Sensing supernatural agency

An empirical quest on the socio-cognitive foundations of supernatural beliefs

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Being a supernatural believer (i.e., believing in culturally specific unverifiable beliefs about non-physical phenomena) can be a costly venture, in terms of time, money and resources. Some fanatic believers are even willing to give up their lives for their faith. So, how come, tens of thousands of years ago, groups of people independently started to hold supernatural beliefs and why do at least 80% of the people still believe in the supernatural today? This question has triggered many philosophers and scholars and it has resulted in niches of academic fields with their own theories and flagship journals that are centered around this sole research question. The past four years, my aim was to stand on the shoulders of these giants by empirically testing several of their influential hypotheses. This quest into the socio-cognitive foundations of supernatural beliefs has resulted in the dissertation you are holding.

David L. R. Maij

Sensingsuper natural agency

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SENSING SUPERNATURAL AGENCY

An empirical quest on the socio-cognitive foundations

of supernatural beliefs

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Faculteit Maatschappij- en Gedragswetenschappen

“Religion is a culture of faith; science is a culture of doubt.”

— Richard Feynman

CONTENTS

APPENDIX

Chapter 1

GENERAL INTRODUCTION

Being a supernatural believer (we will define this below) can be a costly venture, in terms of time, money and resources. More than 40.000 years ago primitive Homo sapiens already sacrificed valuable belongings such as food or their spouse to supernatural beings (Hubert & Mauss, 1964). During medieval times, scholars estimated, it would take around 150 years to build a gothic church, which could take up more than 20% of the regional economy while around two- to three hundred labourers were present daily at the building site (Denning, 2012). Even in the twenty-first century, some fanatic believers are willing to give up their lives for their faith by blowing up themselves – while forcing others to go along with them. These observations seem to contradict Darwinian laws, as they appear to make it harder for our species to pass on their genes. Nevertheless, supernatural beliefs have been traced back to the earliest Homo Sapiens (Trinkaus & Shipman, 1993), supernatural beliefs were universal among hunter gathers (Rappaport, 1999) and a decade ago at least 80% of the world population believed in some form supernaturalism (Zuckerman, 2007). Why do so many people believe in the supernatural? This question has triggered many philosophers (see for reviews, Meister, 2015; Thrower, 1980; Whitmarsh, 2016) and scholars (see for a review Guthrie et al., 1980) and it has resulted in niches of academic fields with their own theories and flagship journals (e.g., Religion; The International Journal of the Psychology Religion; Religion, Brain and Behaviour; Journal for the Cognitive Science of Religion; Journal for the Scientific Study of Religion) that are centred around this sole research question. The past four years, our (i.e., my supervisors and I) aim was to stand on the shoulders of these giants by empirically testing several of their influential hypotheses. This quest into the socio-cognitive foundations of supernatural beliefs has resulted in the dissertation you are holding.

In this dissertation, we hinge on an ethnocentric and Western conception of supernatural beliefs - similarly as the scholars whose theories we tested (see for example Norenzayan's 'Big God's', 2013). We define supernatural (Latin: *supranaturalis*) beliefs as all entities or events entailed by those beliefs that supposedly exist beyond (*supra*) nature (*naturalis*)[1]. They are culturally specific, unverifiable beliefs about non-physical phenomena that do not coincide with the current naturalistic worldview, and are therefore invisible, intangible, and immeasurable. We try to refrain from using the term ‘religion’ (apart from Chapter 6) as religions have appeared relatively recently (Baumard & Boyer, 2015; Boyer, 2003; Norenzayan, 2013), while we are interested in the more fundamental general foundations of supernatural beliefs. Answers to the ‘why do people believe in the supernatural’ question have been proposed by scholars from different academic disciplines such as philosophers (see for a review Meister, 2015), anthropologists (e.g., Guthrie et al., 1980), biologists (e.g., Dawkins, 2016) and psychologists (e.g., Barrett, 2000). Ultimately, for a thorough understanding of the answer to this question, explanations from all disciplines contribute at different levels and should be empirically tested. Coming from an experimental psychological background, we zoomed in on specific theories that relate to the psychological domain.

Psychologists interested in the domain of supernatural beliefs have mainly contributed to two fields. In the field of the Psychology of Religion, psychological theories emphasize motivations of the individual. For example, it has been argued that faith provides psychological security against high amounts of anxiety such as fear of death (i.e., terror-management theory, Greenberg, Solomon, & Pyszczynski, 1997) or low feelings of control (i.e., compensatory control, Kay, Gaucher, Napier, Callan, & Laurin, 2008; Kay, Whitson, Gaucher, & Galinsky, 2009; Proulx, Inzlicht, & Harmon-Jones, 2012). In the main field of interest in the present dissertation, called the ‘Cognitive Science of Religion’ (from here on CSR), scholars from different disciplines start from an evolutionary perspective and focus on the more socio-cognitive foundations of supernatural beliefs (Xygalatas, 2014). The theories of the CSR can be broadly distinguished in theories in which supernatural beliefs are

[1] Guthrie (commentary on Andersen), and others (see Guthrie) have criticized the term ‘supernatural beliefs’ for being too vague. According to them, mermaids and atoms might also be considered supernatural. By our definition, however, mermaids or martians are not supernatural, as they refer to physical entities. Atomic particles and forces are not supernatural because they are measurable, albeit indirectly.

considered as evolved adaption or as by-product (Pyysiäinen & Hauser, 2010; Sosis, 2009).

In theories relating to the evolved adaptation account, the main idea is that supernatural beliefs may have formed in response to social stressors such as cooperation problems (Pyysiäinen & Hauser, 2010). In larger groups of people, cooperation problems likely emerged. Hunter-gatherers had to cooperate together to prevent that predators ate them and to be able to catch large prey. Groups of supernatural believers may have had a higher chance of surviving (and passing on their genes through cultural selection) by increasing in-group cooperation through supernaturalistic rituals (Fischer et al., 2014; Xygalatas, Mitkidis et al., 2013), or by believing that they would be punished by a supernatural deity if they did not behave in according with the moral rules of the deity (Boyd & Richerson, 1992).

In theories relating to the by-product account, on which we mostly focus in the present dissertation (i.e., Chapters 2, 3, 4, 6 and A1), the main idea is that supernatural beliefs are a side effect of a set of adaptive cognitive functions[2]. In other words, some evolutionary useful cognitive functions, such as the ability to internally represent imagery (e.g., visualizing a dangerous predator), indirectly also made it possible to visualise supernatural agents (e.g., the God of thunder). A combination of several of such cognitive functions could account for a specific supernatural belief (e.g., thunder is caused by an angry supernatural agent), while a combination of other cognitive functions could account for another supernatural belief (e.g., this highly coincidental event must have been caused by a supernatural force). This means that by-product theories involve theories about functions that are necessary for supernatural beliefs, but alone may be insufficient to explain it. For example, to interact with God (i.e., praying) you need cognitive functions related to imagery, theory of mind, internal speech and so forth. By-product theories have also been named 'naturalness' theories (Boyer, 1994), as they may be understood as the 'natural product of aggregated ordinary cognitive functions' (Barrett, 2000, p.29). In essence, by-product theories hold that there is nothing 'special' about supernatural

[2] In contrast to the adaptation view, supernatural beliefs were not originally selected for to increase cooperation, but once all cognitive functions were in place, it could be selected for.

beliefs, and that they can be explained by cognitive functions like any other cultural system (Geertz, 2010; Geertz & Markússon, 2010).

The necessity of testing socio-cognitive theories of supernatural beliefs

Within the by-product account, scholars have marked several cognitive functions that may have been especially thriving for encouraging supernatural beliefs. In the CSR, the most frequently mentioned are teleology, mind-body dualism, the hypersensitive agency detection device and mentalizing (Norenzayan & Gervais, 2013). Teleology refers to people's natural cognitive tendency to infer that events and objects exist for a purpose (Kelemen, 2003; Kelemen & Rosset, 2009; Kelemen, 2004). Young children, for example, often think that clouds are for making rain and that birds are for flying (Kelemen, 1999). Also to adults, sentences such as "The sun makes light so that plants can photosynthesize", or "Water condenses to moisten the air" seem intuitive. Especially in speeded-judgements task (Kelemen & Rosset, 2009), whereby participants quickly have to judge the correctness of the sentence. These outcomes are used to illustrate that people have a bias towards teleological reasoning and that this encourages people's belief of purposefully designed phenomena in the world (i.e., creation and intelligent design, Evans, 2001).

One concern we have with the outcomes of teleological reasoning studies is to what extent the results are just a semantic issue. Could it be that teleological reasoning (or teleological language for that matter) is just a human heuristic to explain concepts in the easiest form? Does it necessarily imply that people believe their teleological statements are true? And to what extent is teleological reasoning at all related to supernatural beliefs? Empirically testing the assumptions of teleological reasoning was beyond the scope of this dissertation. This example nevertheless illustrates the necessity of empirically testing theories that have been put forward by scholars of the CSR that have attracted considerable amounts of research interest (i.e., Kelemen's articles on teleological reasoning and supernatural beliefs have been cited thousands of times). In a similar fashion, we raised questions for the hypersensitive agency detection device (see Chapters 2, 3 and 4) and mentalizing (see Chapter 6). We set out to experimentally test these, so we will discuss these in more detail[3].

The Hypersensitive Agency Detection Device

The hypersensitive agency detection device (HADD from here on) is a hypothesized cognitive mechanism that responds over-actively to ambiguous information that could potentially signal the presence of other agents such as other humans, animals or creatures (Barrett, 2000; Barrett & Burdett, 2011; Guthrie, 1993). For instance, the sound of a branch breaking in a dark forest could potentially trigger the HADD, causing the false perception of an agent (e.g., "There's a bear"). Having a sensitive cognitive mechanism that infers the presence of agents while the presence of agents has not yet been confirmed by sensory input, is evolutionary advantageous. It allows organisms to prepare a fight or flight response before other organisms have been encountered, and quickly detecting other organisms (i.e., predator and prey) is often vital to survive. Probably, at least all mammals have some form of a HADD. To illustrate, when a dog starts barking due to noise caused by wind, it is likely that the dog inferred the sound as indicating the presence of some other agent. In humans, the same process of interpreting events as being caused by agents could encourage people's belief that some events are caused by supernatural agents (e.g., Barrett, 2000). For example, flickering lights can be interpreted as being caused by a deceased relative.

There are certainly other cognitive functions than the HADD that could explain why people from so many different cultures interpret a wide range of phenomena as being caused by deceased ancestors. It could be the result of pattern detection (e.g., Valdesolo & Graham, 2014), anthropomorphisation (e.g., Guthrie, 1993), a causal reasoning bias (e.g., Scholl & Tremoulet, 2000), teleological reasoning (e.g., Kelemen, 2004), attachment theory (e.g., Kirkpatrick & Shaver, 1990), predictive coding (e.g., Andersen, 2017, and see Chapter A1) or a combination of these. We still thought investigating the HADD was a worthwhile venture. First, apart from its supposed relationship with supernatural beliefs, it had not yet been

[3] Michiel van Elk received a NWO Veni grant to experimentally test theories put forth by the CSR that attracted a lot of research interest but were relatively unexplored.

investigated whether humans indeed have a bias towards detecting intentional agents[4]. Second, despite the fact that the supposed encouraging influence of the HADD on supernatural beliefs has been one of the most influential theories in the CSR (Atran & Norenzayan, 2004; Barrett, 2000; Barrett, 2004; Barrett & Lanman, 2008; Nola, 2014; Norenzayan, 2013; Norenzayan, 2016), only few researchers set out to experimentally test the relationship (e.g., van Elk, Rutjens, van der Pligt, & van Harreveld, 2014; van Elk, 2013).

Let's start with the notion that the HADD by itself is worth of investigation. Is it plausible that a cognitive bias to interpret agency evolved? According to proponents of the error management theory, cognitive biases can evolve if they have higher fitness than organisms that are weakly biased, especially if there is a strong imbalance between the costs and benefits for specific decisions (Haselton & Nettle, 2006; Johnson, Blumstein, Fowler, & Haselton, 2013). In case of the HADD, failing to detect the presence of another agent in a threatening situation (e.g., a dark and scary forest) is costlier (e.g., an agent can kill you) than incorrectly assuming the presence of another agent for which the potential costs are relatively small (e.g., you waste energy). Thus, although it makes sense from an error-management perspective that threat intensifies the sensitivity of the HADD (Barrett, 2010), this specific hypothesis has so far not been directly tested. Some preliminary findings suggest that we may indeed have a bias towards detecting agency and that this bias is related to threat. For example, babies quickly associate snakes with fear (DeLoache & LoBue, 2009) and look longer to pictures of spiders than to reconfigured and distorted images of these spiders (Rakison & Derringer, 2008). Five and six-year-old children in cities are afraid of monsters with claws, while they are initially unafraid of urban threats (Maurer, 1965; Boyer & Bergstrom, 2011). However, in a series of experiments consisting of biological motion (i.e., detecting whether an agent is embedded within a varying number of randomly moving point lights) and face-house categorization tasks (i.e., detecting whether an agent is present in a picture that consists of a varying degree of a house or face) no general response bias towards agents was observed (van Elk et al., 2014). Thus, the implicit

[4] The aims in all are articles were always two-folded. First, the topic of interest had to be relevant for science by itself. Second, the topic of interest had to relate to foundations of supernatural beliefs.

assumption of the HADD that people have a bias towards detecting intentional agents has yet to be confirmed, and presenting participants with a threatening situation while investigating the effects on agency detection would be a critical test.

The second reason why the HADD warranted experimental investigation was the sheer volume of theoretical papers written on the relationship between the HADD and supernatural beliefs[5] (e.g., Barrett, 2012; Barrett, 2000; Barrett & Lanman, 2008; Barrett & Burdett, 2011; Bertolotti & Magnani, 2010; Bloom, 2007; Green, 2015; McKay & Whitehouse, 2015; Nola, 2014; Norenzayan, Hansen, & Cady, 2008; Petrican & Burris, 2012). The appealingness of the theory lies probably in the fact that it extends Guthrie's (1980) antropomorphisation account of supernatural beliefs, which is considered the first cognitive framework with which supernatural beliefs were explained. Guthrie proposed that due to the importance of humans in our lives, we take the human model as a default and as a result we easily incorrectly infer the presence of humanness (i.e., humans, human minds and human language). For example, thousands of years ago when thunder stroke, people attributed this to an angry supernatural humanlike agent - Wodan, Zeus, and Indra, are all Gods of thunder. Barrett generalized Guthrie's relatively human-centred antropomorphisation theory of religion towards the inference of intentional agents in general.

To sum up, HADD theorizing has been influential in the CSR and we set out to experimentally test two of its assumptions. The first assumption is that people have a bias towards inferring the presence of intentional agents – especially in threatening situations. The second assumption is that there is a relationship between agency detection and supernatural beliefs. In Chapter 2, we manipulated threat in three different ways (i.e., pictures, music and virtual reality). We investigated whether people generally have a bias to infer the presence of agency with different operationalizations of agency detection (i.e., The Biological Motion Task, an Auditory Agency Detection Task and a Geometrical Figures Task), and whether threat increased agency detection. In the pre-registered Chapter 3, we manipulated threat by means of a more ecologically valid virtual reality forest

[5] Barrett and Burdett (2011) even called upon psychologists to start experimentally investigating the relationship: "Psychologists, CSR needs you." (pp. 255)

through which participants physically walked (a scary forest compared to a neutral forest), by means of music (ambient horror music compared to meditating music) and by means of the pre-experimental context (i.e., watching a horror or neutral movie). In both studies, we also investigated whether individual differences in supernatural beliefs were related to agency detection. In Chapter 4, we wanted to investigate the supposed bidirectional relationship between agency detection on the one hand and supernatural beliefs and experiences on the other hand (Barrett & Lanman, 2008), by more thoroughly manipulating supernatural beliefs. To be able to do that, we first had to devise a manipulation that increases supernatural beliefs or experiences in the lab. Before we turn to this manipulation, we will first discuss the other cognitive bias we investigated: mentalizing.

Mentalizing

Closely linked to the HADD is the ability to mentalize (Barrett & Lanman, 2008). According to Barrett and Lanman (2008), people first detect agency with the HADD and then the ability to mentalize causes people to attribute intentions to the agent. Thus, mentalizing, or theory of mind reasoning, is the ability to attribute intentions and beliefs to other minds. For example, interpreting that your father is angry when he slams the door. Mentalizing is thought to be the most important cognitive mechanism underlying supernatural beliefs (e.g., Atran, 2002; Barrett, 2012; Barrett, 2000; Bering, 2002a; Bering, 2002b; Bering, 2006; Bloom, 2007; Boyer, 2003; Geertz, 2010; Gervais, 2013; Jong, 2013; McCauley, 2011; Norenzayan, Gervais, & Trzesniewski, 2012; Norenzayan et al., 2014; Willard & Norenzayan, 2013). The logic behind this prevailing hypothesis is that belief in a mind or belief in a supernatural agent's mind is processed by the same cognitive mechanism (Gervais, 2013), like thinking that God is angry because something bad happened to you. In addition, over-mentalizing might result in attribution of intentions to inappropriate domains (e.g., Bering, 2002a, for example ascribing supernatural intentions to thunder). Furthermore, mentalizing abilities have also been thought to underlie other cognitive biases that have been marked as important encouragers for supernatural beliefs (i.e., HADD, teleological reasoining, dualism and anthropomorphism, Banerjee & Bloom, 2013; Barrett & Lanman, 2008; Norenzayan, 2016; Willard & Norenzayan, 2013).

In contrast to the HADD, numerous research efforts have been undertaken to investigate mentalizing capacities and its relationship with supernatural beliefs, both in correlational questionnaire studies (Jack, Friedman, Boyatzis, & Taylor, 2016; Riekki, Lindeman, & Raij, 2014; Willard & Norenzayan, 2013), as well as neuroimaging studies (Epley, Converse, Delbosc, Monteleone, & Cacioppo, 2009; Kapogiannis et al., 2009; Neubauer, 2014; Riekki et al., 2014; Schjoedt, Stodkilde-Jorgensen, Geertz, & Roepstorff, 2009). An underlying assumption in most of these studies was that if mentalizing abilities encouraged supernatural beliefs, then higher mentalizing abilities should be positively related to supernatural beliefs. What follows from this assumption is that people who are known to have reduced mentalizing abilities (i.e., people with autism) should have reduced supernatural beliefs (Atran & Norenzayan, 2004; Bering, 2002a; Bloom, 2007; Deeley, 2004; Deeley, 2009; McCauley, 2011) and this has indeed been observed (Caldwell-Harris, Murphy, Velazquez, & McNamara, 2011; Norenzayan et al., 2012).

The assumption of a causal relationship between mentalizing abilities and supernatural beliefs is, however, questionable. The fact that the same cognitive mechanism is recruited when you try to understand your father's intentions as when trying to understand God's intentions does not necessarily imply that increased mentalizing abilities result in increased supernatural beliefs. To test whether mentalizing abilities increase supernatural beliefs, we investigated the relationship between different operationalizations of mentalizing abilities (i.e., the Empathy Quotient, the Autism Quotient and the Geometrical Figures Task) and supernatural beliefs in three different countries with over 67.000 participants in a pre-registered study (i.e., Chapter 6). We also conducted a direct replication of a study of Norenzayan and colleagues (2012), who observed a negative relationship between autism and supernatural beliefs, by comparing adolescents from a high school with children with high functioning autism and a high school with neurotypical adolescents.

Finally, we wanted to compare the relative importance of mentalizing for supernatural beliefs with a socio-cultural factor of supernatural beliefs, namely, the extent to which people observed credible acts (i.e., credibility enhancing displays or CREDs) for the existence of a supernatural realm during their upbringing (Gervais & Najle, 2015; Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017). The idea behind CREDs is intuitive and relates to social learning theory (e.g., Bandura & McDonald, 1963). If parents or caretakers act in according to what they believe, they are credible sources and their beliefs are more likely to be transmitted to their children. For example, if they say they believe in God, while also praying and frequently visiting church, their actions converge with their beliefs. If, however, they say they believe in God, while fighting, swearing, drinking or visiting prostitutes, their actions disperse from their beliefs, thereby decreasing the likelihood that beliefs are transmitted. Thus, CREDs provide a comprehensive proximal sociocultural explanation for the emergence of both theism and atheism. Supportive preliminary data for the theory of CREDs were presented (Gervais & Najle, 2015; Lanman & Buhrmester, 2017) while we were conducting our study. However, a direct comparison with cognitive biases, which provide an ultimate explanation for the emergence of supernatural beliefs, was still missing (see Chapter 4).

