusions, but not to paranormal beliefs (Svedholm & Lindeman, 2013a). Our result together with these findings suggests that the inhibition, when measured with Stroop, is not directly associated with paranormal beliefs, but may be indirectly related to paranormal beliefs, because the weak cognitive inhibition enhances ontological confusions that contribute to paranormal beliefs.

Still, the results from the Stroop test and WSCT can be seen as contradicting. One possible explanation for this potential discrepancy is that cognitive inhibition is a complex concept that lacks clear definition, is hard to measure, and may refer to several related but distinct concepts or processes (Aron et al., 2004; Aron, 2007; Friedman & Miyake, 2004; Lustig et al., 2007). Thus, it is not certain that the Stroop and WSCT even capture the same cognitive processes.

In Paper III we further investigated the possible role of cognitive inhibition in paranormal beliefs. We utilized an fMRI imagining during a task in which a story and a picture pair formed an association that lured a paranormal explanation. The fMRI results showed that for skeptics, the activation of right IFG was stronger than for paranormal believers during the task. The behavioral results showed that believers interpreted the pictures more often as signs than skeptics, and, importantly, when groups were pooled, the average of reporting seeing signs in the picture was negatively associated with the right IFG activation strengths. In other words, regardless of subject group, the more the right IFG was activated during the task, the fewer paranormal interpretations regarding signs were made.

The right IFG activation has been associated with cognitive inhibition in several studies (Aron et al., 2004; De Neys et al., 2008; Goel & Dolan, 2003; Tsujii & Watanabe, 2010) and with automatic conflict resolution in the case of cognitive dissonance (Jarcho, Berkman, & Lieberman, 2011). It is also associated with conflict detection in syllogistic reasoning tasks if the world knowledge and logical answers are inconsistent (Goel, 2007; Stollstroff, Vartian, & Goel, 2012). These findings support the suggestions that the activations that correlated with non-paranormal interpretations

could reflect cognitive inhibition or a similar process that is involved in successful resolution of reasoning conflicts.

It should be noted, however, that only the outcome of the behavioral task that was done after the imaging and the activation during the task done in the scanner were assessed and there was no direct measurement of cognitive inhibition during the imaging. This leads to a risk of reverse inference (Poldrack, 2006) in the interpretation of the cognitive nature of the found right IFG activation. Reverse inference means that we cannot know the psychological content of an activation without direct decoupling of the cognitive measurement representing change in the process and the activation change of the fMRI signal. This was even more of a risk in the case of the present study, as there was no simple, direct way of measuring cognitive inhibition.

Although right IFG has been found to be associated with inhibitory processing in numerous studies, the exact role of the right IFG in inhibition, attention control, or suppression of thoughts is unclear and currently the subject of debate (see for example Aron, 2007; 2011; Hampshire et al., 2010; Munakata et al., 2011). It may be that what is considered as inhibition at the behavioral or psychological level, may not be inhibition of irrelevant information at the brain level, but rather enhancement of task relevant information (Egner & Hirsch, 2005). Thus, the concept of inhibition at the psychological level (ability to suppress or reject thought processes) may be mechanically different at the brain level (there is not a network in the brain that suppresses another network). In other words, it is currently better known in which kinds of tasks the right IFG is activated, for example, suppression of thoughts and response inhibition, than to what exact underlying psychological process it is related.

Taken together, the results of Papers II and III support the idea that cognitive inhibition or related cognitive control mechanisms, functions as a regulator of conflicts between intuitive and analytic thinking by downplaying intuitive biases associated with paranormal beliefs. Hood (2009) has proposed that paranormal beliefs may be latent and that they can re-emerge when inhibition is compromised. Thus, effective regulation of intuitions has an important role in disbelieving.

5.3 Dualistic conceptions about the mind-body problem are strongly associated with paranormal beliefs and are forms of ontological confusions

The two studies of Paper IV explored how intuitive and explicit conceptions of the mind-body problem are related to paranormal beliefs. In other words, we explored how perceptions of how the mind and the body (the brain) are connected are related to believing and unbelieving. The results showed that if the mind was seen dualistically as independent from the body, paranormal beliefs and ontological confusions were common and the implicit and explicit dualistic mind-body conceptions went hand in hand. In contrast, monism, the opposite view, that the mind and the body are the same, was negatively associated with the paranormal beliefs and ontological confusions. In line, the view in the middle, the emergentistic view that the mind is qualitatively different from the body but still interdependent of it, was only slightly associated with paranormal beliefs and not at all with ontological confusions.

We also tested the idea that the separating factor between paranormal believers' and skeptics' mind-body conceptions stems from ontological confusions. The tested model explained paranormal beliefs well (coefficient of determination being between .54-.78) suggesting that dualism, whether implicit or explicit, is an important stepping-stone to paranormal beliefs. This model, where general ontological confusions precede dualistic conceptions, can also explain why dualistic views are related to paranormal beliefs that have nothing to do with the mind-body problem, such as the belief in protective amulets. These results also suggest that in adults, it is not only the ability to think about mind and body in different terms that exposes them to belief in souls or spirits (Bering, 2006; Bering & Bjorklund, 2004; Bloom; 2004), but also the tendency to mix up fundamental categorical properties of mental, physical, and biological phenomena. This is a bias to which some are more inclined than others.