Manipulating Supernatural Beliefs and Experiences

As explained previously, we wanted to manipulate supernatural beliefs and experiences, in order to investigate the bidirectional relationship between supernatural beliefs and agency detection. Problematically, supernatural beliefs are fairly robust traits of individuals, so they cannot be easily pushed around in lab settings. Often, scholars from the CSR have used 'priming' techniques: exposing participants to religious concepts so that these were more strongly cognitively available. However, the effects of priming on behaviour have been heavily criticized (e.g., Bower, 2012; Kahneman, 2012) and meta-analyses showed that if priming of supernatural concepts works at all, it likely only influences people who already believe (Shariff, Willard, Andersen, & Norenzayan, 2016; Van Elk et al., 2015). Other techniques to manipulate supernatural beliefs have been pursued, such as extreme rituals (e.g., Xygalatas, Schjoedt et al., 2013) and magic tricks (Benassi, Singer, & Reynolds, 1980), although the use of mind-altering substances (Griffiths, Richards, McCann, & Jesse, 2006; Griffiths, Richards, Johnson, McCann, & Jesse, 2008; Griffiths et al., 2011; Pahnke & Richards, 1966) is definitely the most convincing. Naturally, such a method leads to ethical concerns, let alone practical problems: “It is a response box you are holding, not a keyboard”.

Placebo brain stimulation

A potential alternative resulted from an initially failed replication. Granqvist (2005) tried to replicate a now controversial effect of Persinger and colleagues (Cook & Persinger, 1997; Persinger, 1993; Persinger, Tiller, & Koren, 2000), who claimed to be able to elicit extraordinary experiences by means of a brain stimulation device placed in a helmet (it was termed the ‘God Helmet’ by popular media). In a double blind randomized controlled trial, participants in both a helmet on and helmet off condition reported extraordinary experiences, such as the feeling of a presence and out-of-body experiences. These observations suggested that the God Helmet could potentially be used to investigate extraordinary experiences and their consequences in a non-invasive laboratory setting (Andersen, Schjoedt, Nielbo, & Sørensen, 2014). In a small, correlational, proof of concept study, Andersen et al. (2014) found that this was indeed the case. Participants reported a wide range of extraordinary experiences while they were wearing a transformed scooter helmet that was not attached to electrical current by any means.

We followed through on the study of Andersen et al. (2014) to investigate whether we could use the God helmet manipulation as a way to manipulate supernatural beliefs, while investigating the downstream consequences on agency detection. First, we wanted to establish whether we could replicate the effects. Therefore, in Chapter 4, we used placebo brain stimulation in both a within- and between-subjects design. To investigate what caused the effects, we looked into the role of expectancy effects (by presenting a helmet on and helmet off condition), suggestibility (by means of the Tellegen Absorption Scale), demand characteristics (by means of a White Christmas Task, in which participants have to press a button when they hear Bing Crosby’s ‘White Christmas’ while they are in fact listening to white noise) and individual differences in supernatural beliefs. We indeed established that placebo brain stimulation is capable of eliciting authentic extraordinary experiences in a minority of the participants through manipulating participants' expectancies, while controlling for suggestibility and demand characteristics. We also investigated whether the extraordinary experiences resulted in increased agency detection. This follows from Barrett and Lanman (2008), who propositioned that the HADD, extraordinary experiences and discourse about the supernatural mutually reinforce supernatural beliefs. Thus, we expected that by manipulating an extraordinary experience, people would be more inclined to perceive agency.

Although the results of Chapter 4 were promising in the sense that a substantial amount of participants reported authentic extraordinary experiences, the majority of the participants did not report them. Especially people who were already supernatural believers (Andersen et al., 2014; Granqvist & Larsson, 2006), or who get easily immersed in internal processes (see Chapter 4) seemed susceptive to the placebo brain stimulation. In the pre-registered Chapter 5, we wanted to investigate whether people intoxicated with alcohol were more susceptible to the placebo brain stimulation manipulation. There were several reasons why we expected this. First of all, alcohol is frequently used in ‘supernatural’ ritualistic settings (Dietler, 2006; Royce, 1985). It has already been hypothesized more than a century ago that the role of alcohol in such settings is to facilitate extraordinary experiences (James, 1902; Smith, 1964), but it has never been tested. This is all the more interesting because the spread of reports of extraordinary experiences throughout tribes is likely to be an enhancer of supernatural beliefs (Blackmore, 1999; Hardy, 1979; James, 1902). Second, alcohol has been found to increase people’s suggestibility (Dienes et al., 2009; Van Oorsouw, Merckelbach, & Smeets, 2015). Third, alcohol decreases executive functioning (Zoethout, Delgado, Ippel, Dahan, & van Gerven, 2011) and decreased executive functioning has been related to increased suggestibility (see for a review Parris, 2016). The tricky part was to get ethical approval to intoxicate people with alcohol. To circumvent this problem, we conducted the study out in the field, at Lowlands festival (a Dutch popular music festival), where participants had already intoxicated themselves.

In short

To summarize; the aim of the PhD-project was to test assumptions of cognitive biases supposedly underlying supernatural beliefs that received a lot of interest in the CSR literature. In Chapter 2, we investigated in six experiments whether people have a bias towards interpreting events as the actions of intentional agents, whether this was increased by ambiguous and threatening situations, and whether agency detection was related to supernatural beliefs. In Chapter 3, we pursued the same goal as in Chapter 2. However, we increased the ecological validity by letting people physically walk through a virtual reality forest in four different experiments. In Chapter 4, we wanted to investigate the relationship between agency detection and supernatural beliefs, by explicitly manipulating supernatural beliefs by means of placebo brain stimulation. In Chapter 5, we tried to find out whether the placebo brain stimulation was more effective when people were intoxicated by alcohol. In Chapter 6, we tested the most endorsed cognitive bias and compared its relative importance to that of a social cultural factor (i.e., CREDs). In Chapter 7, we place all chapters in perspective.

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Chapter 2

THE BOUNDARY CONDITIONS OF THE HYPERSENSITIVE AGENCY DETECTION DEVICE

An empirical investigation of agency detection in threatening situations

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Abstract

It has been hypothesized that humans have evolved a hypersensitivity to detect intentional agents at a perceptual level, as failing to detect these agents may potentially be more harmful than incorrectly assuming that agents are absent. Following this logic, ambiguous threatening situations should lead people to falsely detect the presence of agents. In six threat-inducing experiments (N = 233) we have investigated whether threat-induction increases agent detection. We operationalized human agent detection by means of a Biological Motion Detection Task (Experiments 1 and 2) and an Auditory Agent Detection Task (Experiment 4). Intentionality detection was operationalized by means of a Geometrical Figures Task (Experiment 3). Threat manipulations that were either weak (threatening pictures, classical horror music) or moderate (virtual reality) did not increase false human agent or intentionality detection. Moreover, participants generally had a response bias towards assuming that agents were absent (Experiment 1a, 1b, 2a, 2b, and 4). Further, agent and intentionality detection measures were unrelated to individual differences in supernatural beliefs, although they were related to the negativity bias. This study reveals the boundary conditions under which the agent and intentionality detection is not intensified and provides recommendations for future research.

A common feature shared across many supernatural beliefs is the belief in supernatural agents (e.g., souls, spirits, gods; Pyysiainen, 2009). By belief in the supernatural (Latin*: supranaturalis*), we refer to all of the entities or events entailed by those beliefs that supposedly exist beyond (*supra*) nature (*naturalis*). They are culturally specific, unverifiable beliefs about non-physical phenomena that do not coincide with a naturalistic worldview, and are therefore invisible, intangible and immeasurable. Scholars within the cognitive science of religion (i.e., the research niche that investigates the [neuro-] cognitive foundations of supernatural beliefs; e.g., Barrett & Burdett, 2011; Xygalatas, 2014) have proposed that belief in supernatural agents may have its basis in evolutionarily-evolved cognitive biases (Barrett, 2000; Barrett & Burdett, 2011; Guthrie, 1993; Johnson, 2009; and for a review of biases see: Norenzayan & Gervais, 2013). One of these biases that has generated a considerable amount of research interest is the *hypersensitive agency detection device* (i.e., HADD, e.g., Barrett, 2000; Barrett, 2012; Barrett & Lanman, 2008; Bertolotti & Magnani, 2010; Bloom, 2007; Green, 2015; McKay & Whitehouse, 2015; Nieuwboer, van Schie, & Wigboldus, 2014; Nola, 2014; Norenzayan, Hansen, & Cady, 2008; Petrican & Burris, 2012; Riekki, Lindeman, & Raij, 2014; van Elk, Rutjens, van der Pligt, & van Harreveld, 2014; van Elk, 2013) – a hair-triggering device that responds over-actively in response to ambiguous information that could potentially signal the presence of other agents such as other humans or animals (Barrett, 2000; Barrett & Burdett, 2011). For instance, the sound of a branch breaking in a dark forest could potentially trigger the HADD, causing the false perception of an agent.

The HADD can be considered a specific instance of the error management theory (Johnson, 2009; Nola, 2014), which is an attempt to explain biases from an evolutionary perspective (Haselton & Nettle, 2006; Johnson, Blumstein, Fowler, & Haselton, 2013). This theory builds on the logic of Pascal's Wager argument (i.e., bet), who reasoned that people should logically live their lives as if God exists. He argued that the potential costs are much greater if you live a Godless life and God exists (i.e., you might end up in hell) than if you live a moral life and God does not exist. In addition, error-management builds on signal detection principles (Green & Swets, 1966). The main idea is that strongly biased systems have higher fitness than weakly biased ones, especially if there is an imbalance between the costs and benefits of specific decisions. For instance, when decisions have to be made regarding the presence or absence of a possible agent, two possible errors can occur: a false alarm (i.e., false agent detection when an agent is absent) and a false negative (i.e., failure to detect an agent that is present). Usually the costs of these two errors are asymmetrical and over many years of natural selection a bias for the least costly error has developed (Guthrie et al., 1980; Guthrie, 1993; Haselton & Nettle, 2006). In case of the HADD, failing to detect the presence of another agent in a threatening situation (e.g., a dark and scary forest) is often more costly (e.g., an agent can kill you) than incorrectly assuming the presence of another agent for which the potential costs are relatively small (e.g., you waste energy).

Crucially for the present study, although it could be argued that threat is not a necessary component to elicit agent detection (e.g., people believing that agents are behind crop circles), threat is central to HADD reasoning for two other reasons. First, it has been predicted that threat intensifies the hypersensitivity of the HADD (Barrett, 2010), i.e., more false positives are expected in potentially threatening situations. Second, the evolution of the HADD is typically explained in terms of error management principles (Barrett, 2000; Barrett & Lanman, 2008; Guthrie, 2002; Johnson, 2009; Nola, 2014), favoring a bias to the least costly error in ambiguous threatening situations. Accordingly, an important first step towards assessing the validity of an evolutionary account of agent detection biases would be to investigate whether humans become more biased towards detecting agents in ambiguous potentially threatening situations. In the present study, we used weak to moderate threat-eliciting manipulations to investigate whether they would invoke the false perception of human agents and intentionality.

From agent detection to supernatural beliefs

An influential theory within the cognitive science of religion is that the false alarms generated by the HADD in threatening situations encourages belief in supernatural agents. Thus, belief in supernatural agents is seen as a by-product of the HADD (although this is just one contributing factor of many cognitive mechanisms that may lead to the evolution of supernatural beliefs). The foundations of this hypothesis can be traced back to Guthrie's anthropomorphism account of religion (1980; 1993; 1997; 2007). Guthrie suggested that due to the central importance of humans in our lives, we take the human model as a default, and consequently, we easily incorrectly infer the presence of humanness (i.e., humans, human minds and human language). For example, thousands of years ago when thunder struck, people attributed this to an angry, supernatural, human-like agent (e.g., Wodan, Zeus, and Indra are all gods of thunder).

Building on ideas of Guthrie (1993) and Darwin (1871), Barrett (2000) argued that this propensity for inferring the presence of other humans also applies to inferring other intentional agents more generally (i.e., all agents with self-propelled, purposeful and goal-directed behavior). The underlying reasoning was that a general agent detection system could have evolved to detect the presence of other organisms (predator and prey), conferring great increases to the survival chances of early hominids (Atran & Norenzayan, 2004; Barrett, 2008; Barrett & Burdett, 2011). Due to the apparent ease (i.e., hypersensitivity) with which agents are detected in ambiguous situations, it was termed the HADD (Barrett, 2000; Barrett & Lanman, 2008; Barrett & Burdett, 2011). Important to note is that Barrett (2000) first proposed an 'agent' detection device, which was later changed to an 'agency' detection device (Barrett, 2004) to account for the intentional aspect of agents. According to Barrett (2008), attributing intentions to agents involves two mutually reinforcing steps. In the first step, people's HADD merely detects the presence of agents. In the second step, people's mentalizing capabilities (i.e., theory of mind) cause them to attribute beliefs and desires to these agents. Thus, the HADD may be a necessary but insufficient contributing factor in explaining belief in supernatural agents; it merely encourages these beliefs. Mentalizing and other cognitive mechanisms may be additional important mechanisms that enable belief in supernatural agents. Nevertheless, HADD reasoning predicts that in threatening or ambiguous situations, the HADD will detect intentional agents' presence with little apparent evidence (Barrett, 2010).

Further, clarification on how a HADD may encourage supernatural beliefs was proposed by Lisdorf (2007; building on earlier work by Bacon, Spinoza, Hume, and Dennett), who suggested that it is not the *perceptual* detection of physical intentional agents that encourages humans to believe in supernatural agents. Instead, supernatural beliefs are encouraged due to our sensitivity for inferring *intentionality* in physical entities (i.e., a hypersensitive intentionality detection device). This has been termed the 'intentional stance' (Dennett, 1987). Dennett (2006) suggests that the intentional stance leads people to sense that there is something and that something is interpreted as an agent. Indeed, it has been empirically supported that the human default seems to be to judge actions as if they were intentionally caused (e.g., Kelemen & Rosset, 2009; Rosset, 2008). So accordingly, automatically inferring that the sound of a branch breaking is due to an agent occurs because we automatically infer that the sound was caused by something with an intentional purpose, rather than that we always perceive agents.

In sum, it has been argued that ambiguous, threatening situations may increase the false detection of humanness (i.e., anthropomorphism; Guthrie, 1993), agents (Barrett, 2000), agency (Barrett, 2008) or intentionality (Lisdorf, 2007), which in turn encourages belief in supernatural agents. The present study is an attempt to investigate an assumption of HADD theory that until now, has not been directly tested. Specifically, ambiguous threatening situations (e.g., a dark forest) should lead people to automatically detect the presence of agents, because failing to detect agents could potentially be more harmful than not detecting agents[6]. Furthermore, we investigated whether ambiguous threatening situations led to the false detection of humanness and intentionality, which converges with the ideas of Guthrie and Lisdorf. Finally, previous suggestions (Barrett & Burdett, 2011; McKay & Whitehouse, 2015) and studies (van Elk, 2013; van Elk et al., 2014) have indicated that individual differences in religious and paranormal beliefs may be an important moderator of agent detection biases. Therefore, we added the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004) and religiosity questions as possible covariates to the study.

[6] The hypothesized relation between the HADD and supernatural beliefs has been discussed elsewhere (van Elk, Rutjens, van der Pligt, & van Harreveld, 2014) and is not the topic of the present study.

Integrating threat- and agent detection literature

Literature on concepts closely related to the HADD provides indirect, tentative support to the idea that threatening situations can lead to false agent detection. It has also been shown that, with regards to automatic responses being a result of threatening situations, that adults (Chouchourelou, Matsuka, Harber, & Shiffrar, 2006; Öhman, Flykt, & Esteves, 2001; Windmann & Krüger, 1998), young children (LoBue & Matthews, 2014; Lobue & DeLoache, 2008), both from rural and urban backgrounds (Penkunas & Coss, 2013), infants (LoBue & DeLoache, 2010; Rakison & Derringer, 2008) and even nonhuman primates (Shibasaki & Kawai, 2009) detect threat-relevant stimuli (e.g., snakes, spiders and angry human walking figures) more quickly than threat-irrelevant stimuli in visual detection paradigms. With regards to human-like agent detection biases, it has been shown that people have a universal tendency to perceive patterns (e.g., face-like stimuli) in noisy pictures or in natural objects (e.g., seeing faces in cars or clouds) – a phenomenon that is known as *pareidolia* (Liu et al., 2014). It has been found, for instance that false face detection rates for pure white noise stimuli can be as high as 30 – 40 % (Gosselin & Schyns, 2003; Hansen, Thompson, Hess, & Ellemberg, 2010). Further, literature on negativity biases has shown that during an ultimatum game, participants more often believed that other players are human agents, rather than computers, in case they were confronted with negative compared to positive outcomes (Morewedge, 2009), a finding that could be interpreted as false detection of human-like agents in potentially threatening situations. Finally, people attribute more intentionality towards threatening phenomena (e.g., volcano eruption) than towards non-threatening phenomena (e.g., sunset; Nieuwboer et al., 2014).

In all, the discussed findings are in line with the idea that people have a tendency (i.e., response bias) towards detecting negative and threatening stimuli and human agents. Yet the questions of whether and how threat detection and agent detection are cognitively linked still stands. More specifically, our research will try to answer the question of whether threatening events lead people to detect agents more readily. Literature in which negative events were related to agent detection is in accordance with HADD reasoning and error management theory, suggesting that negative events can indeed increase agent detection. For example, people are more likely to misinterpret a rope as a snake when listening to fearful music, than when listening to control music (Prinz & Seidel, 2012). It has also been shown that decreasing control, or increasing uncertainty or loneliness, can result in increased anthropomorphism (Epley, Akalis, Waytz, & Cacioppo, 2008) and the false attribution of human actions to inanimate objects (Barrett & Johnson, 2003; Valdesolo & Graham, 2014). Probably the most indicative was a study in which the link between threat- and agent detection was investigated (Hoskin, Hunter, & Woodruff, 2014). In this study, it was found that threat-inducing pictures resulted in increased false alarms on a speech detection task for people scoring high on trait anxiety. We tried to conceptually replicate and extend these findings.

Present Study

Here we present the results of six behavioral experiments aimed at extending the findings on threat and agent detection. Specifically, we tested the hypothesis that a threatening manipulation activates the HADD, which should be reflected in the false detection of human agents or intentionality in ambiguous stimuli (see Figure 1 for an overview of all experiments). Effects of threat priming on human agent detection were determined by using a Biological Motion Detection Task (Experiments 1a, 1b, 2a, and 2b; van Elk, 2013; van Elk et al., 2016) and an Auditory Agent Detection Task (Experiment 4; Barkus, Stirling, Hopkins, McKie, & Lewis, 2007). Effects of threat priming on intentionality detection were determined using a Geometrical Figures Task (GFT; Experiment 3; Heider & Simmel, 1944; Riekki et al., 2014). In both the Biological Motion Detection Task and the Auditory Agent Detection Task, participants were required to perceptually detect a human agent embedded in varying amounts of either visual or auditory noise. By including different numbers of distractor stimuli, the levels of visual noise and, consequently, the ambiguity of the stimuli could be systematically manipulated to allow assessment of the boundary conditions for the false detection of agents. In the Geometrical Figures Task, participants were required to determine whether geometrical figures were moving intentionally or not, while the figures were moving in a mechanistic, intentional, or random fashion. The false detection of intentionality was operationalized as the attribution of intentionality when figures were moving randomly or mechanistically. All tasks were designed in such a way that signal detection analysis could be used to measure the response bias towards detecting human agents or intentionality in a systematic fashion (Stanislaw & Todorov, 1999), thereby closely mirroring the rationale of error management theory (Haselton & Nettle, 2006). We also looked at perceptual sensitivity (i.e., *d*'), which provides an indication of how well participants are able to distinguish signal from noise trials (i.e., agent present vs. agent absent trials).

In the first biological motion experiments (Experiments 1a and 1b), each trial was preceded by either a threat or control (i.e., neutral) picture – similar to the methods that have been used to study emotional attention (Vuilleumier, 2005). In the next biological motion experiments (Experiments 2a and 2b), as well as the Geometrical Figures Task (Experiment 3), participants were contextually primed with threatening non-linear music (classical horror music), which has been shown to increase feelings of anxiety (Blumstein, Davitian, & Kaye, 2010). In the auditory agent detection experiment (Experiment 4), we used a virtual reality horror scenario (i.e., a dark basement) to contextually prime threat. For all experiments, it was expected that threatening situations would activate the HADD more strongly than control situations, which would be reflected in an increased response bias towards detecting human agents or intentionality. With regard to the perceptual sensitivity, we had no a priori expectations. It could be reasoned that people's ability to discriminate agents from white noise increases due to increased attention, or decreases due to stress. Finally, in accordance with HADD reasoning and previous findings from our lab (van Elk, 2013), we hypothesized that individual differences in the detection of agents or intentionality would be related to supernatural beliefs.

Methods

General overview

The behavioral experiments share the same rationale in which threat priming (Experiment 1) or contextual (Experiments 2 – 4) effects on human agent detection and intentionality attribution were investigated (see Figure 1 for a schematic overview). Each experiment started with the presentation of practice trials to familiarize the participant with the experimental task. All experiments were programmed using Presentation software (Neurobehavioral Systems, CA, USA). At the end of the experiment, participants completed religiosity questions and the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004), and for explorative purposes, several other questionnaires were taken into account[7].

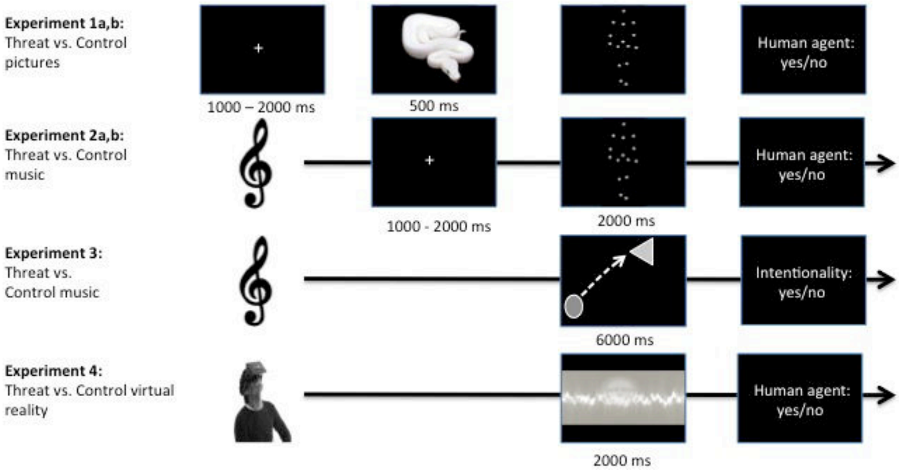


Figure 1. Schematic overview of the different experiments. In all experiments we investigated the effects of threat manipulation on agent detection. In Experiments 1a and 1b, threat was manipulated by presenting pictures of the international affective picture system; in Experiments 2a, 2b (between-subjects) and 3 threat was manipulated by presenting horror music; in Experiment 4 threat was manipulated by means of a virtual reality horror scenario. In Experiments 1 and 2, we used a Biological Motion Detection Task as our dependent measure; in Experiment 3 we used a Geometrical Figures Task as our dependent measure; in Experiment 4 we used an Auditory Agent Detection Task as our dependent measure.

[7] For explorative purposes, we added three questionnaires to the experiments (except for Experiment 1a and 2b as the chronological order of the experiments in the article differs from the order in which the experiments were conducted); the Anthropomorphisation Scale (Waytz et al., 2010), the Short Intolerance of Uncertainty Scale (Carleton et al., 2007) and the Negativity Bias Scale (Fessler, et al., 2014). The details are explained in Experiment 1 and the explorative analyses.

Participants

To determine the sample size, a power analysis was conducted using G-Power (version 3.1.9.2; Faul, Erdfelder, Buchner, & Lang, 2009). We based the analysis on the effect size found in an earlier study in which a similar paradigm was used (Van Elk, 2013). Given an effect size of $\eta_p^2 = 0.13$ ($d = 0.77$), an alpha of .05, and a power of .8, the required sample size was 16 for a within-subjects design and 58 for a between-subjects design. To ensure sufficient statistical power, we recruited at least 30 participants for the within-subjects design and 65 for the between-subjects design. A priori, we decided to exclude participants from analysis who pressed the same button in more than 95% of all trials in the signal detection task. This indicated that they had not understood the task, as in the low noise condition (i.e., trials with only a few distractor stimuli) it was relatively clear whether an agent was present or absent. All experiments were conducted in the behavioral lab of the University of Amsterdam and most of our participants were students. Psychology students received research credits, whereas students from other departments received five euros for participation. The ethics committee of the University of Amsterdam approved the experimental protocol and all participants were treated in accordance with the Declaration of Helsinki.

Experiment 1: Threat Pictures vs. Control Pictures

We conducted two different studies using threatening vs. control pictures as stimuli, which were derived from the International Affective Picture System (IAPS) database. In the first experiment (i.e., 1a), threatening pictures were selected to be more negative ($M = 3.3$, $SD = 0.4$) than control pictures ($M = 7.4$, $SD = 0.4$), $t(9) = 14.54$, $p < .001$ (1 = negative, 10 = positive), while these pictures were matched on their arousal ratings, $t(9) = 0.20$, $p = .850$ (mean arousal of threat pictures $M = 6.65$, $SD = 0.59$; mean arousal of neutral pictures $M = 6.60$, $SD = 0.66$; 1 = not arousing, 10 = very arousing). In the second experiment (i.e., 1b), threatening pictures were selected to be more arousing ($M = 6.65$, $SD = 0.59$) than control pictures ($M = 5.22$, $SD = 0.27$), $t(9) = 7.58$, $p < .001$, while these pictures were matched on their valence ratings, $t(9) = 0.74$, $p = .476$ (mean valence of threat pictures $M = 3.00$, $SD = 0.59$; mean valence of control pictures $M = 3.31$, $SD = 0.84$; 1 = negative, 10 = positive).

Experiment 1a

Methods. ***Participants.*** In total 30 participants were tested (mean age = 22.4 years; 13 females).

Experimental manipulation and paradigm. To manipulate threat, participants were primed with pictures from the IAPS. We used two categories: threatening pictures (picture # 1120, 1050, 1300, 1726, 1321, 6260, 6230, 6300, 6510, and 2120), where examples of pictures include a snake, lion, gun, and knife (pointing towards participant); and control pictures (picture # 5450, 8492, 8185, 8030, 8080, 5480, 8179, 8200, 8370, and 5470), where examples of pictures include a skydiver, fireworks, a river rafter, and a bungee jumper. These pictures have been shown to be effective in manipulating a feeling of threat in previous studies on emotional attention and cognitive processing (e.g., Koster, Crombez, Verschuere, & De Houwer, 2004; Mogg et al., 2000; Schimmack & Derry-berry, 2005; Van Damme, van Gallace, Spence, Crombez, & Moseley, 2009; Yiend & Mathews, 2001). To avoid carry-over effects of affective priming from one trial to the next, black and white pictures from either category were presented in different blocks, and in total the experiment consisted of four alternating blocks (ABAB or BABA; counterbalance order was counterbalanced across participants) of 30 trials. Each primed picture was presented for 500 ms (i.e., the prime picture was non-subliminally presented and visible to the participant) and was followed by the presentation of a biological motion stimulus for 2000 ms. After the biological motion stimulus, a screen was presented that read: “Did you perceive a human agent, yes / no?” Participants had a maximum of 10,000 ms to respond from stimulus offset. Immediately after responding, a stimulus interval was presented with a random presentation time between 1000 and 2000 ms.

In the Biological Motion Detection Task, participants were required to judge whether a point-light walker representing a human stick figure was present or absent in moving visual distractor stimuli, by pressing on the left or right arrow button (this was counterbalanced across participants) of a keyboard (this task has been used in a design by one of the authors; van Elk, 2013). The point-light walker consisted of 12 moving white dots against a black background, representing the motion of the joints of a human figure walking on a treadmill. The point-light walker could move in a left or a rightwards direction and could appear at five possible horizontal locations on the screen (−10°, −5°, 0°, 5°, 10°). In half of all stimuli, the walker was presented in an unscrambled fashion and in the other half of all stimuli the walker was presented in a scrambled version by randomly presenting the dots on the screen, while keeping the motion information the same. By varying the amount of distractor points (48, 96, 192), three different levels of visual noise were created, thereby making it more difficult to detect the presence or absence of the walker. All stimuli were generated and rendered using the software package PointLightLab[8].

Questionnaires. *Religious beliefs.* Religious beliefs were measured with two questions, 1) *'To what extent do you consider yourself to be religious?'* (1 = not at all religious, 7 = highly religious); 2) *'How often do you visit a religious institution or meeting?'* (1 = never, 7 = very frequently). The reliability was adequate, Cronbach's Alpha (α) = .93.

Paranormal beliefs. Belief in the paranormal was measured with the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004). Participants had to rate the 26 items (e.g., *'Reincarnation exists'*) by indicating to what extent they believed the statement was true on a seven-point scale (1 = strongly disagree, 7 = strongly agree). The reliability was adequate, α = .89.

Procedure. Participants were told that we were investigating the effects of emotions on motion detection. They conducted 60 trials per condition of the Biological Motion Detection Task. Participants were instructed that they were going to see short videos in which a human walking figure could be present or not. To ensure that participants were able to recognize the point-light displays, a looped video was continuously shown to them at the beginning of the study. This was displayed until they indicated that they indeed perceived a human walking figure in the moving dots. During the experiment each video was presented for 2 seconds,

[8] www.pointlightlab.com

after which the participant was required to indicate whether he or she believed that a walking human figure was present or not by pressing the left or right button on the computer keyboard. The instructions emphasized that if uncertain, participants should trust their first impression of the stimulus and not think too deliberately. At the end of the experiment, participants completed the questionnaire survey.

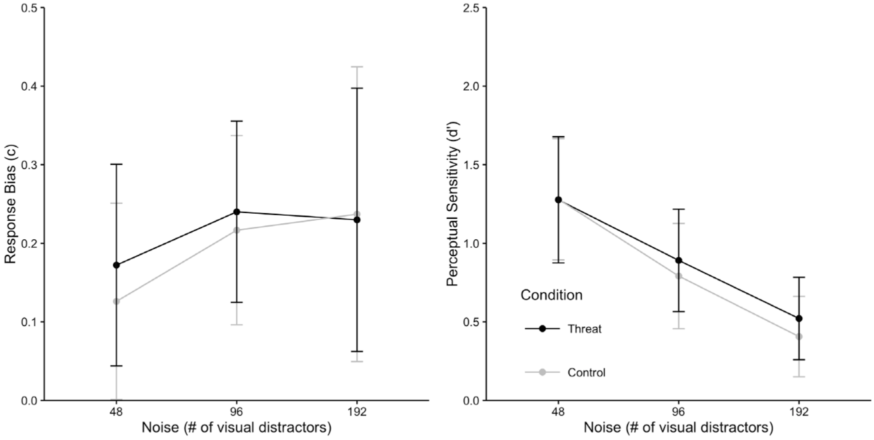
Data analysis. To analyze the Biological Motion Detection Task data, a signal detection analysis was used (D. M. Green & Swets, 1966; Macmillan & Creelman, 2005). As a measure of response bias, the criterion (i.e., *c*) was used. This represents the response strategy of the participants (i.e., saying easily yes or no). It was calculated by the sum of the normalized false alarm rate and the normalized hit rate, multiplying the outcome by minus 1 and subsequently dividing it by 2. A response bias higher than 0 indicates a response bias towards not detecting agents, a response bias lower than 0 indicates a response bias towards detecting agents. As a measure of perceptual sensitivity, the difference of the *z*-transforms (using a normal cumulative distribution function) of the hit and false alarm rates was calculated for each of the different noise levels (i.e., *d′* or *d*-prime) with MatLab (The Mathworks inc.). As discussed in Stanislaw and Todorov (1999), we added 1 to the hits, misses, false alarms and correct rejections to prevent that *Z*-scores becoming infinite.

Repeated measurement analyses of variance (RM-ANOVAs; with Greenhouse-Geisser adjusted *p*-values if Mauchly's test of sphericity was violated) were conducted to analyze whether the perceptual sensitivity was lower and the response bias was higher in the threat condition than in the control condition. We included the within-subjects factors noise level (48 vs. 96 vs. 192 distractors) and condition (threat manipulation vs. control manipulation). We also included the between-subjects variable counterbalance order to investigate whether this had had a significant influence on the results, but for conciseness, the RM-ANOVA without counterbalance order is reported, in case the between-subjects factor was non-significant. Manipulation checks and reaction times were tested with Student paired-sample *t*-tests or Wilcoxon's signed rank *t*-tests in case significant deviations from normality were observed by means of a Shapiro-Wilk test of normality. Similar analyses were applied in all other experiments and significance levels were always set at .05 (two-tailed). Data processing was done in R (R Development Core Team 2017, Version 3.3.3.) and analyses were conducted in JASP (JASP Team, 2017, Version 0.8.3.1.).

Results. The mean religiosity of the participants in Experiment 1a was 2.6 (*SD* = 2.0; 1 = not religious at all, 7 = very religious), the mean score on the church visit question was 1.9 (*SD* = 1.6; 1 = never to church, 7 = very often to church) and the average score on the RPBS was 2.5 (*SD* = 0.9; 1 = low paranormal belief score, 7 = high paranormal belief score). Inspection of the pattern of button presses did not lead to exclusion of participants. Overall, during the Biological Motion Detection Task participants responded correctly on 66.8% of all trials, suggesting that participants were able to complete the task above chance level. Counterbalance order neither had an effect on the response bias, $F(1,28) = 0.34$, MSE = 0.53, $p = .567$, $d = 0.22$, $\omega^2 < 0.01$, nor on the perceptual sensitivity, $F(1,28) = 0.31$, MSE = 3.89, $p = .590$, $d = 0.21$, $\omega^2 < 0.01$. Reaction times did not differ between the two conditions (threat, *M* = 504.2, *SD* = 250.5; non-threat, *M* = 511.8, *SD* = 249.1), $t(29) = 0.56$, $p = .579$, $d = 0.10$, $\omega^2 < 0.01$.

The threatening pictures manipulation did not affect the response bias, $F(1,29) = 0.13$, MSE = 0.02, $p = .717$, $d = 0.14$, $\omega^2 < 0.01$. Similarly, the noise level did not affect the response bias, $F(1.56, 45.15) = 0.85$, MSE = 0.17, $p = .409$, $d = 0.34$, $\omega^2 < 0.01$ (see Figure 2a, left graph). Further, the interaction between the threat manipulation and noise was not significant, $F(1.96, 56.82) = 0.01$, MSE = 0.04, $p = .748$, $d = 0.20$, $\omega^2 < 0.01$, indicating that the response bias as a function of the amount of distractors did not differ between the two conditions. The threatening pictures manipulation, also did not affect the perceptual sensitivity, $F(1,29) = 0.95$, MSE = 0.23, $p = .337$, $d = 0.35$, $\omega^2 < 0.01$. We did find a main effect of noise, $F(1.61, 46.62) = 24.63$, MSE = 0.50, $p < .001$, $d = 1.84$, $\omega^2 = 0.44$, indicating that the experiment provoked the intended result: with an increased number of distractors, the perceptual sensitivity (*d'*) decreased (see Figure 2a, right graph). No significant interaction between condition and noise level was observed, $F(1.94, 56.21) = 0.37$, MSE = 0.17, $p = .686$, $d = 0.23$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the amount of distractors did not differ between the two conditions.

(a)



(b)

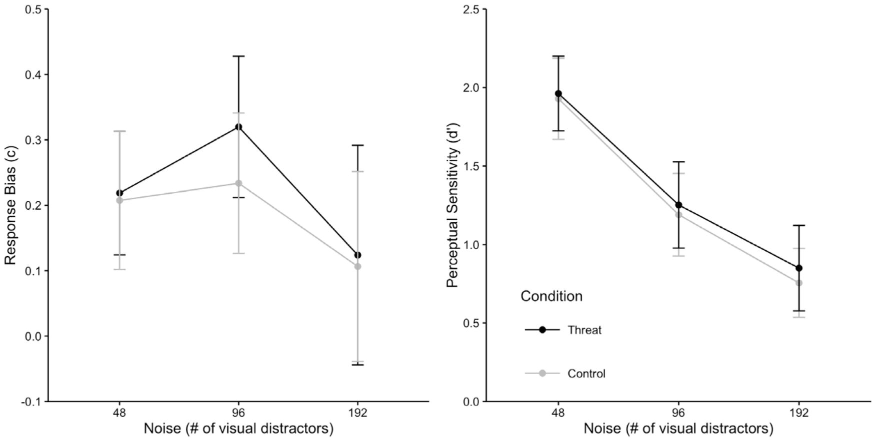


Figure 2a. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the number of visual distractors in Experiment 1a. The dark lines represent the threat condition (i.e., trials preceded by threatening pictures of the IAPS) and the light line represents the control condition (i.e., trials preceded by arousal controlled pictures of the IAPS). Error bars represent 95% confidence intervals. *2b*. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the number of visual distractors in Experiment 1b. The dark lines represent the threat condition (i.e., trials preceded by threatening pictures of the IAPS) and the light line represents the control condition (i.e., trials preceded by

arousal controlled pictures of the IAPS). Error bars represent 95% confidence intervals.

Discussion. Threatening pictures did not lead to an increased response bias to detect agents, nor did it lead to changes in the perceptual sensitivity compared to a control condition. Interestingly, opposing HADD theory, participants generally had a response bias towards judging that there was no agent present in the trials. However, it could be that arousal is a necessary factor underlying the feeling of threat, and it needs to be increased in order to observe increases on the response bias compared to a control condition. Therefore, we repeated this experiment (i.e., Experiment 1b) but this time, we chose pictures that differed significantly on arousal but were matched on valence. We further changed the experiment on three aspects. First, we used four blocks of 30 trials instead of two blocks of 60 trials to decrease the chance that learning effects would emerge. Second, as we failed to include a manipulation check in the first experiment, we added two manipulation checks after each block to investigate whether the threatening pictures manipulation elicited the desired result (i.e., increased anxiety compared to control pictures). The first manipulation check was an anxiety measure, the other a measure of control, as reduced feelings of control have been shown to underlie agency detection (Barrett & Johnson, 2003). Third, for explorative purposes, we added three questionnaires that have been theoretically related to threat and agent detection in past research. The purpose and analysis of these questionnaires will be outlined in detail in the section 'explorative analysis'.

Experiment 1b

Methods. ***Participants.*** In total 33 participants[9] were tested in Experiment 1b. One participant was excluded, because accidently a different experiment was started accidently, leaving 32 participants (24 females) with a mean age of 23.3 years (*SD* = 5.7; range = 18 – 50).

[9] We anticipated that some participants would need to be excluded and therefore collected somewhat more data than the desired 30 participants.

Experimental manipulation and paradigm. Again, participants were primed with pictures from the international affective picture system (IAPS) from two categories: threat pictures (picture # 1120, 1050, 1300, 1726, 1321, 6260, 6230, 6300, 6510, and 2120), examples of pictures are a snake, lion, gun and knife (pointing towards participant); and valence matched control pictures (picture # 9520, 9302, 9043, 9830, 9320, 1271, 1274, 9373, 6800, and 6240), where examples of pictures are a dirty toilet, a cockroach, dirty teeth and garbage. To avoid carry-over-effects of arousal priming from one trial to the next, black-and-white pictures (to keep the colors between the conditions constant) from either category were presented in different blocks and in total the experiment consisted of four alternating blocks (ABAB or BABA; counterbalance order was counterbalanced across participants). The same biological motion detection paradigm as in Experiment 1a was used as dependent measure.

Questionnaires. *Anxiety manipulation check.* Anxiety was measured after each block with six items (e.g., '*To what extent did you feel worried during the task?*') from the Shortened Positive and Negative Affect Scale X (PANAS-X, Watson & Clark, 1999). One item was added (*'To what extent did you feel anxious during the task?'*), to ensure that we manipulated the feeling of anxiety. Participants had to rate the items by indicating to what extent they felt they were applicable to them on a five-point scale (1 = not at all, 5 = very much). The reliability was adequate, α = .95.

Control manipulation check. Control was measured with one question: '*How much control did you experience during the task?'* (1 = none, 7 = a lot; Rutjens, Van Der Pligt, & Van Harreveld, 2010).