Afterlife beliefs or belief in an immortal soul, that were measured as intuitive dualistic conceptions, are suggested to emerge early in life and they are proposed to be naturally emerging and universal, which makes belief in an immortal soul and gods readily adoptable (Bering & Bjorklund, 2004; Bering, 2006; Bloom, 2007). Paper III shows that if this is true, the ones who hold on to these early emerging beliefs have

more loose ontological categorical knowledge in adulthood than people who abandon dualistic conceptions. In other words, abandoning dualistic conceptions is associated with disbelief and integrated core knowledge. Why these changes happen to some and not to others can only be a matter of speculation, based on the current studies.

The factors contributing to the different trajectories of core knowledge development should be investigated more closely in the future. It could be possible that not only does loose core knowledge make beliefs more adoptable, but also that beliefs adopted when young or growing up in an environment that fosters these beliefs affect the development trajectory of core knowledge. The relation of beliefs and core knowledge is probably bidirectional. Understanding how core knowledge and especially core knowledge about the mind develops is important because mind-body conceptions have practical implications. For example, seeing mental illness as "all in the mind" may expose an ill-founded distinction between mental and physical illness that may affect professional decision making of judges and doctors (Kendel, 2001; Gray, Knickman, & Wegner, 2011). In addition, mind-body conceptions are considered to be important in psychologists' and doctors' diagnoses and treatment choices (Fahrenber & Cheetman, 2000, 2007). Thus, we should know better how mind-body conceptions develop and how they affect professionals' decision making that bears ethical consequences.

5.4 Paranormal believers attribute intentionality to randomness and this is associated with activation of the mentalizing network

Paper V tested the possibility that because the ToM-processing is considered to be a continuum and paranormal beliefs are associated with ToM processing, stronger mentalizing is associated with stronger paranormal beliefs. In the study, fMRI signal changes were measured while the participants watched intentional and random animations. The results showed that there were no group differences between skeptics and paranormal believers when they watched intentional animations, but that there was difference when they watched randomly moving animations.

In paranormal believers, the activation of vmPFC, that is part of the mentalizing network, was more active during viewing of random animations than in skeptics. The believers also rated the random animations as more intentional than skeptics did. These

findings are in line with the notions that paranormal beliefs may derive from the ToM-processing (e.g., Barrett, 2000; Bloom, 2007; Boyer, 2001, 2003; Guthrie, 1993; Hood, 2009; Kapogiannis, 2009; Kelemen, 1999). However, because the differences were not in the intentional animations, but in the random animation, it may be that the ToM processing functions as a base for paranormal beliefs only if it is generalized to interpreting non-mental phenomena. The finding that skeptics had no problems interpreting the intentional animations in intentional terms especially supports this interpretation. Similar findings have been obtained in semantic tasks (Lindeman & Aarnio, 2007; Lindeman & Saher, 2007; Norenzayan, et al., 2008; Svedholm, et al., 2010) in which paranormal believers more than skeptics described natural and physical phenomena in more intentional terms as in the sample phrase, 'The volcano is *angry*.' The present results broaden this view by showing that at least when interpreting animations, these over-generalization are related to activation of the mentalizing network at the brain level.

The ToM-network is a large network and functionally specialized to some extent. The vmPFC, where the clear activation difference between the groups was found, is associated with deliberate mentalizing and interpreting higher order intentions (Amodio & Frith, 2006; Frith & Frith, 2006; see also Gobbini et al., 2007). This area is active not only when there is a proper mental stimuli present that subjects try to interpret, but also when they try to determine if something is intentional in the first place, especially if they believe that the stimuli was made by an intentional agent (Steinbeis & Koelsch, 2009). Thus, the activation difference in vmPFC could reflect deliberate attention of trying to find intentions from the random movement in the believers group. If so, the results could be interpreted in such a way that paranormal believers are more persistent than skeptics in trying to find mental content in ambiguous situations. Nevertheless, because paranormal believers rated the random animations as more intentional than skeptics did, the possible persistent search was prolific.

5.5 Paranormal believers are more prone to illusory face perception than skeptics

In Paper VI, we tested differences between paranormal believers and skeptics when they tried to detect face-like features in artifacts and scenery, with and without such features.

The results showed that paranormal believers were more prone to illusory face perception than skeptics were when pictures with and without face-like features were used in the analysis. In other words, paranormal believers reported seeing faces even when no proper stimuli were present. This finding is in line with earlier studies that have found that paranormal believers are sensitive to find “patterns in noise” with various kinds of stimuli and conditions (Brugger et al., 1993; Giannotti, et al., 2001; Fyfe, Williams, Mason, Graham, & Pickup 2008; Elk, 2013; Wiseman & Watt, 2006).

Interestingly, however, because we also asked participants to point to the face-like areas in the pictures if they were perceived, we found that when a face-like area was presented, paranormal believers were more accurate than skeptics in pointing to it in the picture. Thus, even though paranormal believers were prone to illusory face perception, they were also better at spotting the faces if, but only if, face-like features were actually present. This could imply that the believers could have fewer criteria for what constitutes "face-like" than skeptics do. Some of the artifact face pictures were rather abstract; thus, if skeptics had a higher criterion on how much face-likeness is needed for something to constitute as face-like, it would not be surprising that they were not as good as believers in the detection task. Along similar lines, illusory agency detection has been found in paranormal believers (Elk, 2013), but only if the ambiguity of the stimuli was not too high. The interpretation that less information is needed for paranormal believers than for skeptics to trigger a perception, is supported by the results of the rating task where believers rated the artifact face pictures as both more emotional and more face-like than skeptics. The results from the rating task also highlight the common theme carrying through the present studies: paranormal believers tend to relate to a non-mental world in mental terms.