Paranormal beliefs. Paranormal beliefs were again measured with the RPBS and the reliability was adequate, α = .97.

Religious beliefs. Religious beliefs were measured with four questions: *'To what extent do you consider yourself to be religious?', 'To what extent do you believe in the existence of god?', 'How often do you visit a religious institution or meeting?'* and *'How often do you pray?*'. The reliability was adequate, α = .94.

Anthropomorphism. The individual differences in the tendency to anthropomorphize were measured with the Anthropomorphisation Scale (Waytz, Cacioppo, & Epley, 2010). Participants had to rate 14 items (e.g., *'the ocean has a conscious*') by indicating the degree to which they agreed with the statements on a nine-point scale (1 = totally disagree, 9 = totally agree). The reliability was adequate, α = .93.

Negativity bias. The negativity bias was measured with the 3-item (e.g., '*I often fear for my own safety')* Beliefs in the Dangerousness of the World Scale (Fessler, Pisor, & Navarrete, 2014; Navarrete, 2005). Participants rated each item on how applicable they felt it was to them on a nine-point scale (1 = totally disagree, 9 = totally agree). The reliability was adequate, α = .74.

Intolerance of uncertainty. Intolerance of uncertainty was measured by a short version of the Intolerance of Uncertainty Scale (IOU; Carleton, Norton, & Asmundson, 2007). Participants had to rate 11 items (e.g., '*I can't stand being surprised'*) by indicating the degree to which each statement was applicable to them on a five-point scale (1 = totally disagree, 5 = totally agree). The reliability was adequate, α = .81.

Procedure. The procedure was similar to that of Experiment 1a. However, this time participants filled in manipulation checks after each of the four blocks.

Data analysis. Data analysis was conducted in a similar fashion as in Experiment 1a, using a RM-ANOVA with the within-subjects factor noise level (48 vs. 96 vs. 192 distractors) and condition (threat vs. control). Also, the between-subjects factor counterbalance order was taken into account, to control for the possibility that the order of conditions affected the results.

Results. The mean religiosity of the participants in Experiment 1b was 2.1 (*SD* = 1.4; 1 = not religious at all, 7 = very religious) and the average score on the RPBS was 2.7 (*SD* = 1.4; 1 = low paranormal belief score, 7 = high paranormal belief score). Inspection of the button presses did not lead to exclusion of participants. Overall task performance during the Biological Motion Detection Task was 76.0% correct, suggesting that the participants were able to complete the task above chance level. Reaction times did not differ between the two conditions (threat *M* = 501.0 ms, *SD* =

170.5 ms; control *M* = 512.9 ms, *SD* = 173.2 ms), $t(31) = 0.74$, $p = .462$, $d = 0.13$, $\omega^2 < 0.01$. Analysis of the manipulation check questions indicated that participants found the threat pictures (*M* = 1.87, *SD* = 0.49) to be equally anxiety-provoking as the control pictures (*M* = 2.0, *SD* = 0.59; Wilcoxon's $t(31) = 96.0$, $p = .126$, Cohen's $d = 0.36$, $\omega^2 < 0.01$). This indicates that the manipulation did not elicit the desired result. Counterbalance order did not have an effect on the results for both the response bias, $F(1, 30) = 0.13$, $MSE = 0.35$, $p = .720$, $d = 0.13$, $\omega^2 < 0.01$, and the perceptual sensitivity, $F(1, 30) < 0.01$, $MSE = 2.11$, $p = .961$, $d < 0.01$, $\omega^2 < 0.01$.

In contrast to our predictions based on hypotheses, the threatening pictures manipulation did not affect the response bias (*c*), $F(1, 31) = 0.04$, $MSE = 0.07$, $p = .178$, $d = 0.50$, $\omega^2 = 0.03$, indicating that participants were not inclined to detect more agents as a result of the threat manipulation. The noise manipulation also did not significantly affect the response bias, $F(1.36, 42.26) = 3.24$, $MSE = 0.20$, $p = .067$, $d = 0.64$, $\omega^2 = 0.06$, indicating that with increased levels of distractors, the response bias did not increase, reflecting that participants were not inclined to detect more agents (see Figure 2b, left graph). Further, the interaction between the threat manipulation and noise was not significant, $F(1.94, 60.16) = 0.41$, $MSE = 0.07$, $p = .657$, $d = 0.23$, $\omega^2 < 0.01$, indicating that the response bias as a function of the amount of distractors did not differ between the two conditions.

The threatening pictures manipulation also did not affect the perceptual sensitivity, $F(1, 31) = 1.00$, $MSE = 0.19$, $p = .324$, $d = 0.36$, $\omega^2 < 0.01$. We did observe a main effect of noise, $F(2, 62) = 72.17$, $MSE = 0.30$, $p < .001$, $d = 3.06$, $\omega^2 = 0.46$, indicating that the task provoked the intended result: with an increased number of distractors, the perceptual sensitivity (*d'*) decreased (see Figure 2b, right graph). Thus, the participants found it more difficult to discriminate between agent-present and agent-absent trials as the stimuli become more ambiguous. Also, no significant interaction between condition and noise was observed, $F(2, 62) = 0.07$, $MSE = 0.21$, $p = .933$, $d = 0.09$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the amount of distractors did not differ between the two conditions.

Discussion. The two picture threat prime experiments were not very effective in eliciting threat. In Experiment 1b, our manipulation did not provoke the desired result, as the subjective anxiety ratings were comparable between the threat condition and the control condition. In hindsight, it may seem logical that pictures of dirty toilets and cockroaches are equally as anxiety-provoking as pictures of guns and snakes. We merely used this threat manipulation as it has been shown to be effective in manipulating a mild to moderate feeling of threat in previous studies (e.g., Koster et al., 2004; Mogg et al., 2000; Schimmack & Derryberry, 2005; Van Damme et al., 2009; Yiend & Mathews, 2001). Another point of concern could be that the picture context may not have generalized to the Biological Motion Detection Task. Finally, a habituation effect may have emerged due to the repeated presentation of the images, thereby decreasing the overall anxiety level (i.e., feeling of threat) in the participants. Apart from these limitations, it is again interesting to note that participants did not generally have a response bias towards perceiving agents, whereas this would logically follow from a hypersensitive device.

In the next experiment, we used a stronger threat manipulation (i.e., threatening music to induce feelings of threat). Specifically, in Experiment 2 we presented threatening classical horror music with non-linear sounds that have been successfully used in other studies to manipulate feelings of threat (e.g., Blumstein et al., 2010; Prinz & Seidel, 2012). By doing so, we could continually present the threatening context during the Biological Motion Detection Task, thereby easing the generalizability of the manipulation to the Biological Motion Detection Task. Moreover, as the music changes at different points in time, we also intended to decrease the chance of habituation effects. In short, we presented a contextual threat manipulation, as this allowed us to investigate the effects of threat while participants were conducting the human agent detection task.

Experiment 2: Threat Music vs. Control Music

We conducted two different studies using threatening vs. control music. In the first experiment (i.e., Experiment 2a), we conducted the study with a within-subjects design. In the second study (i.e., Experiment 2b), we conducted the study with a between-subjects design in order to prevent participants guessing the hypothesis of the study.

Experiment 2a: within-subjects

Methods. ***Participants.*** Thirty-one participants (21 female), with a mean age of 25.7 years (*SD* = 11.2, range = 19 - 66) were recruited for the third experiment.

Experimental Manipulation and paradigm. In order to contextually manipulate the feeling of threat, threat eliciting classical music (Penderecki, 2012) was contrasted with neutral music (Grieg, 1993). Music was presented via headphones and care was taken so that no agents were present in the music (e.g., voices or crying wolves). The same Biological Motion Detection Task as in Experiment 1 was used as dependent measure.

Questionnaires, procedure and data analysis. The questionnaires, procedure and data analysis were the same as in Experiment 1b.

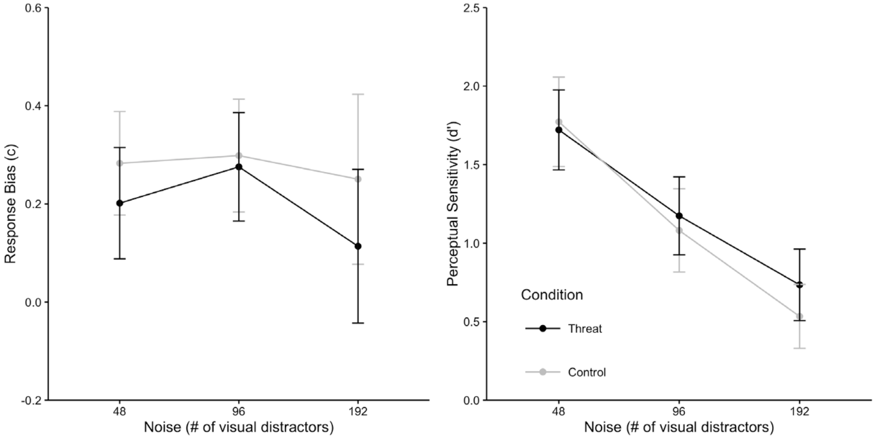
Results. The mean religiosity of the participants in Experiment 2a was 2.1 (*SD* = 1.4; 1 = not religious at all, 7 = very religious) and the average score on the RPBS was 2.7 (*SD* = 1.4; 1 = low paranormal belief score, 7 = high paranormal belief score). Inspection of the button presses did not lead to exclusion of participants. Overall task performance during the Biological Motion Detection Task was 73.2% correct, suggesting that the participants were able to complete the task above chance level. Reaction times did not differ significantly between the two conditions, (threat, *M* = 632.21 ms, *SD* = 286.97 ms; control, *M* = 571.10 ms, *SD* = 202.96 ms), Wilcoxon's *t* = 354, *p* = .095, *d* = 0.31, $\omega^2 < 0.01$. Analysis of the manipulation check questions indicated that participants found the threatening music *(M* = 2.55, *SD* = 0.78) to be more strongly anxiety-provoking than the control music *(M* = 1.87, *SD* = 0.43; *t*(31) = 6.20, *p* < .001, Cohen's *d* = 1.10, $\omega^2 = 0.27$). This indicates that the manipulation provoked the desired result, although participants did not perceive less control in the threat condition *(M* = 3.94, *SD* = 1.28) as compared to the control condition *(M* = 4.14, *SD* = 1.25), *t*(21) = 1.42, *p* = .167, *d* = 0.25, $\omega^2 < .01$. Counterbalance order did not have an effect on the results for the response bias, *F*(1, 30) = 0.53, *MSE* = 0.37, *p*

= .471, d = 0.26 , $\omega^2 < 0.01$, or the perceptual sensitivity, $F(1, 30) = 0.91$, MSE = 1.78, p = .348, $d < 0.35$, $\omega^2 < 0.01$.

In contrast to our predictions, the threatening music manipulation did not significantly affect the response bias (c), $F(1, 31) = 3.49$, MSE = 0.31, p = .071, d = 0.67, $\omega^2 = 0.07$ (see Figure 3a left graph). Analysis of the response bias did not show a main effect of noise, $F(1.28, 39.53) = 1.14$, MSE = 0.28, p = .306, d = 0.39, $\omega^2 < 0.01$, indicating that with increased levels of distractors the response bias did not systematically increase. Further, the interaction between the threat manipulation and noise was not significant, $F(2, 62) = 1.01$, MSE = 0.05, p = .370, d = 0.36, $\omega^2 < 0.01$, indicating that the normalized false alarm rate as a function of the amount of distractors did not differ between the two conditions.

With regard to the perceptual sensitivity, the threatening music manipulation did not affect the perceptual sensitivity, $F(1, 31) = 0.80$, MSE = 0.39, p = .379, d = 0.32, $\omega^2 < 0.01$. We found a main effect of noise, $F(2, 62) = 76.79$, MSE = 0.26, p < .001, d = 3.15, $\omega^2 = 0.70$. This indicates that with an increased number of distractors, the perceptual sensitivity (d') decreased; participants found it more difficult to discriminate agent-present from agent-absent trials (see Figure 3a, right graph). No significant interaction between condition and noise was observed, $F(2, 62) = 1.28$, MSE = 0.20, p = .287, d = 0.40, $\omega^2 = 0.01$, indicating that the perceptual sensitivity, as a function of the amount of distractors, did not differ between the two conditions.

(a)



(b)

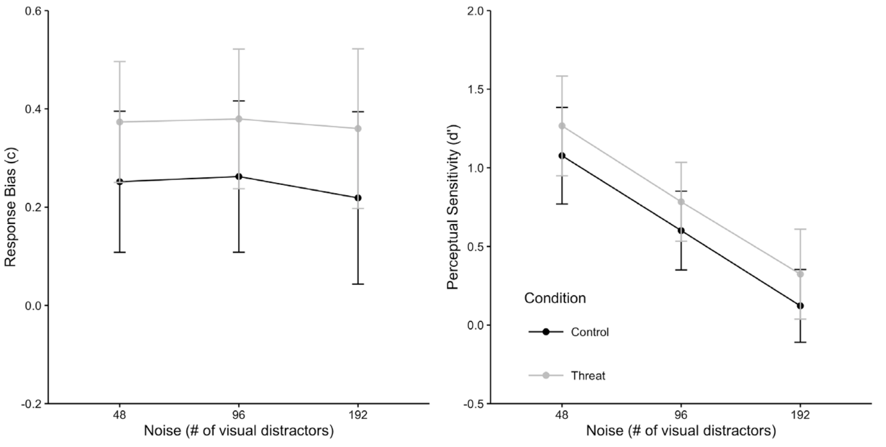


Figure 3a. The response bias (*c*; left graph) and perceptual sensitivity (*d'*; right graph) as a function of the number of visual distractors in Experiment 2a. The dark lines represent the threat condition (i.e., classical horror music) and the light lines represent the control condition (i.e., elevator music). Error bars represent 95% confidence intervals. *3b.* The response bias (left graph) and the perceptual sensitivity (right graph) as a function of the number of visual distractors in Experiment 2b. The dark lines represent the threat condition (i.e., trials run in the

context of threatening music) and the light line represents the control condition (i.e., trials in the context of neutral music). Error bars represent 95% confidence intervals.

Discussion. As was evident from the manipulation checks, we were able to manipulate a somewhat stronger threatening feeling than in the first experiments by presenting threatening horror music. However, the manipulation did not result in significant changes on the response bias or the perceptual sensitivity. Although no participants could guess the hypothesis of this experiment when asked, a within-subject design can affect the validity of the results due to carry-over effects between experimental blocks (Greenwald, 1976). In the next study we addressed this by using a between-subject design.

Experiment 2b: between-subjects

Methods. ***Participants.*** Sixty-three participants (45 female), with a mean age of 22.9 years (SD = 5.3) were recruited for the between-subjects experiment.

Experimental Manipulation and paradigm. The same contextual manipulation (i.e., music) was used as in Experiment 2a and the same Biological Motion Detection Task as in the previous experiments was used.

Questionnaires. The specific questionnaire in this experiment differed from the questionnaires in the other experiments, because the chronological order in which the studies were conducted was different from the order of presentation in this article.

Supernatural beliefs. Supernatural beliefs were measured with the supernatural belief scale (Jong, Bluemke, & Halberstadt, 2013). The scale consists of 10 items (e.g. '*There exists an all-powerful, all-knowing, loving God*') and had an excellent reliability, α = .96. Items were scored on a nine-point Likert scale (1 = totally disagree, 8 = totally agree).

Data Analysis. We conducted a RM-ANOVA with the three-level within-subjects factor noise level (48 vs. 96 vs. 192 distractors) and the two-level between-subjects factor condition (horror music vs. neutral music).

Results. Participants had a low average supernatural belief score of 2.46 (SD = 1.81). Five participants were excluded from further analysis (three from the experimental condition, two from the control condition) because they did not follow the instructions correctly. Of the 60 trials, they pressed 95% or more on only one of the two buttons (i.e., they pressed three or fewer times on only one button), which is below the predetermined criteria outlined above. No significant differences were found regarding the reaction times (threat, M = 574.0 ms, SD = 278.2 ms; control, M = 503.1 ms, SD = 148.3 ms), $t(56) = 1.22$, $p = .226$, $d = 0.32$, $\omega^2 = 0.03$. Overall task performance during the Biological Motion Detection Task was 64% correct, suggesting that the participants were able to complete the task above chance level.

With regards to the response bias, the data were not in line with our predictions. Participants who listened to threatening music did not have a higher response bias for detecting agents than participants who listened to non-threatening music, $F(1, 56) = 2.00$, MSE = 0.35, $p = .163$, $d = 0.38$, $\omega^2 = 0.02$, (see Figure 3b, left graph). Further, we did not observe a main effect of noise, $F(2, 112) = 0.19$, MSE = 0.02, $p = 0.829$, $d = 0.11$, $\omega^2 < 0.01$, indicating that the response bias did not change as a result of the number of distractors. Also the interaction between noise and condition was non-significant, $F(2, 112) = 0.03$, MSE < 0.01, $p = .972$, d = 0.06, $\omega^2 < 0.01$; indicating that the response bias as a function of the amount of distractors did not differ between the two conditions.

The control-threat manipulation also did not affect the perceptual sensitivity, $F(1, 56) = 1.48$, MSE = 1.08, $p = .230$, $d = 0.33$, $\omega^2 = 0.01$. We did observe a main effect of noise, $F(1.80, 100.71) = 39.88$, MSE = 0.36, $p < .001$, $d = 1.69$, $\omega^2 = 0.40$. This indicates that the manipulation provoked the intended result: with an increased number of distractors, the perceptual sensitivity (*d'*) decreased. Participants found it more difficult to discriminate agent-present from agent-absent trials (see Figure 3b, right graph). Also the interaction between noise and condition was non-significant, $F(1.80, 100.71) < 0.01$, MSE = 0.36, $p = .993$, $d < 0.01$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the amount of distractors did not differ between the two conditions.

Discussion. Again, we did not observe a significantly increased response bias towards detecting human agents when participants were contextually primed with threatening music. Similarly, the perceptual sensitivity did not change as a result of the manipulation. In all experiments conducted so far, we used the Biological Motion Detection Task as our dependent measure. However, as indicated in the introduction, it could be argued that the HADD does not primarily involve (human) agent detection, but rather the detection of intentions or of intentional movement. Therefore, in the next experiment we investigated whether the absence of an effect in the first two studies was related to the use of the Biological Motion Detection Task. Thus, in Experiment 3 we used another task tapping more directly into intentionality detection (i.e., the Geometrical Figures Task) and more closely following Lisdorf's (2007) and Dennett's (2006) intentionality account. We also wanted to investigate whether participants rated the intentional movements of figures as more negative (i.e., malevolent) when threatening music was presented. Therefore, additional measures related to the valence of the observed movements were included.

Experiment 3: IV: Threatening Music vs. Control Music

Methods

Participants. Forty-five participants were recruited for the study, six participants had to be excluded because they had at least one block missing on the dependent variable due to a coding error. For one participant, we did not have data on the questionnaires, and one of the participants did not hear the sound as the volume was turned off. The 37 participants (20 female) included for analysis had an average age of 24.4 years (*SD* = 5.1, range 18-39).

Experimental manipulation, questionnaires. The experimental manipulation was the same as in Experiment 2 and the questionnaires were the same as in Experiments 1b and 2a.

Experimental paradigm. We operationalized perceived intentionality by means of a Geometrical Figures Task, originally developed by Heider & Simmel

(1944). We used an adapted version of the Geometrical Figures Task developed by Riekki et al. (2014) in which videos displayed intentional, (semi-) random or mechanical moving geometrical figures. In the intentional movies, geometrical figures moved in goal-directed manners (e.g., one figure was chasing another). In the (semi-) random videos, the figures moved randomly, but could not touch each other - otherwise they would appear to move through each other. . In the mechanical video, moving figures followed the laws of physics (e.g., figures bounced off against each other and against the wall). Participants had to decide whether movements performed by the geometrical figures were intentional, by pressing one of two response buttons (the left or right arrow button of the keyboard). The stimuli of Riekki et al. (2014) were developed for functional magnetic resonance imaging and therefore very easy to rate in terms of intentionality and randomness. In order to increase the difficulty (and ambiguity) we cut the original 30 seconds videos into three parts of 10 seconds. In addition, we increased the speed of the videos by decreasing the length to 6 seconds per video, resulting in faster moving figures.