5.6 Limitations of the study

In one of the studies we used EEG and in two fMRI. These techniques offer unique opportunities to assess cognitive processes, but they also have limitations. For example, lately the power of brain imaging studies has been questioned due to analysis methods and because of the small number of participants used in the studies (Button et al., 2013). Thus, replications with a larger number of participants are needed. Furthermore, in

Paper II, where cognitive inhibition was directly assessed, the number of participants could have been higher.

The fMRI method has some other limitations that should be addressed. Pinpointing specific areas, such as vmPFC in Paper V and rIFG in Paper III and interpreting the activation as mentalizing or cognitive inhibition has its problems. This is because activation in one anatomical area rarely equals to cognitive function, and cognitive functions are usually supported by large networks (Logothesis, 2008). Thus, even though the activation location could be critical or "most active" related to the cognitive function in question, there may be other important parts of the network that are missed simply because it is assumed that signal change in the fMRI is linearly related to strength or importance of cognitive processing.

The representativeness of the data regarding the ends of the paranormal beliefs continuum was relatively good in Papers I, II, III, and V because the participants were chosen from a larger participant pool based on their self-rated paranormal beliefs. In papers IV and VI, many of the participants were university students, which may have had an effect on the skepticism, because Finnish university students are among the most skeptical populations used in studies (Tobacyk & Pirttilä-Backman, 1992). Furthermore, matching and controlling of the demographic and cognitive factors of the skeptics and the paranormal believers in papers where the groups were compared could have been done better. In the current studies the focus was on the paranormal beliefs continuum and better controlling of cognitive factors, for example intelligence or education, could have provided more univocal interpretation of the results.

It should also be noted that using groups from the ends of the paranormal beliefs continuum has pros and cons. Using subjects from the ends of the continuum makes the effects clearer than using subjects from more heterogeneous groups. However, it also means that the effects' strengths in the middle of the paranormal belief continuum are not directly addressed. In other words, the data only show how strongly the ends of the continuum differ, but not how much the people in the middle or along the continuum, differ from the ends. Another advantage of testing the ends of the continuum is that, as discussed in the introduction, cultural learning and contextual factors have clear effects on paranormal beliefs. It could be speculated that in the middle of the continuum individual cognitive factors and cultural factors are more mixed as the individual differences are less strong and guide the behavior less. The micro and macro cultural effects' interaction with individual differences in cognition should be more vigorously

addressed in the future. This is even more so because there is some evidence that the shared environment effect decreases with age regarding religiousness in twin studies (Bouchard, 2004). Although religiousness is not the same as paranormal beliefs, this finding hints at the possibility that the individual differences in cognition become even more meaningful with age.

5.7 Conclusions

Paranormal believers have been found to be more prone to ontological confusions than skeptics as also found in the present study. Thus, it seems that diverse developmental trajectories of core knowledge affects believing and unbelieving. This link was especially strong regarding the core knowledge confusions about mind and mental processes. Another important conclusion from the present studies is that although these confusions are found to diminish in adulthood, when compared to childhood, there is still a large variation among adults and this variation goes hand in hand with believing and unbelieving.

The results concerning cognitive inhibition suggest that efficient cognitive control mechanisms may work as a buffer against intuitively alluring paranormal beliefs by enabling critical and versatile reasoning. A similar mechanism could also work on a perceptual level, as in the case of illusory face perception, in a way that although someone could be prone to illusory face perception, the automatically triggered perceptions are effectively rejected once found meaningless. A simple example of this relation in everyday life could be situations that occur when a person hears or sees something and notices that the percept was biased. If cognitive inhibition, or a similar process, would not work, we would be prone to hold on to these percepts or to try to find explanations for them, instead of declaring them as accidental quirks and moving on. This effect could get enhanced if it is combined with tendency to mentalize non-mental phenomena and weakly categorized core knowledge.

This thesis also sheds light on the relation of the social brain and paranormal beliefs. The ability to form mental representations of the mind may indeed function as a base for many paranormal beliefs, but to set the believers apart from skeptics, the mentalizing processes have to be also used outside the psychological domain to make inferences about the non-mental in mental terms not only metaphorically but literally. This is

because non-believers can also understand the mind and may misattribute intentions. For example, even skeptics may treat badly or shout at a badly functioning computer as if it was an intentional creature. Thus, the relationship of the social brain and paranormal beliefs is more complex than what is often suggested and the individual differences need to be considered to fully understand what contributes to believing and unbelieving. Logically cultural knowledge has important effects on shaping these interpretations about mental beings and processes. For example, without the cumulating scientific evidence and knowledge about what the mind and its functions are it would be significantly more difficult to challenge a person's dualistic intuitions.

The complex picture of the link between believing and unbelieving and social information processing individual differences is also evident if we consider at which level of processing the individual differences function. The results from the fMRI study with intentional and random animations suggest that the differences are on the mentalizing level, a top-down processing of interpreting the stimuli. However, the study regarding illusory face-perception suggests that the differences are related to a lower criterion value of what can be held as face-like or how many emotions can be seen in an artifact face. In other words, it might be that although paranormal believers are prone to answer "yes" in any condition, as found, less information is needed at least in some, maybe social, situations to trigger the perception of the target stimuli. Naturally, this leads to better performance if ambiguous stimuli are present. This suggestion is supported by the finding that paranormal believers are more prone to illusory agency detection than skeptics, but only if the stimuli are not too noisy (Elk, 2013). Thus, it may be that the systems of agency detection and face detection are less picky in paranormal believers than in skeptics and at the same time the rising percepts go through more thorough mentalizing in paranormal believers than skeptics. To sum up the studies, paranormal believers could be sensitive to social information in two ways: at the perceptional level and at the top-down level of mentalizing.

Everyone does mentalize the non-mental, but what seems to set believers apart from skeptics is that this mentalizing is not taken as metaphorical, but as real. The ability to mentalize the non-mental probably has tremendous effects on people's ability to understand the surrounding world and their imagination and creativity. The author Terry Pratchett has written, "The truth may be out there, but the lies are inside your head." Maybe one important difference between believing and unbelieving lies in the ability to

not believe too literally the lies the mind sometimes produces when trying to make sense of the world, or, in the difference of not to taking these ideas too seriously.

6. References

Atran, S., & Norenzayan, A. (2004). Religion's evolutionary landscape: Counterintuition, commitment, compassion, communion. *Behavioral and Brain Sciences*, *27*, 713–730. doi:10.1017/S0140525X04000172.

Anderson, M. C., & Levy, B. J. (2009). Suppressing unwanted memories. *Current Directions in Psychological Science*, *18*, 189–194. doi:10.1111/j.1467-8721.2009.01634.x.

Anderson, M. C., Ochsner, K. N., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S. W., Glover, G. H., & Gabrieli, J. D. (2004). Neural systems underlying the suppression of unwanted memories. *Science*, *303*, 232–235. doi: 10.1126/science.1089504.

Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: The medial frontal cortex and social cognition. *Nature Reviews. Neuroscience, 7*, 268-277. doi:10.1038/nrn1884.

Aron, A. R. (2007). The neural basis of inhibition in cognitive control. *The Neuroscientist*, *13*, 214–228. doi: 10.1177/1073858407299288.

Aron, A. R. (2011). From reactive to proactive and selective control: developing a richer model for stopping inappropriate responses. *Biological Psychiatry*, *69*, e55–e68. doi. 10.1016/j.biopsych.2010.07.024.

Aron, A. R., Robbins, T. W. and Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 8,* 170–177. doi: 10.1016/j.tics.2004.02.010.

Bargh, J. A. (1989). Conditional Automaticity: Varieties of automatic influence in social perception and cognition. In J. S. Uleman & J. A. Bargh (eds.), *Unintended Thought* (pp. 3-51). New York, NY: Guilford.

Baron-Cohen, S. (1999). The evolution of a theory of mind. In M. Corballis & S. Lea (Eds.), *The Descent of Mind: Psychological Perspectives on Hominid Evolution* (pp. 261-277). Oxford: Oxford University Press.

Baron-Cohen, S., Knickmeyer, R. C., & Belmonte, M. K. (2005). Sex differences in the brain: Implications for explaining autism. *Science*, *310*, 819-823. doi:10.1126/science.1115455.

Barrett, J. l. (2000). Exploring the natural foundations of religion. *Trends in Cognitive Sciences, 4,* 29–34.doi: 10.1016/s1364-6613(99)01419-9.

Beck, J., & Forstmeier, W. (2007). Superstition and belief as inevitable by-products of an adaptive learning strategy. *Human Nature*, *18*, 35–46. doi:10.1007/BF02820845.

Bering, J. M. (2006). The folk psychology of souls. *The Behavioral and Brain Sciences, 29*, 453–498. doi:10.1017/S0140525X06009101.

Bering, J.M., & Bjorklund, D.F. (2004). The natural emergence of reasoning about the afterlife as a developmental regularity. *Developmental Psychology, 40*, 217–33. doi: 10.1037/0012-1649.40.2.217.

Blakemore, S. J. (2008). The social brain in adolescence. *Nature Reviews Neuroscience*, *9*, 267–277. doi:10.1038/nrn2353.

Bloom, P. (2004). *Descartes' baby: How the Science of Child Development Explains What Makes us Human*. New York, NY: Basic Books.

Bloom, P. (2007). Religion is natural. *Developmental Science*, *10*, 147–151. doi:10.1111/j.1467-7687.2007.00577.x.

Bloom, P., & Weisberg, D. S. (2007). Childhood origins of adult resistance to science. *Science*, *316*, 996–997. doi:10.1126/science.1133398.

Bonner, C., & Newell, B. R. (2010). In conflict with ourselves? An investigation of heuristic and analytic processes in decision making. *Memory & Cognition, 38,* 186–196. doi:10.3758/MC.38.2.186.

Bollen, K. A., & Stine, R. (1990). Direct and indirect effects: Classical and bootstrap estimates of variability. *Sociological Methodology, 20*, 115–140. doi:10.2307/271084.

Bouchard, T. J. (2004). Genetic influence on human psychological traits a survey. *Current Directions in Psychological Science*, *13*, 148–151. doi:10.1111/j.0963-7214.2004.00295.x.

Boyer, P. (2001). *Religion Explained. The Evolutionary Origins of Religious Thought.* New York: Basic Books.

Brugger, P., & Graves, R. E. (1997). Testing vs. believing hypotheses: Magical ideation in the judgment of contingencies. *Cognitive Neuropsychiatry, 2*, 251–272. doi:10.1080/135468097396370.

Button, K. S., Ioannidis, J. P., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S., & Munafò, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, *14*, 365–376. doi:10.1038/nrn3475.

Chwilla, D. J., & Kolk, H. H. (2005). Accessing world knowledge: evidence from N400 and reaction time priming. *Cognitive Brain Research*, *25*, 589–606. doi:10.1016/j.cogbrainres.2005.08.011.

Coulson S. 2011. Cognitive neuroscience of figurative language. In M. Spivey, M. Joanisse, K. McRrae (Eds.), *The Cambridge Handbook of Psycholinguistics*. London: Cambridge Univ. Press.