Procedure. The procedure was similar to the previous experiments. Participants were told that we were investigating how music and emotions influence perception. Participants had to judge whether or not geometrical figures moved in an intentional manner by means of a keyboard press button (left = intentional, right = not-intentional and vice versa for half of the participants as the instructions were counterbalanced between-subjects). To explain to participants what it meant if figures were moving intentionally, three practice videos were shown: one with figures moving in an intentional fashion, one with figures moving in a mechanical fashion and one with random moving figures. If participants responded that they detected intentionality, they were subsequently asked to indicate on a nine-point scale (1 = positive, 9 = negative) whether the valence of the intentionality was positive or negative. Thus, only when participants had indicated that they saw intentionality, could they rate the valence of the intentionality. In total, 36 clips were presented. Each participant saw each video two times: one time in each condition (i.e., threat vs. control music). In each condition, the order of the trials was randomized. Thus, in total, each participant assessed 72 videos, evenly divided in 24 intentional, 24 random and 24 mechanical videos. There was a 2 second inter stimulus interval between the assessment of the movements and the following video. Completing the Geometrical Figures Task took around 20 minutes in total.

Data analysis. The analysis of the manipulation checks was similar to Experiments 1 and 2, although a one-way ANOVA was added to check whether intentionality ratings were higher for the intentionality videos than for the mechanical and random videos. The response bias (c) and the perceptual sensitivity (*d'*) were calculated somewhat differently from the previous experiments. Similarly to the previous experiments, perceiving intentionality in target trials resulted in hits, whereas not perceiving intentionality in target trials resulted in misses. Unlike the previous experiments, there were no longer three levels of noise trials (i.e., 48, 96 and 192 distractors), but two different types of random trials (i.e., mechanical and random videos). So, perceiving intentionality in either mechanical or random videos resulted in false alarms whereas not perceiving intentionality in these videos resulted in correct rejections. Thus, d' and c were calculated based on the hit rate (i.e., proportion of intentional videos in which intentionality was detected) and the false alarm rate (i.e., the proportion of both mechanical and random videos in which intentionality was detected).

With regard to the valence of the intentionality ratings, these could not be analyzed by a RM-ANOVA as a consequence of the procedure (i.e., participants filled out the intentionality rating only if they had reported to perceive intentionality). Therefore, there was a large variability in the amount of data points that could be analyzed per video for the intentionality ratings. That is to say, for intentional and random videos, there were more data points than for mechanical videos. As the *N* in RM-ANOVA's is based on the category with the least number of repetitions, we analyzed the data with paired sample *t*-tests in which we contrasted the conditions (i.e., threat vs. control) per type of video (intentional, mechanical and random).

Results

The mean religiosity of the participants in Experiment 3 was 1.4 (*SD* = 0.8; 1 = not religious at all, 7 = very religious) and the average score on the RPBS was 2.0 (*SD*

= 1.0; 1 = low paranormal belief score, 7 = high paranormal belief score), which are both low. None of the participants were excluded after inspecting the button presses. Overall task performance during the Geometrical Figures Task was 76.9% correct, and the participants more often detected intentionality in the intentionality videos (96.2%) than in the random (55.1%) and mechanical videos (10.3%) showing that the participants understood the task. Reaction times did not differ significantly between the two conditions, (threat, M = 1060.1 ms, SD = 547.8 ms; control, M = 1077.7 ms, SD = 566.4 ms), $t(36) = 0.27$, $p = .785$, $d = 0.05$, $\omega^2 < 0.01$.

Analysis of the manipulation check questions indicated that participants found the threatening music (M = 1.49, SD = 0.43) to be more strongly anxiety-provoking than the control music (M = 1.13, SD = 0.33; Wilcoxon's t = 554, $p < .001$, Cohen's d = 1.09, $\omega^2 = 0.26$), although the anxiety levels were still relatively low. In addition, participants perceived less control in the threat condition (M = 2.33, SD = 0.90) compared to the control condition (M = 2.70, SD = 0.84), Wilcoxon's t = 32.5, $p < .001$, $d = 0.64$, $\omega^2 = .07$. Counterbalance order did not affect the response bias, $F(1, 35) < 0.01$, $MSE = 0.32$, $p = .970$, $d < 0.01$, $\omega^2 < 0.01$, or the perceptual sensitivity, $F(1, 35) = 0.01$, $MSE = 1.10$, $p = .908$, $d < 0.01$, $\omega^2 < 0.01$.

For the response bias (*c*), we did not find that participants had a higher response bias towards detecting agents during the contextual threat manipulation than during the control condition, $F(1, 36) = 0.05$, $MSE = 0.03$, $p = .820$, $d = 0.02$, $\omega^2 < 0.01$ (see Figure 4, left graph). With regard to the perceptual sensitivity, the threatening music manipulation affected the perceptual sensitivity, $F(1, 36) = 6.84$, $MSE = 0.09$, $p = .013$, $d = 0.85$, $\omega^2 = 0.13$ (see Figure 4, right graph). Participants found it more difficult to judge whether the geometrical figures were moving intentionally or not when the music was threatening than when the music was not threatening.

With regard to the valence ratings, participants viewing the intentionality videos rated the intentional movements as more negative during the threat condition (M = 7.02, SD = 1.03) than during the control condition (M = 6.56, SD = 1.07), *Wilcoxon's* t = 499.50, $p = .009$, $d = 0.48$, $\omega^2 = 0.03$. During mechanical videos, participants rated the mechanical movements similarly negative in the threat condition (M = 7.69, SD = 0.48) as in the control condition (M = 5.49, SD = 1.84), Wilcoxon's t = 10, p = .125, d = 1.74, ω^2 = 0.72, but note that the number of participants who perceived intentionality and hence could fill out the scale was low (i.e., six in the control condition and eight in the threat condition). During random videos, participants did not perceive more negative intentionality in the threat condition (M = 7.34, SD = 1.15) than in the control condition (M = 7.03, SD = 1.53), Wilcoxon's t = 86.50, p = .352, d = 0.25, ω^2 < 0.01.

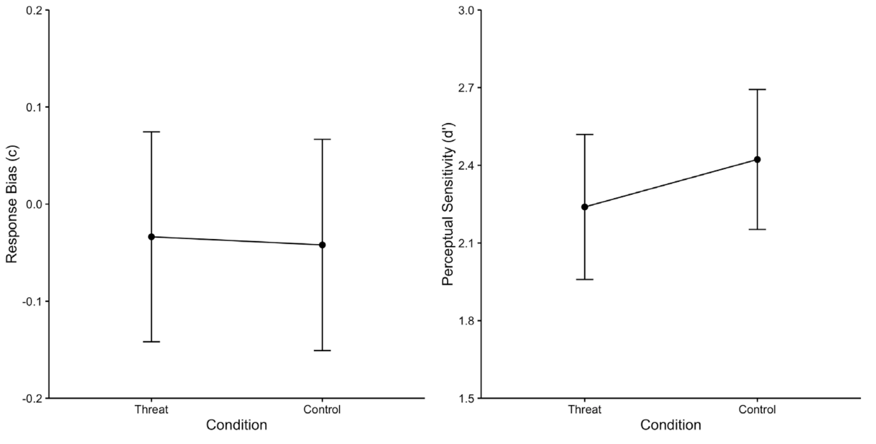


Figure 4. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the type of condition (threat vs. control) in Experiment 3. The dark lines represent the difference between the threat condition (i.e., threatening music) and the control condition (i.e., neutral music). Error bars represent 95% confidence intervals.

Discussion

Similar to the previous experiments, we observed in Experiment 3 that a contextual music threat manipulation did not increase the response bias of participants towards increased intentionality detection. However, in contrast to the previous experiments the perceptual sensitivity was affected by the manipulation; participants found it more difficult to discriminate intentionality present from intentionality absent trials, during a threat manipulation. A possibility is that participants were generally distracted by the threatening music and found it more difficult to judge whether figures were moving intentionally or not. A further interesting finding is that the GFT was the first dependent measure indicating that participants showed a general response bias towards perceiving intentionality (i.e., a negative response bias [c]). These findings are in line with Lisdorf's comments (2007) suggesting that people are more likely to have an intentionality detection bias than an agent detection bias. However, these results have to be interpreted with caution considering that the response bias was close to zero. Moreover, this small response bias towards detecting intentionality did not increase in a mild threatening context, when compared to a control context. This again seems to oppose the idea of a 'hypersensitive' device (e.g., Barrett, 2000), which supposedly evolved on the principles of error management theory, favoring the least costly errors (Haselton & Nettle, 2006; Johnson et al., 2013).

Further, participants attributed more negative emotions towards the intentionality videos in the threat condition, compared to the control condition. Thus, threatening music can affect the nature of the interpretation of the intentions. However, the findings were not consistent: movements were only perceived more negative for intentional movements, but not for random and mechanical moving figures, although for the latter, the power was too low to draw conclusions. A possibility as to why intentional movements were perceived more negative in the threat condition, but not for the other types of videos, may be the result of the figures moving away from each other, which could have been seen as a negative movement in both conditions.

One point of concern is the relatively small absolute difference between the anxiety ratings of the threat and control condition in all previous experiments (max. 0.4 on a five-point scale). Possibly, music presented in the lab induces modest feelings of anxiety, but it might not come close to the intense feeling of threat of being alone in a dark forest. In the final experiment, we used a strong visual contextual prime (virtual reality) that reinforces feelings of threat throughout the experiment, similar to the contextual music manipulation in Experiments 2 and 3, thereby boosting the ecological validity of the study. Due to the fact that virtual reality is a visual contextual manipulation, we had to switch to an auditory version of a human agent detection task (i.e., the Auditory Agent Detection Task). As a result, however, we could also extend our research to the auditory system. The basic idea behind the Auditory Agent Detection Task is similar to the Biological Motion Detection Task; participants were required to detect human agent voices that are embedded within varying levels of white noise, and pure white noise stimuli were also included to investigate to what extent participants falsely detected agents.

Experiment 4: Horror Virtual Reality vs. Control Virtual reality

Methods

Participants. Thirty-one participants (20 female) were tested with a mean age of 24.8 years (*SD* = 7.3; range = 19-58).

Experimental Manipulation. In order to manipulate the feeling of anxiety, demo versions of two virtual reality scenarios were presented on the Oculus Rift development kit 2 (Oculus VR; Irvine, CA, USA). In the contextual threat scenario '*Teratophobia,'*[10], participants were walking around in a dark basement. Participants were warned that the scenario was scary in order to elicit the anticipation of fear (and for ethical purposes). In the control scenario '*alien desert,'*[11], participants were able to walk around in a desert environment and they were told that it would be a neutral scenario.

Experimental paradigm. The Auditory Agent Detection Task was based on the description of the Auditory Signal Detection Task used by Barkus et al. (2007). Participants listened to 60 randomized trials of 3-second epochs of white noise. In half of these, stimuli male agent voices were embedded pronouncing Dutch number words (e.g., '*one', 'ten'*). These 1-second human voice fragments were recorded and normalized regarding their pitch- and dB-levels with Audacity (2.0.5, Boston, MA, USA). Subsequently, we filtered the voices (Low pass filter 3400 Hz, high-pass filter 300 Hz). We varied both the position of the voice within the white noise – after 1, 2 or 3 seconds – as well as the loudness percentage of the noise – attenuated to 50%, 60% or 70% of the original sound level. The white noise and voice stimuli were combined in MatLab (R2013b, Mathworks, Natick, MA, U.S.A.). The stimuli were

[10] https://share.oculus.com/app/teratophobia
[11] https://share.oculus.com/app/alien-desert

presented with over-ear headphones. In between stimuli was a variable interval of 1000 – 1500 ms.

Procedure. Participants were told that we were investigating the effects of virtual reality experiences on the auditory system. Participants were instructed to listen to white noise fragments and that sometimes a voice was embedded within the white noise. They were then told to press one of two buttons if they heard a voice, and another if they did not. To gain high attention of the participants, it was stressed that they had only 3 seconds after each stimulus to indicate whether they had detected an agent voice or not. After 10 practice trials, the experimenter verified that the task was understood and subsequently one of the virtual reality scenarios was started in a semi-random order (in such a way that over the course of the entire study, all scenario orders were completely counterbalanced in order to control for order effects). After completing each scenario, an anxiety questionnaire was filled out. Upon completion, participants filled out the other questionnaires, and were debriefed about the true purpose of the study.

Data analysis. Data were analyzed in the same way as in earlier experiments. The only difference was that the factor noise-level no longer consisted of 48, 96 and 192 distractors but of varying levels of the white noise volume (50%, 60% and 70%).

Results

The mean religiosity of the participants in Experiment 4 was 1.9 (SD = 1.5; 1 = not religious at all, 7 = very religious) and the average score on the RPBS was 2.2 (SD = 1.0; 1 = low paranormal belief score, 7 = high paranormal belief score). Inspection of the button presses did not lead to exclusion of participants. Overall task performance during the Auditory Agency Detection Task was 58.7% correct, while four participants scored below chance level (i.e., less than 50% correct), indicating that the task was more difficult, or perhaps participants were more distracted by the virtual reality manipulation, than in the previous tasks. Reaction times did not differ significantly between the two conditions, (threat, M = 942.9 ms, SD = 403.0 ms; control, M = 987.6 ms, SD = 358.8 ms), Wilcoxon's t = 170, p = .130, d = 0.16, ω^2 <

0.01. Participants reported higher levels of anxiety in the virtual reality threat condition *(M* = 2.82, *SD* = 0.93), than in the virtual reality control condition *(M* = 1.80, *SD* = 0.54), $t(30) = 5.54$, $p < .001$, $d = 1.00$, $\omega^2 = 0.48$, while at the same time participants reported lower levels of control in the threat condition *(M* = 3.87, *SD* = 0.54) than in the control condition *(M* = 4.90, *SD* = 1.38), Wilcoxon'sd $t = 19$, $p < .001$, $d = 0.71$, $\omega^2 = 0.32$, both indicating that the manipulation provoked the intended effect. Counterbalance order did not affect the response bias, $F(1, 29) = 0.05$, $MSE = 1.04$, $p = .828$, $d = 0.09$, $\omega^2 < 0.01$ or the perceptual sensitivity, $F(1, 29) = 0.03$, $MSE = 0.92$, $p = .862$, $d < 0.01$, $\omega^2 < 0.01$.

Participants did not have a significantly higher response bias in the virtual reality threat condition than in the control condition, $F(1, 30) = 1.34$, $MSE = 0.32$, $p = .256$, $d = 0.42$, $\omega^2 = 0.01$ (see Figure 5, left graph). We observed an effect of noise, $F(2,60) = 12.18$, $MSE = 0.06$, $p < .001$, $d = 1.28$, $\omega^2 = 0.26$: suggesting that the response bias changed as a result of the level of white noise. Figure 5 (left graph) indicates that the response bias increased with increments of the level of white noise. Thus, when the level of white noise was higher, participants were more likely to perceive the trials to be absent of agents. Finally, we did not observe an interaction effect, $F(2, 60) = 0.39$, $MSE = 0.08$, $p = .677$, $d = 0.23$, $\omega^2 < .01$.

The threat manipulation did not affect the perceptual sensitivity, $F(1, 30) = 1.78$, $MSE = 0.23$, $p = .192$, $d = 0.49$, $\omega^2 = 0.02$, indicating that participants did not find it more difficult to discriminate between agent-present and agent-absent trials as a result of the manipulation (see Figure 5, right graph). We did find a main effect of noise, $F(2, 60) = 20.01$, $MSE = 0.26$, $p < .001$, $d = 1.63$, $\omega^2 = 0.38$, indicating that perceptual sensitivity decreased as the level of white noise increased. Thus, participants found it more difficult to judge whether an agent was present or not, when the noise was stronger. We did not observe an interaction between condition and noise level, $F(2, 60) = 0.33$, $MSE = 0.26$, $p = .722$, $d = 0.21$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the level of white noise did not differ between the two conditions.

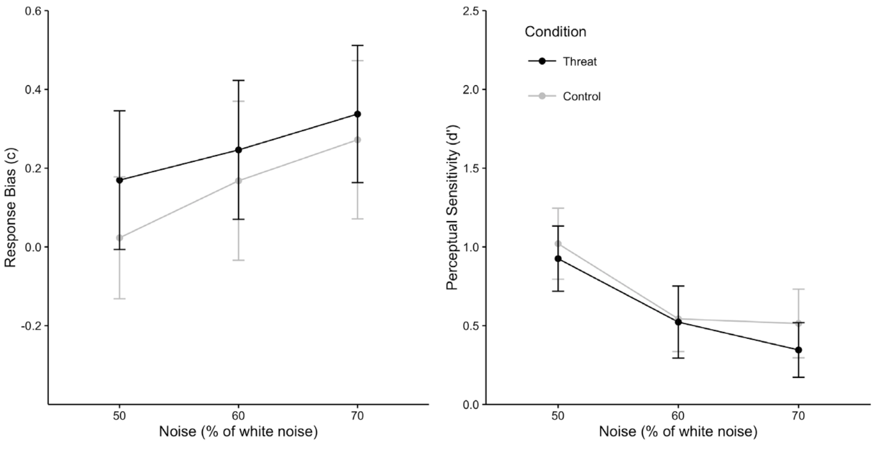


Figure 5. The response bias (left graph) and perceptual sensitivity (right graph) as a function of the percentage of white noise in Experiment 4. The dark lines represent the threat condition (i.e., threatening virtual reality scenario) and the light lines represent the control condition (i.e., neutral virtual reality scenario). Error bars represent 95% confidence intervals.

Discussion

In Experiment 4, we could not find an effect of a threatening contextual condition on the perceptual sensitivity or the response bias: Participants did not perceive more human voices when placed in a threatening contextual situation, compared to a control situation. If anything, the effect was opposite of what we had expected: participants perceived more agents in the desert environment than in the basement. An explanation could be that the desert elicited a feeling of loneliness, causing people to perceive more human agency. For example, it has been suggested that due to people's motivation to stay socially connected, feelings of loneliness can cause people to actively search for sources of social connection (Epley et al., 2008). Of all the experiments, the virtual reality manipulation of Experiment 4 resulted in the highest absolute anxiety score, which shows that manipulation of the experiment was indeed stronger than in the previous experiments. In sum, Experiment 4 seems to present the strongest case against the idea that threatening ambiguous situations lead to increased human agent detection. In the following section, we conducted an explorative analysis in which we investigated whether several concepts that have been theoretically related to supernatural beliefs (i.e., the Anthropomorphisation Scale, the Short Intolerance of Uncertainty Scale and the Negativity Bias Scale) were associated with human agent or intentionality detection.

Explorative analysis

In the explorative analysis, we investigated whether the measures explained in Experiment 1b (i.e., religiosity, the RPBS, the Anthropomorphisation Scale, the Short Intolerance of Uncertainty Scale and the Negativity Bias Scale) were associated with a response bias towards perceiving human agents or intentionality. As agent and intentionality detection have been suggested to underlie supernatural beliefs, we expected that religiosity and the RPBS would be correlated with a response bias towards detecting agents (i.e., $c < 0$), implying an inverse relationship. Instead of taking these questionnaires into account as covariates in each experiment, we grouped all experiments together in order to increase the power to draw conclusions. Exploratively, we added three questionnaires (to Experiment 1b, 2a, 3 and 4) that have been theoretically related to threat and agent detection in past research, and we were interested to find out to what extent they correlated with agent detection. First, the Anthropomorphisation Scale (Waytz et al., 2010) was added to measure individual differences in the tendency to anthropomorphize. By doing so, we could investigate to what extent Guthrie's anthropomorphisation relates to biased agent detection. Furthermore, we expected higher anthropomorphisation scores to be related to stronger supernatural beliefs and agent detection. Second, the Short Intolerance of Uncertainty Scale (Carleton et al., 2007) was added, which reflects one's difficulty in coping with ambiguous events. Thereby, we follow researchers who found that increased intolerance of uncertainty could result in a tendency to perceive agency in random events (Valdesolo & Graham, 2013). We expected uncertainty scores to be positively related to agent detection. Third, the Negativity Bias Scale was added, which provides an indication of the ease with which negative events capture attention compared to positive events (Fessler, et al., 2014). This is in line with the findings of Morewedge (2009), who observed during an ultimatum game[12] that people more often believed that other players were human agents rather than computers in cases where the other players performed negative instead of positive actions. We expected that the negativity bias would be positively related to agent or intentionality detection.