Crespi, B., & Badcock, C. (2008). Psychosis and autism as diametrical disorders of the social brain. *Behavioral and Brain Sciences*, *31*, 241–261. doi:10.1017/S0140525X08004214.

Demakis, G. J. (2003). A meta-analytic review of the sensitivity of the Wisconsin Card Sorting Test to frontal and lateralized frontal brain damage. *Neuropsychology, 17*, 255–264. doi:10.1037/0894-4105.17.2.255.

Demertzi, A., Liew, C., Ledoux, D., Bruno, M., Sharpe, M., & Laureys, S. (2009). Dualism persists in the science of mind. *Annals of the New York Academy of Sciences, 1157*, 1–9. doi:10.1111/j.1749-6632.2008.04117.x.

De Neys, W., Vartanian, O., & Goel, V. (2008). Smarter than we think when our brains detect that we are biased. *Psychological Science*, *19*, 483–489. doi:10.1111/j.1467-9280.2008.02113.x.

Egner, T. (2011). Right ventrolateral prefrontal cortex mediates individual differences in conflict-driven cognitive control. *Journal of cognitive neuroscience*, *23*, 3903–3913. doi:10.1162/jocn_a_00064.

Egner, T., & Hirsch, J. (2005). Cognitive control mechanisms resolve conflict through cortical amplification of task-relevant information. *Nature Neuroscience*, *8*, 1784–1790. doi:10.1038/nn1594.

Elk, M. V. (2013). Paranormal believers are more prone to illusory agency detection than skeptics. *Consciousness and cognition*, *22*, 1041–1046.doi:10.1016/j.concog.2013.07.004.

Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: A three-fact or theory of anthropomorphism. *Psychological Review, 114,* 864–88 6. doi:10.10 37/0033- 295X.114 .4.864.

Epstein, S. (2010). Demystifying intuition: What it is, what it does, and how it does it. *Psychological Inquiry*, *21*, 295–312. doi: 10.1080/1047840X.2010.523875.

Epstein, S., Pacini, R., Denes Raj, V, & Heier, H. (1996). Individual differences in intuitive-experiential and analytical-rational thinking styles. *Journal of Personality and Social Psychology, 71*, 390–405. doi:10.1037/0022-3514.71.2.390.

European Commission (2005). *Social values, Science and Technology. Special Eurobarometer*, *225*. TNS Opinion & Social.

Evans, J.S.B.T. (2008). Dual-processing accounts of reasoning, judgment and social cognition. *Annual Review of Psychology,59* , 255–78. doi:10.1146/annurev.psych.59.103006.093629.

Fahrenberg, J., & Cheetham, M. (2000). The mind-body problem as seen by students of different disciplines. *Journal of Consciousness Studies, 7,* 47–59.

Fahrenberg, J., & Cheetham, M. (2007). Assumptions about human nature and the impact of philosophical concepts on professional issues: A questionnaire-based study with 800 students from psychology, philosophy, and science. *Philosophy, Psychiatry, & Psychology, 14,* 183–201. doi:10.1353/ppp.0.0130.

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborns' preference for face-relevant stimuli: Effects of contrast polarity. *Proceedings of the National Academy of Sciences of the United States of America*, *102*, 17245-17250. doi:10.1073/pnas.0502205102.

Federmeier, K. D., Kluender, R., & Kutas, M. (2002). Aligning linguistic and brain views on language comprehension. *The Cognitive Electrophysiology of Mind and Brain*, 115–140.

French, C. C., & Wilson, K. (2007). Cognitive factors underlying paranormal beliefs and experiences. In S. Della Sala (Eds.), *Tall Tales about the Mind & Brain* (pp. 3–22). New York: Oxford University Press.

Friedman, N., Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of Experimental Psychology: General, 133*, 101–35. doi:10.1037/0096-3445.133.1.101.

Frith, U. (2001). Mind blindness and the brain in autism. *Neuron*, *32*, 969-979. doi:10.1016/S0896-6273(01)00552-9.

Frith, C. D., & Frith, U. (2006). How we predict what other people are going to do. *Brain Research, 1079*, 36–46. doi:10.1016/j.brainres.2005.12.126.

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 358*, 459–473. doi:10.1098/rstb.2002.1218.

Gobbini, I. M., Koralek, A. C., Bryan, R.E., Montgomery, K. J., & Haxby, J.V. (2007). Two takes on the social brain: A comparison of theory of mind tasks. *Journal of Cognitive Neuroscience, 19, 1803–1814.*

Fyfe, S., Williams, C., Mason, O. J., & Pickup, G. J. (2008). Apophenia, theory of mind and schizotypy: Perceiving meaning and intentionality in randomness. *Cortex*, *44*, 1316–1325. doi:10.1016/j.cortex.2007.07.009.

Gallup, 2005. Three in Four Americans Believe in Paranormal. Retrieved from http://www.gallup.com/poll/16915/three-four-americans-believe-paranormal.aspx#1.

Gervais, W. M., & Norenzayan, A. (2012). Analytic thinking promotes religious disbelief. *Science*, *336*, 493–496. doi:10.1126/science.1215647.

Gervais, W. M., Willard, A. K., Norenzayan, A., & Henrich, J. (2011). The Cultural Transmission of Faith: Why innate intuitions are necessary, but insufficient, to explain religious belief. *Religion*, *41*, 389–410. doi:10.1080/0048721X.2011.604510.

Giannotti, R. R., Mohr, C., Pizzagalli, D., Lehmann, D., & Brugger, P. (2001). Associative processing and paranormal belief. *Psychiatry and Clinical Neurosciences, 55*, 595–603. doi:10.1046/j.1440-1819.2001.00911.x.

Goel, V. (2007). Anatomy of deductive reasoning. *Trends in cognitive sciences*, *11*, 435–441. doi:10.1016/j.tics.2007.09.003.

Goel, V., & Dolan, R. J. (2003). Explaining modulation of reasoning by belief. *Cognition, 87*, 11-22.

Gray, K., Knickman, A. T., & Wegner, D. M. (2011). More dead than dead: Perceptions of persons in the persistent vegetative state. *Cognition, 121*, 275–280. doi:10.1016/j.cognition.2011.06.014.

Green, D., & Swets, J. A. (1966). *Signal Detection Theory and Psychophysics*. New York: Wiley.

Guthrie, S. (1993). *Faces in the Clouds*. New York: Oxford University Press.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. (2010). Ego depletion and the strength model of self-control: a meta-analysis. *Psychological Bulletin*, *136*, 495–525. doi:10.1037/a0019486.

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science*, *304*, 438–441. doi:10.1126/science.1095455.

Hampshire, A., Chamberlain, S. R., Monti, M. M., Duncan, J., & Owen, A. M. (2010). The role of the right inferior frontal gyrus: inhibition and attentional control. *Neuroimage*, *50*, 1313–1319. doi:10.1016/j.neuroimage.2009.12.109.

Hirschfeld, l. A., & Gelman, S. A. (Eds.). (1994). *Mapping the Mind: Domain Specificity in Cognition and Culture*. Cambridge: Cambridge University Press.

Hood, B. M. (2009). *SuperSense: From Superstition to Religion- the Brain Science of Belief*. London: Constable and Robinson.

Inagaki, K., & Hatano, G. (2004). Vitalistic causality in young children's naive biology. *Trends in cognitive sciences*, *8*, 356–362. doi:10.1016/j.tics.2004.06.004.

Irwin, H. J. (2009). *The psychology of paranormal. A researcher's handbook*. Hertfordshire: University of Hertfordshire Press.

Jarcho, J. M., Berkman, E. T., & Lieberman, M. D. (2011). The neural basis of rationalization: Cognitive dissonance reduction during decision-making. *Social Cognitive and Affective Neuroscience*, *6*, 460–467. doi:10.1093/scan/nsq054.

Kanazawa, S. (2010). Evolutionary psychology and intelligence research. *American Psychologist*, *65*, 279–289. doi:10.1037/a0019378.

Kapogiannis, D., Barbey, A. K., Su, M., Zamboni, G., Krueger, F., & Grafman, J. (2009). Cognitive and neural foundations of religious belief. *PNAS*, *106*, 3876–4881.

Keinan, G. (2002). The effects of stress and desire for control on superstitious behavior. *Personality and Social Psychology Bulletin*, *28*, 102–108.

Kelemen, D. (1999). Function, goals and intention: Children's teleological reasoning about objects. *Trends in Cognitive Sciences*, *3*, 461–468. doi:10.1016/S1364-6613(99)01402-3.

Kelemen, D. (2004). Are children "intuitive theists*"? Psychological Science, 15*, 295–301. doi:10.1111/j.0956-7976.2004.00672.x.

Kelemen, D., & Rosset, E. (2009). The Human function compunction: teleological explanation in adults. *Cognition, 111*, 138–143. doi:10.1016/j.cognition.2009.01.001.

Kendell, R. E. (2001). The Distinction between mental and physical illness. *The British Journal of Psychiatry, 178,* 490–493. doi:10.1192/bjp.178.6.490.

Keysar, B., Lin, S., & Barr, D. J. (2003). Limits on theory of mind use in adults. *Cognition*, *89*, 25–41. doi:10.1016/s0010-0277(03)00064-7.

King, L. A., Burton, C. M., Hicks, J. A., & Drigotas, S. M. (2007). Ghosts, UFOs, and magic: Positive affect and the experiential system. *Journal of Personality and Social Psychology 92*, 905–919. doi:10.1037/0022-3514.92.5.905.

Kriegeskorte, N., Simmons, W.K., Bellgowan, P.S.F.,& Baker, C. I. (2009). Circular analysis in systems neuroscience: the dangers of double dipping. *Nature Neuroscience, 12*, 535–540. doi:10.1038/nn.2303.

Krummenacher, P., Mohr, C., Haker, H., & Brugger, P. (2010). Dopamine, paranormal belief, and the detection of meaningful stimuli. *Journal of Cognitive Neuroscience, 22,* 1670–1681. doi:10.1162/jocn.2009.21313.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*, *62*, 621–647. doi:10.1146/annurev.psych.093008.131123.

Legare, C. H., & Gelman, S. A. (2008). Bewitchment, biology, or both: The co-existence of natural and supernatural explanatory frameworks across development. *Cognitive Science*, *32*, 607–642. doi:10.1080/03640210802066766.

Lindeman, M. (2011). Biases in intuitive reasoning and belief in complementary and alternative medicine. *Psychology & Health, 26*, 371–382. doi:10.1080/08870440903440707.

Lindeman, M. & Aarnio, K. (2006). Paranormal beliefs: Their dimensionality and correlates. *European Journal of Personality, 20,* 585–602. doi:10.1002/per.608.

Lindeman, M., & Aarnio, K. (2007). Superstitious, magical, and paranormal beliefs: An integrative model. Journal of Research in Personality, *41*, 731–744. doi: 10.1016/j.jrp.2006.06.009.