Data analysis

All experiments in which the questionnaires were added (i.e., 1b, 2a, 3, and 4) were taken into account (N = 130). We calculated the average response bias (criterion c) of the three noise conditions in order to have a measure for the agent and the intentionality detection task that was comparable over experiments. A RM-ANCOVA was conducted, with condition as within-subjects factor and experiment number as between-subjects factor. The five different measures (i.e., religiosity, RPBS, the Anthropomorphization Scale, the Short Intolerance of Uncertainty Scale and the Negativity Bias Scale) were taken into account as covariates. As the religiosity measure and the RPBS were more positively skewed (skewness = 2.12 and 1.23 respectively) than the suggested cut-off score of 1 (Field, 2009), we performed a log natural (LN) transformation on the data before they were added as covariates. After transformation, the skewness was 1.06 and 0.30 respectively. Although 1.06 is slightly higher than 1, another LN transformation did not change the interpretation of the results.

Results

Table 1 shows the within-subjects effects of the RM-ANCOVA (i.e., the interaction between condition and the covariates) and Table 2 shows the outcomes of the between-subjects effects (i.e., experiment and the covariates). None of the within-subjects effects were significant, indicating that over the included experiments, condition did not have an influence on the response bias and condition was also not systematically influenced by one of the covariates. With regards to the between-subjects effects, the type of experiment, as well as the Negativity Bias

[12] An ultimatum game is an economical decision game in which one player needs to divide money with a second player, who on its turn can either accept or reject the proposal. As a result, the money is split or neither player receives anything.

Scale, were significant covariates of the model. Thus, while holding the other variables constant, both the type of experiment and the Negativity Bias Scale were related to the response bias. An additional non-parametric Spearman rho correlation (to account for deviations in normality) indicated that the direction of the Negativity Bias Scale was in the predicted negative direction, implying that the response bias towards detecting agents increased with a stronger negativity bias. To investigate whether the covariate was still significant if the covariates were added independently, we conducted one additional RM-ANCOVA in which we independently added the Negativity Bias Scale as a covariate. The between-subjects effect of the Negativity Bias Scale remained significant, $F(1, 126) = 4.10$, $MSE = 0.18$, $p = .045$, $d = 0.36$, $\omega^2 < 0.01$. This additional analysis suggests that the negativity bias seems to have an independent relationship with the response bias. Finally, the type of experiment had a large effect on the response bias. This was mainly related to Experiment 3 (i.e., the geometrical figures experiment), in which the average response bias was negative (i.e., implying a response bias towards perceiving agents) whereas it was positive in the other experiments (i.e., implying a response bias towards perceiving absence of agents).

Table 1. *Within-Subject Effects of the Repeated Measures Analysis of Covariance, with Condition as Within-Subject Factor and Measures Associated with Agent Detection as Covariates, and the Response Bias (c) as Repeatedly Measured Dependent Variable.*

	SS	***df***	***MS***	***F***	***p***	***d***	**ω^2**
C	< 0.01	1	< 0.01	0.08	.779	0.06	< 0.01
C*LN_Rel	0.02	1	0.02	0.55	.461	0.13	< 0.01
C*LN_RPBS	< 0.01	1	< 0.01	0.06	.807	< 0.01	< 0.01
C*NB	0.03	1	0.03	0.57	.452	0.14	< 0.01
C*AS	0.03	1	0.03	0.69	.406	0.16	< 0.01
C*IoU	0.02	1	0.02	0.47	.495	0.13	< 0.01
C*Experiment	0.26	3	0.09	1.94	.127	0.44	0.01
Residual	5.32	121	0.04				

Note. Type III Sum of Squares. C = Condition, LN_RPBS = natural log natural transformation of the Revised Paranormal Belief Scale, LN_Rel = log natural transformation of the Religiosity measure, NB = Negativity Bias, A = Anthropomorphization Scale, IoU = Intolerance of Uncertainty.

Table 2. *Between-Subjects Effects of the Repeated Measures Analysis of Covariance, with Experiment as Between-Subjects factor, the Measures Associated with Agent Detection as Covariates, and the Response Bias (c) as Repeatedly Measured Dependent Variable.*

	SS	***df***	***MS***	***F***	***p***	***d***	**ω^2**
Intercept	0.56	1	0.56	3.13	.079	0.32	< 0.01
LN_Rel	0.56	1	0.56	1.16	.078	0.32	< 0.01
LN_RPBS	0.25	1	0.25	1.40	.239	0.21	< 0.01
NB	1.21	1	1.21	6.79	.010	0.47	0.01
AS	0.64	1	0.64	3.57	.061	0.35	< 0.01
IoU	0.47	1	0.47	2.65	.106	0.29	< 0.01
Experiment	3.58	3	1.19	6.69	< .001	0.81	0.37
Residual	21.56	121	0.18				

Note. Type III Sum of Squares. C = Condition, LN_RPBS = log natural transformation of the Revised Paranormal Belief Scale, LN_Rel = log natural transformation of the Religiosity measure, NB = Negativity Bias, A = Anthropomorphization Scale, IoU = Intolerance of Uncertainty.

Discussion

This explorative analysis revealed that, over the four experiments in which we included the questionnaires (i.e., Religiosity, RPBS, the Anthropomorphization Scale, the Short Intolerance of Uncertainty Scale, and the Negativity Bias Scale), supernatural beliefs (i.e., religiosity and the RPBS) were not related to increased agent detection, whereas the Negativity Bias Scale was related to increased agent detection. With regards to supernatural beliefs, these findings appear to be in contrast with the theoretical suggestions of authors who reasoned that a bias towards agent detection may underlie supernatural beliefs (e.g., Barrett, 2012; Barrett, 2000; Barrett, 2008). Other previous attempts to investigate whether a bias to detect agents have resulted in mixed findings (for a critical discussion, see van Elk et al., 2014). In the general discussion, we elaborate on the causes that may explain why we failed to find a relationship between supernatural beliefs and agent detection, for example, the relative lack of supernatural beliefs in our samples.

Interestingly, the negativity bias was related to increased agent detection. In line with earlier findings (e.g., Hamlin & Baron, 2014; Morewedge, 2009), this suggests that people who have a bias to interpret events as if they are negative, more often interpret ambiguous situations as if they are (caused by) agents. In other correlational studies, anxiety (Grzesiak-Feldman, 2007), and uncertainty (Prooijen & Jostmann, 2013) had already been linked to supernatural beliefs. However, this effect was not intensified in the threatening conditions. Thus, it may be that particularly anxiety-prone individuals try to compensate for their anxious feeling by applying false models to the world in order to perceive it in a more structured fashion (e.g., Landau, Kay, & Whitson, 2015). In addition, these findings again highlight the importance of individual differences when investigating agent detection (Barnes & Gibson, 2013). Finally, with regard to the finding that the response bias differed in Experiment 3 from the other Experiments, this is likely the result of the different means by which agent detection was operationalized. Compared to Experiments 1, 2 and 4, Experiment 3 differed because the dependent variable (i.e., the Geometrical Figures Task) was an operationalization of intentionality detection, whereas human agent detection was measured in the other experiments.

General discussion

The observed data are generally not in line with the notion that threatening conditions lead to a bias to detect human agents or intentionality in ambiguous situations compared to control conditions. Furthermore, in all experiments in which the dependent variable was operationalized in terms of human agent detection (Experiments 1, 2, and 4), participants had a bias towards responding that human agents were absent. This tendency to judge human agents as being absent decreased with increasing ambiguity of trials (i.e., with increments of noise). Only when the dependent variable was operationalized in terms of intentionality detection (Experiment 3), did participants show a small response bias towards perceiving intentionality, albeit close to zero. Further, by means of an explorative analysis, it was observed that individual differences on the negativity bias were related to agency detection. Below, we will discuss these findings in more detail. First, we argue that the data could still be compatible with HADD reasoning. Second, we discuss several concerns that may have prevented us from finding an increased response bias as a result of the threat manipulations. Third, we discuss the questionnaires in relation to agency detection. Finally, we discuss recommendations for future research.

At first sight, our findings may appear to diverge from HADD reasoning (e.g., Barrett, 2000). However, in all experiments, participants falsely detected agents in ambiguous stimuli such as point-lights, geometrical figures, and white noise. Over all the experiments this was the case in 26.1% of all the noise trials (i.e., half of all trials in which no agent was included). In addition, participants often perceived intentionality in moving geometrical figures, even if these were moving randomly. These observations converge with the findings of numerous other researchers (e.g., Liu, J Li, Feng, L Li, Tian, & Lee, 2014; Gosselin & Schyns, 2003; Nees & Phillips, 2015; van Elk, 2013; van Elk, Rutjens, van der Pligt, & van Harreveld, 2014; Scholl & Gao, 2013): People often perceive false agents and intentionality on the basis of ambiguous information. Thus, the data are still in support of the idea that humans easily detect human agents and intentionality in ambiguous information.

However, the data do seem to diverge from HADD reasoning in two respects. Firstly, apart from Experiment 3, participants consistently had a response bias towards detecting the absence of agents. Therefore, the term 'hypersensitive' agency detection device seems a bit misplaced. Secondly, mild to moderate feelings of threat did not change the response bias towards perceiving agents. Similarly, Hoskin et al. (2014) found stressful pictures to be unrelated to false alarms on a Speech Detection Task, a paradigm comparable to our Auditory Agent Detection Task. These observations appear to be in contrast with the predictions derived from error management theory (Haselton & Nettle, 2006; Johnson et al., 2013). Nevertheless, we raise several concerns for why we may have failed to find a threat-dependent agent detection bias in the presented experiments.

A first concern is that the threat manipulations used were not close enough to real-life threatening situations, leading to an insufficient level of threat elicited (i.e., a problem with ecological validity). On the one hand, comparable forms of threat manipulations used in Experiment 1 to 3 have been successfully used in a range of studies as a means of inducing a feeling of fear or threat in which cognitive processing was the dependent variable (e.g., Koster, Crombez, Verschuere, & De Houwer, 2004; Mogg, McNamara, Powys, Rawlinson, Seiffer, & Bradley, 2004; Van Damme, Gallace, Spence, Crombez, & Moseley, 2008; Schimmack, 2005; Yiend and Mathews, 2001). In the experiment with the highest anxiety ratings (i.e., the virtual reality experiment), the effects also did not support the idea that threat increases human agent detection. On the other hand, it may well be possible that at higher threat levels illusory agent detection is increased. Our study indicates, at the very least, that the term 'hypersensitive' seems inadequate. Specifically, it would follow logically from a hypersensitive agent detection device, that participants would jump to agent detection as a result of a small boost in anxiety. This was not observed in the present series of studies.

A second concern is the way in which agent and intentionality detection were operationalized. First, there was no intrinsic or direct relation between the threat manipulations (i.e., fearful pictures) and the dependent measures (i.e., biological motion stimuli). This may have decreased the likelihood that the threatening context generalized to the agent or intentionality detection paradigm. An advantage of the used tasks is that they yield clear signal-detection based estimates of the response bias and the perceptual sensitivity. At the same time, the signal detection stimuli were not intrinsically threatening at all. Perhaps, if cues of agents would have been immersed more strongly with the virtual reality scenario, like breaking branches within a threatening dark forest, this may have resulted in an increased false agent detection rate, compared to a non-threatening forest in daylight. Unfortunately, we were dependent on available virtual reality scenarios so such an experiment was not feasible, but it may be worthwhile for future researchers to use a more integrative approach to manipulate and assess agent detection. Secondly, it could be argued that the paradigms were not reflecting the detection of agents, but rather the detection of biological motion. This is indeed a concern for the first three experiments, but this argument does not hold for the virtual reality experiment, in which a real human agent voice was embedded within white noise. Again, it is problematic that this voice was relatively independent from the threat manipulation. In future studies, researchers could manipulate the emotional content of the dependent measures (e.g., by embedding a threatening voice in the auditory noise stimuli). Future researchers could also try to focus more on positive rewards, instead of threat. For example, it may be evolutionarily advantageous to detect agents when seeking help, or when looking for prey to eat.

A third concern is that the principles underlying error management theory do not fully apply to our experiments. For example, the theory predicts a bias towards the least costly error when there is an *imbalance* in the costs between both errors. On the one hand, it could be argued that none of the threats utilised in the present experiments posed an ecologically valid potential threat to participants. In follow-up studies, researchers could increase the imbalance of the potential costs and benefits of the errors, for example, by reducing the incentives for false negatives. Nevertheless, it could also be argued that only in the absence of an imbalance of error costs, can the error management theory be tested to be sure that the bias is implicit (McKay, personal communication). If the payoffs are asymmetric, then all people should show this bias purely on the basis of expected utility theory.

A final concern is that all conditions included markers indicative of human agents, as all stimuli were the product of intentional humans. This on its own may explain the null-findings observed. We agree that all man-made products reveal markers of agents, but we do want to stress that on a perceptual level, and within the context of the experimental paradigm, agency was objectively absent in the control conditions. Furthermore, the fact that increasing the ambiguity of the tasks (i.e., increases in distractors/ noise) resulted in lower *d* prime values, suggests that the participants were able to discriminate the presence of agents vs. the absence of agents within the well-defined context of the experimental task and paradigm that we used. Thus, it is unlikely that our observations were the result of participants over-detecting agency in the control conditions. Nevertheless, in future studies, researchers would benefit from trying to disentangle further the concepts of agents, agency, and intentionality, in relation to humanness.

With regards to the questionnaires, it is interesting that the supernatural belief scales (i.e., religiosity and the RPBS) were not significantly related to the response bias. However, this observation should be interpreted with caution, as an important limitation of our study is that the samples consisted of people scoring low on supernatural beliefs. Furthermore, it may be argued that scholars such as Guthrie and Barrett were not trying to account for individual variability in religiosity. On the other hand, an experimental psychological approach towards investigating the relationship between agency detection and supernatural beliefs has been proposed by Barrett and Burdett (Barrett & Burdett, 2011) and others (e.g., McKay & Whitehouse, 2015). Further, in previous studies from our lab, a relationship between supernatural beliefs and agency detection had been observed with comparable designs (e.g., van Elk 2013, van Elk et al., 2014). Interestingly, the Negativity Bias Scale was related to increased agent detection. In the discussion of the explorative analysis, it has already been explained that this is consistent with previous work by others (Grzesiak-Feldman, 2007; Hamlin & Baron, 2014; Morewedge, 2009; Prooijen & Jostmann, 2013). More generally, this individual difference measure is likely to have an effect on agent detection by influencing the expectations of people. Thus, future studies may shift the focus towards investigating individual differences (Barnes & Gibson, 2013), and more specifically, the expectations that people have when it comes to agency detection. For example, some people may expect there to be dangerous agents in the forest due to the movies they have watched, whereas other people who cycle through a dark forest every day may not expect dangerous agents at all. These individual differences should be taken into account when conducting studies on agent detection.

In conclusion, our study confirms previous research that people occasionally detect agents in ambiguous stimuli (in line with HADD reasoning). This study nuances the idea that we have a 'bias' towards agent detection (in contrast to HADD reasoning), as people generally did not detect agents and because mild to moderate threatening situations never intensified agent detection. Thus, the term 'hypersensitive' seems unwarranted. Moreover, the observations in the present study highlight the importance of further experimental investigation of the HADD and error management theory. Admittedly, our conclusions are preliminary, as we have outlined several concerns that may have prevented us from finding an effect of threat on the response bias. Summing up, this study contributes to the HADD literature by providing clear instructions for future research (in terms of the individual differences that should be taken into account and by providing recommendations for the design) and by revealing the boundary conditions under which agent and intentionality detection are not intensified.

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Chapter 3

FEELING THE PRESENCE OF AGENTS IN A VIRTUAL REALITY ENVIRONMENT

Two pre-registered experiments

This chapter is based on a paper that is still work in progress:

Maij, D. L. R., Van Schie, H., Van 't Veer, K., Amodio, D., M., Van Elk, M. (in progress). Feeling the presence of agents: Three pre-registered experiments.

Abstract

An evolved module for agency detection has been hypothesized to predispose supernatural beliefs. An underlying assumption of this theory is that ambiguous and threatening situations lead to increased sensitivity of the module, thereby fostering agency detection. We examined this hypothesis by instructing participants to report the detection of agents when they walked through virtual threatening (i.e., haunted house, threatening forest) and non-threatening environments (i.e., maze, non-threatening forest), while auditory (e.g., breaking branch) and audio-visual agency cues (e.g., falling branch), were presented. We observed that agency cues more frequently resulted in agent detection in threatening ambiguous than in non-threatening unambiguous environments (i.e., pilot and Experiment 1), but that the effect was strongly diminished when the ambiguity was kept constant (Experiment 2). The type of agents reported reflected context expectancies; in threatening forests participants report wolves and humans, and in the non-threatening forests birds and squirrels. We did not observe a relationship between supernatural beliefs and agency detection. We discuss that the findings are better accounted for by the predictive processing framework, that explains agency detection as the result of prior expectancies and bottom-up sensory processing, than by the idea that humans have an evolved agency detection bias.

Imagine that you are sitting at home watching a horror movie. As soon as the movie is finished and you are about to go up to your bedroom you suddenly hear the stairs squeak. It is possible that this will result in the feeling that someone (a murderer) or some being (an animal or even a ghost) is present. It turns out, however, that the noise was just the result of the old stairs and that you falsely detected the presence of an agent. Now suppose what would have happened if you walked up the stairs without having seen the threatening movie. We expect that in this case, you would not have interpreted the noise at all. Either because the noise did not reach your conscious awareness or because you would have interpreted the noise differently, such as having been caused by the oldness of the stairs. The aim of the present study is to investigate whether contextual threat makes people more likely to interpret stimuli in terms of being caused by intentional agents, such as people, animals or creatures.

The term 'agency detection' has been used to refer to the detection of agents (e.g., interpreting squeaking stairs as a murderer being present) as well as to the attribution of an intentional intervention of an agent (e.g., assuming that a volcano eruption was a punishment from God, Nieuwboer, van Schie, & Wigboldus, 2014). In the present study, we particularly refer to the first notion of agency detection. The apparent ease with which humans detect agency has been explained by several working mechanisms - not necessarily competing with each other. One mechanism, first proposed by philosophers such as Hume and Nietzsche, is that by default humans immediately interpret phenomena as being intentionally caused (Bornedal, 2010). This process has been termed ‘taking the intentional stance’ by Daniel Dennett (Dennett, 1987; Dennett, 2006). Another proposed mechanism is that due to the central importance of humans in our lives, we automatically infer the presence of humanness in many different situations (Guthrie et al., 1980; Guthrie, 1993). Yet another hypothesized mechanism is that agency detection stems from evolved cognitive capacities to detect predators and preys (Boyer & Bergstrom, 2011; Öhman & Mineka, 2001). The latter two ideas build on error management theory, according to which cognitive biases are to be explained as being the evolutionary result of an imbalance between the costs and benefits associated with making specific errors, whereby committing the least costly error is favoured (Moscarello & Hartley, 2017; Nola, 2014). For instance, in the case of predators and preys, an organism may be better off with a bias towards false positives (i.e., detecting agents that are not there) which costs some energy, than a bias towards false negatives (i.e., failing to detect agents), which could potentially cost its life (e.g., Moscarello & Hartley, 2017). Following this reasoning, we may understand how over thousands of years, humans and animals could have developed a sensitivity towards detecting intentional agents (Barrett, 2012; Barrett, 2000).

A final and encompassing working mechanism with which agency detection phenomena are explained is by means of predictive processing (Andersen, 2017; Andersen, Pfeiffer, Müller, & Schjoedt, 2017; Schjoedt & Andersen, 2017; van Elk & Aleman, 2016; Van Leeuwen & van Elk, 2017). The general idea of predictive processing is that the way we, and all other agents, perceive and make judgements about the environment is not a passive process. It rather results from a combination of top-down prior predictions and bottom-up sensory processing (Friston, 2005; Friston & Kiebel, 2009; and see Firestone & Scholl, 2016 for a discussion on the role of top-down effects on perceiving vs judging). The predictions brains make are based on cognitive models, which are the result of life-long interactions with the environment. These predictions are compared to the incoming sensory input. This all happens in a hierarchical fashion, whereby models of higher layers try to predict the input of lower layers (Friston, 2005; Friston & Kiebel, 2009). Discrepancies between predictions and sensory input result in prediction errors, by which the prediction models are updated (Clark, 2013).