Lindeman, M., & Saher, M. (2007). Vitalism, purpose, and superstition. *British Journal of Psychology*, *98*, 33–44. doi:10.1348/000712606X101808.

Lindeman, M., & Svedholm, A. M. (2012a). What's in a term? Paranormal, superstitious, magical, and supernatural beliefs by any other name would mean the same. *Review of General Psychology, 16,* 241–255. doi:10.1037/a0027158.

Logothesis, N. K. (2008). What we can do and what we cannot do with fMRI. *Nature, 453,* 869–878.

Lustig, C., Hasher, L. and Zacks, R. (2007). Inhibitory deficit theory: Recent developments in a "new view". In Gorfein, D. S. and MacLeod, C. M. (Eds.), *Inhibition in cognition*, pp. 145–162. American Psychological Association, Washington, DC.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin*, *109*, 163–203. doi:10.1037/0033-2909.109.2.163.

MacLeod, C. M. (2005). The Stroop task in cognitive research. In A. Wenzel & D. C. Rubin (Eds.), *Cognitive Methods and Their Application to Clinical Research* (pp. 17–40). Washington, DC: American Psychological Association.

MacLeod, C.M. (2007). The concept of inhibition in cognition. In D. S. Gorfein, C. M. MacLeod, (Eds.), *Inhibition in Cognition (*pp. 3–23). Washington, DC: American Psychological Association.

Macmilan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide* (2nd Eds.). Mahwah New Jersey: Erlbaum.

Munakata, Y., Herd, S.A., Chatham, C.H., Depue, B. E., Banich M. T., & O'Reilly, R. C. (2011). A unified framework for inhibitory control. *Trends in Cognitive Sciences, 15,* 453–9. doi:10.1016/j.tics.2011.07.011.

Nemeroff, C., & Rozin, P. (2000). The makings of the magical mind: The nature of function of sympathetic magic. In K. S. Rosengren, C. N. Johnson & P. L. Harris (Eds.), *Imagining the impossible: Magical, Scientific, and Religious Thinking in Children* (pp. 1–34). New York: Cambridge University Press.

Nigg, J. (2000). On inhibition/disinhibition in developmental psychopathology: views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*, 220–46. doi:10.1037/0033-2909.126.2.220.

Norenzayan, A., & Hansen, I. G. (2006). Belief in supernatural agents in the face of death. *Personality and Social Psychology Bulletin*, *32*, 174–187.

Norenzayan, A., Gervais, W. M., & Trzesniewski, K. H. (2012). Mentalizing deficits constrain belief in a personal God. *PLoS ONE, 7*, *e36880*. doi:10.1371/journal.pone.0036880.

Osterhout, L., McLaughlin, J., & Bersick, M. (1997). Event-related brain potentials and human language. *Trends in Cognitive Sciences*, *1*, 203–209. doi:10.1016/S1364-6613(97)01073-5.

Piaget, J. (1929/1951). *The Child's Conception of the World*. London: Routledge & Kegan.

Pennycook, G., Cheyne, J. A., Seli, P., Koehler, D. J., & Fugelsang, J. A. (2012). Analytic cognitive style predicts religious and paranormal belief. *Cognition*, *123*, 335–346. doi:10.1016/j.cognition.2012.03.003.

Poldrack, R. A. (2006). Can cognitive processes be inferred from neuroimaging data?. *Trends in Cognitive Sciences*, *10*, 59–63. doi:10.1016/j.tics.2005.12.004.

Redick, T. S., Heitz, R. P., & Engle, R. W. (2007). Working memory capacity and inhibition: Cognitive and social consequences. In D. S. Gorfein & C. M. Macleod (Eds.), *Inhibition in cognition* (pp. 125–142). Washington: American Psychological Association.

Rogers, P., Davis, T., & Fisk, J. (2009). Paranormal belief and susceptibility to the conjunction fallacy. *Applied Cognitive Psychology*, *23*, 524–542. doi:10.1002/acp.1472.

Rozin, P., Millman, L., & Nemeroff, C. (1986). Operation of the laws of sympathetic magic in disgust and other domains. *Journal of Personality and Social Psychology, 50*, 703–712. doi:10.1037/0022-3514.50.4.703.

Sadler-Smith, E. (2011). The intuitive style: Relationship with local/global and verbal/visual styles, gender, and superstitious reasoning. *Learning and Individual Differences, 21*, 263–270. doi:10.1016/j.lindif.2010.11.013.

Saxe, R., Carey, S., & Kanwisher, N. (2004). Understanding other minds: Linking developmental psychology and functional neuroimaging. *Annual Review of Psychology*, *55*, 87–124. doi:10.1146/annurev.psych.55.090902.142044.

Schilbach, L., Eickhoff, S. B., Rotarska-Jagiela, A., Fink, G. R., & Vogeley, K. (2008). Minds at rest? Social cognition as the default mode of cognizing and its putative relationship to the "default system" of the brain. *Consciousness and Cognition*, *17*, 457–467. doi:10.1016/j.concog.2008.03.013.

Sharps, M. J., Matthews, J., & Asten, J. (2006). Cognition and belief in paranormal phenomena: Gestalt/feature-intensive processing theory and tendencies toward ADHD, depression, and dissociation. *The Journal of Psychology*, *140*, 579–590. doi:10.3200/JRLP.140.6.579-590.

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: new procedures and recommendations. *Psychological Methods, 7*, 422–445. doi:10.1037//1082-989X.7.4.422.

Sobel, M. E. (1982). Asymptotic intervals for indirect effects in structural equations models. In S. Leinhart (Eds.), *Sociological methodology 1982* (pp. 290–312). San Francisco, CA: Jossey-Bass. doi:10.2307/270723.

Spelke, E. S., & Kinzler, K. D. (2007). Core Knowledge. Developmental *Science, 10*, 89-96. doi:10.1111/j.1467-7687.2007.00569.x.

Stanovich, K. E. (1989). Implicit philosophies of mind: The dualism scale and its relation to religiosity and belief in extrasensory perception. *The Journal of Psychology, 123*, 5–23. doi:10.1080/00223980.1989.10542958.

Stanovich, K. E. (2009a). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory? In J. St. B. T. Evans & K. Frankish (Eds.), *In two minds. Dual Process and Beyond* (pp. 55–88). Oxford & NY: Oxford University press.

Stanovich, K. E. (2009b). *What intelligence tests miss. The Psychology of Rational Thought*. New Haven & London: Yale University Press.

Stanovich, K. E., & Toplak, K. (2012). Defining features versus incidental correlates of Type 1 and Type 2 processing. *Mind & Society, 11,* 3–13. doi:10.1007/s11299-011-0093-6.

Steinbeis, N., & Koelsch, S. (2009). Understanding the intentions behind man-made products elicits neural activity in areas dedicated to mental state attribution. *Cerebral Cortex*, *19*, 619–623. doi:10.1093/cercor/bhn110.

Stollstorff, M., Vartanian, O., & Goel, V. (2012). Levels of conflict in reasoning modulate right lateral prefrontal cortex. *Brain Research, 1428*, 24–32. doi:10.1016/j.brainres.2011.05.045.

Svedholm, A. M., & Lindeman, M. (2013). The separate roles of the reflective mind and involuntary inhibitory control in gatekeeping paranormal beliefs and the underlying intuitive confusions. *British Journal of Psychology*, *104*, 303–319. doi:10.1111/j.2044-8295.2012.02118.x.

Svedholm, A. M., & Lindeman, M. (2013). Healing, mental energy in the physics classroom: Energy conceptions and trust in complementary and alternative medicine in grade 10–12 students. *Science & Education*, *22*, doi:677-694. 10.1007/s11191-012-9529-6.

Svedholm, A. M., Lindeman, M., & Lipsanen, J. (2010). Believing in the purpose of events—why does it occur, and is it supernatural? *Applied Cognitive Psychology, 24,* 252–265. doi: 10.1002/acp.1560.

Tarkkonen, l., & Vehkalahti, K. (2005). Measurement errors in multivariate measurement scales. *Journal of Multivariate Analysis, 96*, 172–189. doi:10.1016/j.jmva.2004.09.007.

Thalbourne, M. A. (1996). Belief in life after death: Psychological origins and influences. *Personality and Individual Differences, 21*, 1043–1045. doi:10.1016/s0191-8869(96)00167-5.

Tieteen tiedotus ry (2013). Tiedebarometri 2013. Porvoo: Kirjapaino Uusimaa.

Tobacyk, J. J. (2004). A revised paranormal belief scale. *The International Journal of Transpersonal Studies, 23*, 94–98.

Tobacyk, J.J., & Milford, G. (1983). Belief in paranormal phenomena: Assessment instrument development and implications for personality functioning. *Journal of Personality and Social Psychology*, *44*, 1029–1037. doi.10.1037/0022-3514.44.5.1029.

Tobacyk, J. J., & Pirttilä-Backman, A. M. (1992). Paranormal beliefs and their implications in university students from Finland and the United States. *Journal of Cross-Cultural Psychology*, *23*, 59–71. doi:10.1177/0022022192231004.

Tooby, J., & Cosmides, L. (1990). On the universality of human nature and the uniqueness of the individual: The role of genetics and adaptation. *Journal of Personality*, *58*, 17–67. doi:10.1111/j.1467-6494.1990.tb00907.x.

Tsujii, T., Masuda, S., Akiyama, T., & Watanabe, S. (2010). The role of inferior frontal cortex in belief-bias reasoning: an rTMS study. *Neuropsychologia*, *48*, 2005–2008. doi:10.1016/j.neuropsychologia.2010.03.021.

Tylén, K., Wallentin, M., & Roepstorff, A. (2009). Say it with flowers! An fMRI study of object mediated communication. *Brain and Language*, *108*, 159–166.doi: 10.1016/j.bandl.2008.07.002.

Van Overwalle, F., & Baetens, K. (2009). Understanding others' actions and goals by mirror and mentalizing systems: A meta-analysis. *Neuroimage*, *3*, 564–584. doi:10.1016/j.neuroimage.2009.06.009.

Vyse, S. A. (2014). *Believing in Magic*. The Psychology of Superstition. New York: Oxford University Press.

Wellman, H M., & Gelman, S. A. (1998). Knowledge acquisition in foundational domains. In D. Kuhn & R. S. Siegler (eds.), *Handbook of Child Psychology. Cognition, Perception, and Language* (2nd ed., pp. 523–573). New York, NY: Wiley.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory of mind development: the truth about false belief. *Child Development*, *72*, 655–684. doi:10.1111/1467-8624.00304.

Wilkowski, B. M., & Robinson, M. D. (2007). Keeping one's cool: trait anger, hostile thoughts, and the recruitment of limited capacity control. *Personality and Social Psychology Bulletin, 33*, 1201–1213. doi:10.1177/0146167207301031.

Wiseman, R., Watt, C. (2006). Belief in psychic ability and the misattribution hypothesis: a qualitative review. *British Journal of Psychology, 97*,323–38. doi:10.1348/000712605X72523.