Ultimately, contexts can trigger predictions for perceiving certain phenomena, influencing our judgement and possibly even the perception of these phenomena (Pajani, Kok, Kouider, & de Lange, 2015, but see Firestone & Scholl, 2016). For example, if you are home together with your partner who just left the living room, it is a logical judgement that the noise from the squeaking stairs was caused by your partner walking up the stairs. Similarly, if you just watched a horror movie in which you were absorbed, it may be an equally logical judgement of the brain to predict some type of dangerous agent causing the stairs to squeak. Moreover, due to the increased anxiety the brain is likely to be much more attentive on interpreting bottom-up sensory input from the environment (Capitão et al., 2014; Hoskin, Hunter, & Woodruff, 2014; Koelsch et al., 2013; Moscarello & Hartley, 2017; van Marle, Hermans, Qin, & Fernández, 2009), especially when living creatures are involved (Mermillod, Droit-Volet, Devaux, Schaefer, & Vermeulen, 2010). On the contrary, chances are that the noise of the stairs caused by your partner did not even reach your attentional awareness.

An important brain area involved in directing attention to the environment and likely mediating the presumed effects of threat on agency is the amygdala. The amygdala is thought to play an important role in identifying and directing attention to relevant stimuli on the basis of low-level perceptual input (Adolphs, 2008; LeDoux, 2000; Moscarello & Hartley, 2017; Phillips & LeDoux, 1992). The amygdala was also activated when detecting goal-directed motion (Bonda, Petrides, Ostry, & Evans, 1996). The amygdala has further been found to be especially responsive to looming threats of agency, such as approaching animals (Coker-Appiah et al., 2013). In addition, functional connectivity between the amygdala and face-related areas was increased for threatening as opposed to non-threatening faces (Miyahara, Harada, Ruffman, Sadato, & Iidaka, 2011; Spechler et al., 2015). Importantly, under circumstances of threat, amygdala activation appears to result in heightened attentive sensitivity (Koelsch et al., 2013; van Marle et al., 2009).

Thus, we may expect that a threatening context can drive attention to the environment, and as a result of top-down predictions, this could lead to an increased response bias to stimuli that are contextually relevant. In a windstorm, we might be more likely to have false positives for falling bricks and in a scary forest we might be more likely to have false positives for threatening animals or people (Andersen, 2017). In a virtual reality forest, participants have been found to more frequently have false positives regarding the presence of agents when their priors were elevated, and conversely, fewer false positives when their priors were lowered (Andersen et al., 2017). Increasing and decreasing ambiguity also resulted in more or fewer false alarms respectively, although the effect was much smaller. Similarly, people might have a response bias towards detecting agents such as murderers after having seen a horror movie. Preliminary evidence for the idea that general fear could increase agency interpretation can be found in a study, in which participants listened to fearful music, making them more inclined to interpret ambiguous objects as agents than while listening to control music (Prinz & Seidel, 2012). Building on all previous studies, we aimed to investigate whether manipulating the amount of contextual fear increases attentiveness, thereby affecting the amount and type of agency that is detected.

Agency detection and supernatural beliefs

Apart from our goal to illuminate the influence of contextual threat on agency detection and interpretation, we aim to make a contribution to the literature on the foundations of supernatural beliefs (i.e., the so-called cognitive science of religion (Barrett & Burdett, 2011; Xygalatas, 2014), by investigating the relationship between agency detection and supernatural beliefs. Scholars from this research niche have hypothesized that a universal agency detection bias may facilitate beliefs in supernatural agents (Barrett, 2012; Barrett, 2000). For this reason, the influence of a range of contexts on agency detection has mostly been explored by scholars from the cognitive science of religion. For example, in one correlational study (Barnes & Gibson, 2013), researchers found that especially threatening and ambiguous environments were related to supernatural agency occurrences (e.g., perceiving a ghost in a dungeon). In another study, supernatural beliefs were found to be correlated to whether participants believed a house was haunted (Dagnall, Drinkwater, Denovan, & Parker, 2015).

In experimental studies, the relationship between agency detection and belief in supernatural agents yielded mixed findings. In one study, listening to threatening music as opposed to relaxing music increased the amount of agents participants reported in random visual white noise, but no relationship between agency detection and supernatural beliefs was observed (Hennig & Van Schie, in progress). In another study, mixed findings were observed. Supernatural believers did not perceive more stimuli in random noise, but they were quicker to respond to stimuli and where more confident of their guesses (Simmonds-Moore, 2014). In contrast to these findings, in a previous series of experiments from our lab, threat induction did not result in increased false agent detection and agency detection was also not related to individual differences in supernatural beliefs (Chapter 2). What is more, participants did not seem to have an agency detection bias at all, as shown by the absence of an overall response bias to detecting agents across the different experiments. We note that the absolute anxiety ratings in response to the threat cues in previous studies were low to moderate and the agency detection operationalizations were conceptually far removed from the threat manipulations. The inconsistent findings and the shortcomings of previous attempts highlight the importance of re-investigating whether people have an agency detection bias in the first place and whether agency detection is indeed related to supernatural beliefs - as hypothesized by the HADD account of religion. This was the second aim of the present study.

In the present study, we addressed most limitations of our previous series of studies (Chapter 2) by using a combination of virtual reality and threatening music to induce threat. In addition, multimodal (i.e., visual cues combined with sound) and auditory agency cues were presented to trigger the perception of agents. Agency detection was measured by asking subjects to press on a button when they had the feeling that an agent was present in one of two virtual reality scenarios' (i.e. threatening vs. non-threatening context) through which they were walking with a joystick (i.e., Pilot study) or by physically walking (i.e., Experiments 1 and 2). Agency interpretation was measured by asking participants what type of agents they detected. In the threatening scenario, participants walked through a scenario programmed to elicit anxiety (i.e., Pilot study: a ghost house, Experiments 1 - 2: threatening forests), while they were listening to threatening music[13]. In the control scenario, participants walked through a non-threatening scenario (i.e., Pilot study: a maze, Experiments 1 – 2: non-threatening forests), while they were listening to non-threatening relaxation music[14] (Seinfeld et al., 2016). In all experiments (apart from the pilot), a set of four multimodal agency cues (dust cloud, falling branch, rolling tumbleweed and thunderclap) and a set of four auditory agency cues (snapping branch, water splash, rustling bushes and collapsing foliage) were presented in each condition. During the experimental task, we measured subjective ratings of anxiety (Chapter 2) and feelings of control (Barrett & Johnson, 2003) by means of a questionnaire as well as objective measures of anxiety by means of physiological heart rate measures. We also measured participants' subjective attentiveness (Experiment 1 – 2) in order to determine whether attention mediates the relationship between threat and agency detection. All experiments were pre-registered (https://osf.io/dzxej/).

In short, we investigated whether contextual threat increased agency detection and changed agency interpretation. Following the logic from HADD theory and predictive coding, the agency cues in both forests could potentially trigger the perception of agents and hence result in more button presses. From HADD theory, we expected more hypersensitivity, as reflected by more button presses, in a threatening compared to a non-threatening context. Barrett (2010) for example wrote, "*The degree of sensitivity may vary depending upon the degree of 'urgency' for survival in the context. If life and limb are on the line, the ADD may become particularly hypersensitive to evidence of agency." [page 3].* Following the predictive coding framework, we expected that threatening contexts, by implicitly changing the prior expectations of the type of agents people can expect (i.e., animals in a forest), should result in the detection of more threatening agents than non-threatening contexts (e.g., a wolf compared to a squirrel). We further expected that there would be a positive relationship between threat, attention and agency detection. Similar as in our previous study on the relationship between threat and agency detection (Chapter 2) we expected a relationship between the negativity bias and agency detection. A negativity bias reflects a tendency to attend to negative outcomes instead of positive (Fessler, Pisor, & Navarrete, 2014). To control for suggestibility and demand characteristics that may explain effects of top-down expectations on perceptual judgments (Firestone & Scholl, 2016), we included the White Christmas Task (Merckelbach & van de Ven, 2001; van de Ven & Merckelbach, 2003). Participants have been found to report to hear Bing Crosby's 'White Christmas' in white

[13] https://www.youtube.com/watch?v=Dp3BlFZWJNA
[14] https://www.youtube.com/watch?v=mY4IzALikd4

noise, when they were told that this song was present in white noise – while it was actually absent (Merckelbach & van de Ven, 2001; van de Ven & Merckelbach, 2003). With regard to supernatural beliefs, we expected a relationship between general supernatural beliefs and personal beliefs (as measured with the survey of anomalous experiences [SAE]) on the one side and agency detection on the other side.

Pilot study

Methods

Participants. To determine the sample size, a power analysis was conducted using G-Power (version 3.1.9.2; Faul, Erdfelder, Buchner, & Lang, 2009). Given a small effect size of d = 0.30, an alpha of .05, and a power of .80, the required sample size was 34 for a RM-ANOVA with two within-subjects measurements. Thirty-five participants were recruited via the University of Amsterdam and via social media; they were mostly highly educated and scored generally low on religious beliefs (M = 1.8, SD = 1.5, range = 1 – 2). Three participants did not finish the experiment; two due to motion sickness, one participant was afraid of the threatening virtual reality scenario, which we had to warn for in the information voucher due to ethical considerations. The data of two participants were not recorded due to human failure, leaving 30 participants (M age = 22.6, SD age = 7.4, 86.2% female). The experiments were conducted in the behavioral lab of the University of Amsterdam. Psychology students received research credits, whereas students from other departments received five euros for participation. The ethics committee of the University of Amsterdam approved the experimental protocol under the terms that we stressed to participants that the manipulation could elicit fear and motion sickness and that they could raise their hand whenever they wanted to quit the experiment.

Manipulation. In order to manipulate anxiety, demo versions of two virtual reality scenarios were presented on the Oculus Rift development kit 2 (Oculus VR; Irvine, CA, USA). In the threatening condition, participants walked through a haunted house (Affected, the Mansion, Fallen Planet Studios, Southport, United Kingdom, see Figure 1, left picture for a screenshot). Participants started in an elevator that stopped at a floor. There, they entered a hallway where paintings (portraying humans) were present. Two of the rooms of the house could be entered and in one of the rooms was a moving table (it floated above the ground). In the non-threatening control condition, participants walked through a randomly generated maze (Endless Labyrinth, EndlessLabyrinthVR.com, Mike Porosser, private developer, see

Figure 1, right picture for a screenshot). There were several statues of agents (e.g., a lion). Throughout the maze diamonds could be collected as tokens. We replaced the original music. During the threatening condition, threatening music was presented (i.e., a part of Hermann's Pscycho[15] followed up by the prologue of Loduca's Army of Darkness[16], which were combined using Audacity; 2.0.5, Boston, MA, USA). During the non-threatening condition, jazz music[17] was presented. Throughout the music, short sound fragments were presented that could indicate the presence of agents in both conditions. These consisted of two slamming doors, two breaking branches and two rustling leaves and they were presented after every 45 seconds. When these were presented, the music was attenuated, so that the sounds would be noticeable to an equal extent in both conditions. The sound fragments were combined with the music by using Audacity.

Participants navigated five minutes through each scenario. However, as their non-writing hand had to be held still for GSR measures and their writing hand was occupied with the Response Button Task, an experimenter navigated the participants through the scenario by means of a joystick that was placed in another room. This also allowed us to keep the path participants walked in the threatening condition constant (note that this could not be done for the maze as it was randomly generated).

Figure 1. Screenshots from the virtual reality scenarios used in the pilot study.

Note: In the left picture, a screenshot is presented of the threatening scenario from The Mansion - Affected (Affected, the Mansion, Fallen Planet Studios, Southport, United Kingdom). In the right picture, a screenshot is presented for the non-threatening scenario from Endless Labyrinth (Endless Labyrinth, EndlessLabyrinthVR.com, Mike Porosser, private developer).

[15] https://www.youtube.com/watch?v=qMTrVgpDwPk
[16] https://www.youtube.com/watch?v=PQsjf25V9t8&list=PL6DC218A18B7B5CBD
[17] https://www.youtube.com/watch?v=mY4IzALikd4

Experimental paradigms. ***Agency Detection.*** To measure the frequency of agency experiences, participants had to press the response button each time they felt the presence of an agent during the five minutes that they walked through the scenario. Specifically, they were instructed to press when they felt the presence of a person, animal or creature, as there is no direct translation of 'agent' in Dutch. This task was programmed and responses were recorded using Presentation software (V.16.2, Neurobehavioral systems, Albany, CA, USA).

Suggestibility and demand effects. We used a 'White Christmas Task' (Merckelbach & Van de Ven, 2001) as a behavioral measure of suggestibility and demand effects. In this task, participants are asked to press a button on a response box whenever they heard Bing Crosby's 'White Christmas' in white noise while in fact only white noise was presented for three minutes. Before white noise was presented, participants had to listen to the song for 30 seconds, so that they remembered what the song was like. Participants were told that the task provides a measure of auditory sensitivity, which we needed to know because we used sound fragments with different volumes during the virtual reality conditions. We stressed that participants had to trust their intuition and that there were no right or wrong answers.

Questionnaires. Considering the overlap between the questionnaires in the present study and our previous attempt to investigate the relationship between threat and agency detection (Chapter 2), several parts of this study were similar to our earlier studies.

Manipulation checks. *Threat.* Threat was measured with six items (e.g. '*to what extent did you feel tense during the task?'*) from the anxiety subscale of the Positive and Negative Affect Scale (PANAS; Watson & Clark, 1988). Participants had to rate different feelings by indicating to what extent they were applicable to them on a five point Likert-scale (1 = not at all, 5 = to a strong extent). The reliability was adequate, Cronbach's Alpha (α) = .81.

Control. Feelings of control were measured with a single item: '*How much control did you experience during the task?*' (Rutjens, Van Der Pligt, & Van Harreveld, 2010, 1 = none, 7 = a lot).

Covariates. *Religious beliefs.* Religious beliefs were measured with four questions on a 7-point Likert scale (1 = not at all, 7 = very much/often): *'To what extent do you consider yourself to be religious', 'To what extent do you belief in the existence of god', 'How often do you visit a religious institution or meeting?'* and *'How often do you pray*'. The reliability was adequate, α = .91.

Spirituality. Spirituality was measured with two questions*: 'To what extent do you consider yourself to be spiritual?'* and '*To what extent do you believe in a higher power*? The reliability was adequate, α = .85.

Paranormal beliefs. Paranormal beliefs were measured with the revised paranormal belief scale (RPBS; Tobacyk, 2004). Participants had to rate the 26 items (e.g., *'Reincarnation exists'*) by indicating to what extent they believed the statement was true on a 7-point scale (1 = strongly disagree, 7 = strongly agree). The reliability was adequate, α = .94.

Negativity bias. The negativity bias was measured with the three-item Beliefs in the Dangerousness of the World Scale (Fessler et al., 2014; Navarrete, 2005). Participants rated items (e.g., *'I often fear for my own safety')* in terms of the extent to which they thought that these were applicable to them on a nine-point scale (1= totally disagree, 9 = totally agree. The reliability was adequate, α = .75.

Exploratively, we added the Intolerance of Uncertainty Scale and the Antropomorphism Scale (see the supplementary material).

Physiological measures. Physiological responses were measured with a custom-made amplifier developed by the technical support group of the UvA psychology department. For skin conductance, the amplifier used a 50Hz, sine-shaped excitation voltage with an amplitude of 1Vpp. A pair of curved Ag/AgCl electrodes (20 x 16 mm) were connected to the medial phalanxes of the middle and index finger of the non-dominant hand. Electrocardiogram (i.e., heart rate) was measured using a set of three Ag/AgCl electrodes (3M Red Dot disposables). Both signals were sampled with Vrssp98 version 8.5 software (developed by UvA's technical support department) and a NI-6224 A/D converter with a sample speed of 1000S/s.

Procedure

Participants read a cover story in which they were told that people are generally good in feeling the presence of other agents (e.g., feeling that someone is watching). We explained that in view of current developments in virtual reality we were interested whether this feeling could translate into the virtual world. We told participants that we manipulated the virtual reality scenarios in such a way that they could not see other agents as we had made them transparent. We explained that participants should press the response button each time they felt the presence of another being in the virtual reality world. We stressed that they should trust their intuition and should not think too long. When participants confirmed that they understood the task, they were first placed in a practice scenario, so that they could get acquainted to virtual reality and could practice with being navigated around by the experimenter. In this scenario, the Operating Room Environment[18] (Arch Virtual, Madison, Wisconsin, US), participants could walk around in an operating room. After both conditions, participants had to fill in the anxiety and control questionnaires. After the second condition ended, all physiological measures were taken off and they filled in the remaining questionnaires. Finally, participants were debriefed about the true purpose of the study.

Data analysis

The scores on the manipulation checks (i.e., anxiety and control) between the threatening and the non-threatening condition were compared with paired-samples *t*-tests. Then, a RM-ANOVA was conducted with button presses as dependent variable, condition as within-subject variable and counterbalance order as between-subjects factor to investigate whether counterbalance order had an influence on the number of button presses. In case the between-subjects factor was non-significant, counterbalance order was removed from the analysis. Then a RM-ANCOVA was conducted in which the centered (i.e., score – mean) scores of religiosity, the Negativity Bias Scale and the White Christmas Task were added. Data processing was done in R (R Development Core Team 2017, Version 3.3.3.) and analyses were conducted in JASP (JASP Team, 2017, Version 0.8.3.1.).

Results

Manipulation checks

The manipulation checks indicated that participants were successfully manipulated to feel more anxious, $t(29) = 5.93$, $p < .001$, $d = 1.08$, and less in control, $t(29) = 3.20$, $p = .003$, $d = 0.59$, in the threatening condition (anxiety $M = 2.97$, $SD = 0.75$; control $M = 3.73$, $SD = 0.65$) than in the non-threatening condition (anxiety $M = 1.92$, $SD = 0.65$; control $M = 4.63$, $SD = 1.56$).

Main analyses

The RM-ANOVA with counterbalance order as between-subjects factor indicated that the counterbalance order did not affect the number of times the buttons were pressed, $F(1,28) = 0.04$, $MSE = 34.73$, $p = .846$, $\eta^2 < 0.01$, $\omega^2 < 0.01$. There was also no interaction

[18] https://www.youtube.com/watch?v=8q_GpFta7mY

between counterbalance order and condition, $F(1,28) = 1.45$, $MSE = 18.15$, $p = .239$, $\eta^2 = 0.03$, $\omega^2 = 0.01$. Therefore, the between-subjects factor counterbalance order was removed from further analyses.

The outcomes of the RM-ANCOVA are provided in Table 1, and a graphical representation of the outcomes is provided in Figure 2. As expected, there was a large effect of condition (Cohen, 1992); participants more often reported feeling the presence of agents (as indicated by the Button Press Task) in the threatening as opposed to the non-threatening condition. With regard to the covariates, we observed a significant between-subject effect for religiosity. Thus, the higher the scores on religiosity were, the more agents participants generally reported. We further observed no interactions between all covariates and condition.

Table 1. *Outcomes of the RM-ANCOVA for the pilot study, with number of agency reports as dependent variable, condition as within-subject factors, and the questionnaires as covariates.*

Factor	***df***	***MS***	***F***	***p***	**η^2**
Within-subjects					
C	1	350.64	17.96	< .001	0.41
C ∗ Religiosity	1	0.04	<0.01	.964	<0.01
C ∗ NB	1	0.01	<0.01	.982	<0.01
C ∗ WCT	1	14.25	0.73	.401	0.02
Residual	25	19.52			
Between-subjects					
Religiosity	1	222.31	9.42	.005	0.25
NB	1	4.33	0.18	.672	0.01
WCT	1	61.47	2.60	.119	0.07
Residual	25	23.61			

Note. C = condition (threatening vs non-threatening); NB = the Negativity Bias Scale; WCT = the White Christmas Task.

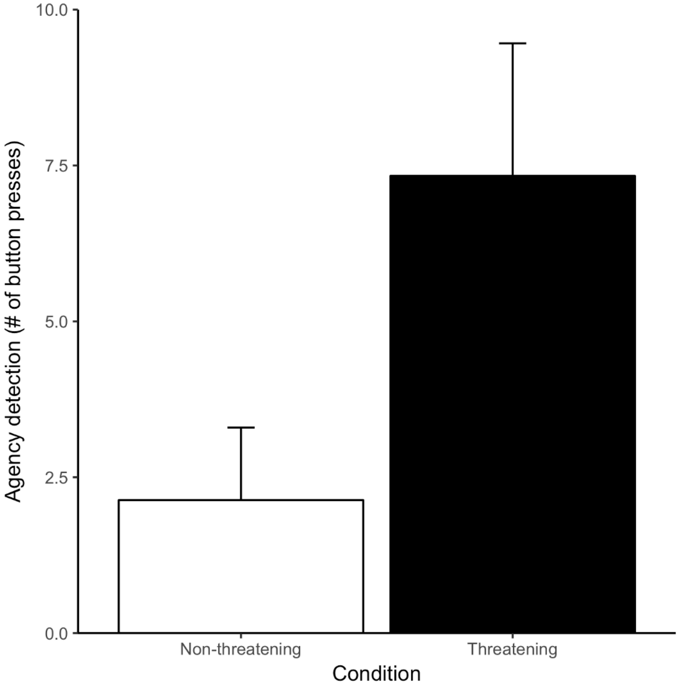

Figure 2. Graphical representation of the outcome of the RM-ANCOVA of the pilot study.
Note. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the condition (i.e., threatening vs. non-threatening). The error bars represent 95% confidence intervals.

Discussion

We found higher anxiety ratings and participants reported more agency experiences in the threat compared to the control condition. Further, people scoring higher on religiosity generally seemed to report more agency experiences. However, the overall level of religiosity was generally low: only three people scored 2 (i.e., 1 = not at all) on a scale from 1 to 7. Visual inspection of the correlation plot showed that these three participants mainly drove the correlation. In a previous attempt to investigate the effects of threat on agency detection, our manipulation was insufficiently anxiety provoking and the ecological validity was low (Chapter 2). In the present study, our strategy was to maximize the anxiety-provoking nature of the threat-condition to increase the effect of threat on agency detection. If this manipulation would not cause an effect in a pilot study, then it would be questionable whether anxiety is related to agency detection.

As a result of our strategy to maximize the difference between both conditions, however, there were obvious limitations and accordingly it remains difficult to establish which factor was driving the effect on agency detection. First, comparing the haunted house with the maze demo may have been problematic. In a haunted house, agents are more likely to be expected than in a maze. We did try to artificially reduce this expectancy-effect by means of the cover story, in which we told participants that in both conditions an equal number of agents was made transparent. Additionally, in the haunted house, a moving object was present (i.e., a moving table), suggesting the presence of invisible agents, whereas in the maze, moving objects were absent. Furthermore, the haunted house was somewhat darker, and therefore more ambiguous than the maze, while ambiguity has been shown to increase subjective agency detection in a virtual reality forest (Andersen et al., 2017). The sounds used may have been problematic. In the threatening sound, there were more abrupt changes in the pitch, possibly inducing startle reflexes, whereas the changes in the non-threatening sound were more gradual. Finally, the ecological validity was still rather low. Participants sat still on chairs while the experimenter navigated them, which can also lead to motion sickness.

Nevertheless, the results from the pilot study were promising, so in Experiment 1 efforts were taken to reduce the above confounds that could have contributed to the effects observed. First, a virtual reality programmer was included to create two virtual reality scenarios that were more similar to each other. Specifically, two comparable forests were created, as forests have been used previously in the context of hypersensitive agency detection (Andersen et al., 2017) and forest environments make sense from an evolutionary perspective (van Elk, 2013). One of the forests had a threatening appearance, while the other had a non-threatening appearance (see Figure 3). Secondly, different, more gradual background music was used. For the threatening scenario, we used ambient horror music[19], while we used meditating music for the non-threatening scenario[20,21]. Similar sounds for comparable manipulations have been used by Hennig & Van Schie (in progress). Thirdly, the ecological validity was significantly boosted. By using another virtual reality set supporting room-scale body movements (HTC Vive, HTC America Inc., WA, US), participants physically walked through the environment, instead of using a joystick, which also reduced motion sickness.

[19] https://www.youtube.com/watch?v=AlDivIaiuMU
[20] https://www.youtube.com/watch?v=suW_Fhv9wPU
[21] By accident, we pre-registered the background music used in a previous study (i.e., Chapter 2).

Eight other changes were made. First, to increase the variability in supernatural beliefs, half of the participants we recruited were participants who indicated to have some 'affiliation with supernatural beliefs'. Second, we measured religiosity with a more standardized measure and made a distinction between general supernatural beliefs (i.e., the Supernatural Belief Scale, Jong, Bluemke, & Halberstadt, 2013) and supernatural interpretations (i.e., the survey of anomalous experiences, Irwin, Dagnall, & Drinkwater, 2013). Third, to investigate whether the contextual setting influenced the type of agents participants detected, we asked them what type of agents they reported at the end of the experiment. Fourth, we added questions aimed at measuring the ecological validity of the scenarios. Fifth, we no longer used GSR, as this conflicted with walking around. Sixth, we increased the power by testing 100 participants in a within-subjects design to be able to draw conclusions about the covariates with more certainty. Seventh, we presented the manipulation check questionnaires within the virtual reality environment, to keep participants immersed within the virtual reality conditions while they responded to questions about the feelings the virtual reality environment elicited (Seinfeld et al., 2016). Eighth, we no longer told participants that there were transparent agents, as we only did this to try to induce similar expectations regarding the frequency of agents that participants could encounter in both demo scenarios.

We expected that: 1) a feeling of threat (i.e., anxiety) would result in increased sensitivity (i.e., attention) to agency cues in the threatening compared to the neutral context, resulting in more frequent button presses in the threat condition; 2) top-down expectations about the threatening forest would result in a more threat-related interpretation of the type of agents perceived (e.g., wolves compared to squirrels); 3) we expected the following individual differences: SBS, SAE, suggestibility, negativity bias, and general anxiety, to correlate positively with agency detection; 4) people's acquaintance with forests was expected to be negatively correlated with agency detection; 5) if people report to feel the presence of supernatural agents, we expected that the frequency of these interpretations would be more strongly correlated with the survey of anomalous experiences (i.e., supernatural interpretations) than the supernatural belief scale (i.e., general supernatural beliefs); 6) we had no specific expectation which type of cue would be related to more frequent agency interpretations. We pre-registered our experimental plan and all hypotheses on the Open Science Framework (see https://osf.io/nwmku/ and https://osf.io/jncb3/).

Figure 3. Screenshots from the virtual reality scenarios used in Experiment 1.

Note: The top picture represents the forest in the threatening scenario, the bottom picture represents the forest in the non-threatening scenario.

Experiment 1: reducing confounds from the pilot study

Methods

Participants

One-hundred participants were recruited of which 50 participants reported to have affiliation with supernatural beliefs (i.e., they answered ‘yes’ on the question whether they had affiliation with supernatural beliefs). The participants were recruited via the website of the University of Amsterdam and via social media. The virtual reality data of three participants were not saved due to human failure. One participant indicated to not have understood the task and was dropped from analysis. This left 96 participants (*M* age = 24.1, *SD* age = 8.1, 53.6% female).

Experimental manipulation

In order to manipulate anxiety, two different VR forests were developed (see Figure 3 for screenshots) and one small forest environment. This small environment was used for letting the participants get accustomed to VR and the procedures, and was always presented first. Two larger environments formed the experimental conditions. The threatening forest had a threatening appearance as it took place during nighttime (i.e., illuminated by the moon) and was decorated with swamp-like lakes and dead spiky foliage. The other forest had a non-threatening appearance, as it took place during daytime (i.e., illuminated by the sun) and was decorated with rivers and live leafy foliage. The luminance of both forests was attempted to be equalized by shadowing the daytime forest with broad leafy branches extending from the trees, while lighting the nighttime forest with a very strong moonlight in the absence of leafy branches obstructing the light. In the threatening environment, ambient horror music played in the background[7], while in the non-threatening environment, meditation music was played[8]. Agent voices (e.g., crying wolves) were absent in all background music. The environments were programmed using Unreal Engine (Unreal Engine 4.15, Epic Games, NC, US). The environments were presented on the HTC Vive VR headset (HTC Vive, HTC America Inc., WA, US) and sounds were presented via over-ear headphones. The experiment took place in in a 4.3m by 4.3m surface of a larger room.

Experimental paradigms

Agency detection. Similar as in the pilot study, a Button Press Task was used to measure agency detection. Participants carried a single handheld HTC Vive controller, with two functioning buttons. The trigger button (pressed with the index finger) was used to report the felt presence of agency, the directional tracking (pressed with the thumb) was used to fill in the questionnaires that were presented at the end of each condition within the VR environment. Movement throughout the environment was performed by physically walking through the room. Due to the surface restrictions, the virtual environments were invisibly divided into areas of the same size. Each virtual "room" of the experiment contained a curved path spanning most of its space. Right before the path ended at the edge of the invisible room, a small tree trunk was placed on the floor that seamlessly teleported the participant to the next virtual room. By doing so, participants were still able to navigate through a large virtual environment by repeatedly walking through the same physical area. As there was no support for a wireless system at the time of the experiment, participants performed the experiment without shoes, in order to prevent tripping over the headset cable. While walking through both experimental conditions, participants were presented with eight triggered agency cues, of which four were auditory and four multimodal (see Table 2). These cues were triggered by invisible collision boxes. When a participant collided with this box, the events tied to that cue were initiated. When participants pressed the button (i.e., reported feeling the presence of agency) more than four seconds after a cue, we considered the agency report as being spontaneously triggered. Otherwise the response was labeled as triggered by the cue. Markers were sent at each agency report, cue and teleportation from Unreal Engine 4 on the stimuli computer to Vsrrp98 on the auxiliary computer using a COM-interface in order to be able to integrate this information with the heart measurements (see below). We recorded walking times and the X, Y and Z coordinates of the head movements.

Table 2. *Description of the eight cues that were presented in each of two experimental virtual reality environments.*

Cue type	Cue name	Effects
Audio	Snapping branch	Sound of a snapping branch sounds from the direction of a nearby branch on the floor.
Audio	Water splash	Sound of an object falling into the water sounds from the direction of a nearby body of water.
Audio	Rustling bushes	Several seconds of rustling sound from the direction of a nearby bush.
Audio	Collapsing foliage	Sounds of collapsing branches and foliage sound from the direction of nearby tree leaves.
Multimodal	Dust cloud	A small dust cloud emerges from a nearby mushroom, together with a soft sound of excretion.
Multimodal	Falling branch	A small branch attached to a nearby tree falls down using real-time physics. Makes a sound on release and on impact.
Multimodal	Tumbleweed	A small bush nearby releases from the ground and rolls off. Makes sounds on release.
Multimodal	Thunderclap	A thunderbolt strikes in distant mountains in front of the participant. Makes a loud thunderous sound and also emits environmental light during its three short flashes.

Suggestibility and demand effects. As in the pilot study, the White Christmas Task was used to measure suggestibility to control for demand effects.

Questionnaires

Manipulation checks. After each condition, the manipulation checks were presented on a screen within the virtual reality environment, while the participants were still immersed in the forest.

Threat. Similarly as in the pilot, threat was measured with six items from the anxiety subscale of the Positive and Negative Affect Scale. We added two items to the scale (i.e., feelings of control and anxiety). The reliability was adequate, for both the threatening $\alpha = .89$ and the non-threatening condition, $\alpha = .87$.

Ecological validity. As a subjective indication of how real the virtual reality environment felt to the participants, they responded to two items (the questions were derived from, Seinfeld et al., 2016) that were measured on a continuous scale from 0 to 1. 1) *"During the simulation I felt present in…* (0 = the university laboratory – 1 = the virtual environment"). 2) "*The forest felt real to me…* (0 = not a moment – 1 = the entire time").

Presence of agency. Participants responded to two items that referred to the presence of agency and were measured on a continuous scale from 0 to 1) *"To what extent did you feel that you were alone in the forest?* (0 = I did not feel alone – 1 = I felt alone). 2*)* *"To what extent did you really feel that other people/animals/creatures* (i.e., agents) *were present in the forest?* (0 = Not at all – 1 = to a strong extent). The reliability was adequate for both the threatening $\alpha = .80$ and the non-threatening condition, $\alpha = .80$.

Attention. Participants responded to two items that referred to the amount of attention they had for their environment and these were measured on a continuous scale from 0 to 1. 1) *"How much attention did you pay to the virtual reality scenario?"* (0 = No attention at all – 1 = a lot of attention). 2) *"How much attention did you pay to the sounds?"* (0 = No attention at all – 1 = a lot of attention).

Acquaintance with forests. How acquainted people are with forests in general was measured with a single item (*"We would like to know how often on average you been in forests in your life"*) with a 6-point Likert scale (1 = once a year, 2 = multiple times per year, 3 = once a month, 4 = multiple times per month, 5 = once week, 6 = multiple times per week).

Heart rate measure. A Polar H7 (Polar Electro Netherlands B.V., Almere, Netherlands) unit was used for measuring heart rate in combination with the software

Vsrrp98, programmed by the technical department of the University of Amsterdam (Molenkamp, 2011). The setup was divided between two computer systems. One computer was used for running Unreal Engine to deliver stimuli, carrying hardware for powerful graphics performance (Core i7 6700K, GeForce GTX 1080, 32GB RAM), while the White Christmas Task and the heart rate measurements were performed on another computer.

Qualitative data. ***Type of agents.*** At the end of each condition participants arrived at a sign with a microphone icon and they were instructed to say out loud what type of agents they had detected. The experimenter wrote down what type of agents the participants reported. In the subsequent experiments, we audio recorded these responses. To categorize the reported agents, we classified all comments in a categorization scheme on two characteristics; the type of agent (i.e., animal, human, something) and on the type of affect (i.e., threatening, non-threatening, unclear). We only classified the affect of an agent when the affect was clear. For example, when participants reported that there was a 'scary animal' or a predator (e.g., a wolf), agents were marked as having a threatening affect. At other times, when participants reported that there was 'someone' or 'an animal', we marked the affect as being unclear. All responses were categorized independently by two of the authors (DLRM and MvE) and inter-rater reliabilities were calculated.

Covariates. ***General beliefs.*** General religious beliefs were measured with the Supernatural Beliefs Scale (Jong et al., 2013). It consists of 10 items and there is a relatively strong focus on (supernatural) agents (e.g., "There exist evil, personal spiritual beings, whom we might call demons"). We a-priori excluded items 2 and 3 to decrease the length of the study and because these items were similar to other items. The reliability was adequate, α = .93.

Personal beliefs**.** To get an indication of how participants interpret anomalous experiences, we used the Survey of Anomalous Experiences (Irwin et al., 2013). This survey consists of 20 anomalous experiences (e.g., "I have had the impression of a figure nearby, yet nobody could possibly have been there"). Three responses are possible to each item. The first response reflects agreement with the statement in terms of a paranormal explanation (e.g., "Yes, and it was probably a ghost"). The second reflects agreement with the statement, in terms of a naturalistic explanation (e.g., "Yes, but it was probably just an illusion or misperception"). The last reflects a denial of the statement (i.e., "No, I never had such an experience"). The questionnaire provides two measures (Irwin et al., 2013), but we were only interested in the percentage of paranormal explanations: response 1/ (response 1 + response 2)*100. We a-priori excluded item, 6, 7, 10, 13, 14-18 and 20 to decrease the length of the study and because these items were similar to items from other scales we included. The reliability was moderate, $\alpha = .70$ (for a discussion on how the reliability of the SAE should be calculated see Irwin et al., 2013).

General anxiety. Participants' self-reported general anxiety was measured with a single item on a seven-point Likert-scale: *"In general, I think I am an anxious person"* (0 = not at all – 7 very much).

Negativity bias. The negativity bias was measured the same way as in the pilot study. The reliability was low, $\alpha = .69$.

Procedure

A protocol was used to treat all participants in the exact same manner. Participant and instructor were situated in the same room, but were occluded from each other's sight by a tall opaque screen. The participant instruction differed somewhat from the pilot study. Similar as in the pilot study, participants were instructed that we interested in investigating the transfer from feeling the presence of others in the real word to virtual reality. Again, participants were instructed to press a button when they felt that an agent was present and that they should trust their intuition. However, we no longer told participants that we made agents transparent. When participants confirmed that they understood the task, they were first placed in a practice scenario, so that they could get acquainted to virtual reality. After both conditions, participants had to fill in the manipulation checks while they were still in within the virtual reality scenarios. After the second condition ended, the VR glasses and the heart rate measurement device were taken off and they conducted the White Christmas Task and filled in the remaining questionnaires. Finally, participants were debriefed about the true purpose of the study.

Data analysis

For the manipulation checks, paired-samples student *t*-tests were conducted and Cohen's *d* effect sizes are provided. In case the Shapiro-Wilk Test of Normality indicated a significant deviation from normality, Wilcoxon's tests are reported with matched rank biserial correlations as effect sizes. Further, we provided a Spearman correlation table (see Table S1 in the supplementary material), considering that not all of the variables were normally distributed (e.g., button press scores). We also conducted a mediation analysis for each condition to investigate whether there was a relationship between anxiety (i.e., PANAS) and agency detection, and if so, whether it was mediated by the attention that participants paid to the sounds that were presented (see Figures S1 and S2 in the supplementary material).

For the main analyses, we conducted RM-ANCOVAs. We first conducted a RM-ANOVA with condition (threat vs non-threat) as within-subjects variable, type of cue (i.e., spontaneous, multimodal and auditory) as within-subjects variable, the questionnaires (i.e., the Supernatural Belief Scale, the Survey of Anomolous Experiences, the Negativity Bias Scale, general anxiety and the White Christmas Task) as covariates and counterbalance order as between-subjects variable, to see whether counterbalance order did affect the results. If counterbalance order was not significant, we dropped this variable from the analysis. To visually represent the potential effects of the covariates, we presented median split graphs (i.e., a RM-ANOVA for low and high values of a covariate). To prevent over-interpretation of small effects, we only visualised the effects of covariates that were still significant after correction for multiple comparisons (i.e., the p-value was only considered significant if $p < .003$; as 18 comparisons were made with the different within-subjects factors, the p-value was adjusted according to: $.05/18 = .003$). We used Greenhouse-Geisser corrected values if Mauchly's test of sphericity indicated that the assumption of sphericity was violated ($p < .05$). For post-hoc tests we used Bonferroni corrected tests. Considering that we had strong expectations about the direction of some of the effects, we conducted one-sided tests (Lakens, 2017) and pre-registered these (i.e., osf.io/nwmku/). For the assessment of the main-effects and inter-action effects of the within-subjects factors using the RM-ANCOVA this meant that the *p*-values were divided by two . For comparisons where we did not expect directional effects we conducted two-sided tests. Finally, to compare the type of agents and their valence, chi-square's were calculated with Cramer's *V* effect size. To take into account that two observers rated these, we calculated inter-rater reliabilities and based the between condition comparisons on average scores of the two raters.

Results

Manipulation checks

The descriptive statistics and the outcomes of the manipulation checks are shown in Table 3. As expected, participants felt more threatened, as indicated by the higher PANAS scores and heart rates, in the threatening as opposed to the non-threatening condition. Further, participants were more attentive to sound and more strongly felt the presence of agents in the threatening as opposed to the non-threatening condition. They did not feel more attentive in general in the threatening condition. Further, the averages of the ecological validity measures indicated that participants generally found the VR environment to be realistic and they generally felt more present in the VR environment than in the lab. We did not observe differences between the conditions on these ecological validity measures. Further, participants moved slower in the threatening condition and they moved their heads more often in the control condition as opposed to the non-threatening condition.

Table 3. *Paired Samples t-Test for the manipulation checks in experiment 1.*

Variable	**Test**	**Statistic**	***df***	***p***		***ES***	**Condition**	***M***	***SD***
One-sided tests									
PANAS							T	2.85	0.83
	W	4559.00		< .001	***	0.96	C	1.92	0.65
Heart rate							T	92.08	15.26
	W	3564.50		< .001	***	0.53	C	89.91	14.12
Attention							T	0.74	0.22
	W	1858.00		.522		-0.20	C	0.74	0.20
Attention to sound							T	0.73	0.20
	W	2685.00		.006	**	0.27	C	0.67	0.25
Presence of agents							T	2.93	0.25
	W	3909.00		< .001	***	0.68	C	2.81	0.21
Two-sided tests									
Walking time							T	239.71	63.31
	W	3370.00		< .001	***	0.89	C	190.70	61.07
Head movements							T	4.77	1.06
	S	-5.53	96	< .001	***	-0.56	C	5.13	1.13
Realism							T	0.68	0.19
	W	2182.00		.850		-0.06	C	0.69	0.19
Feeling in lab							T	0.75	0.18
	W	2089.00		.713		-0.10	C	0.75	0.18

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. For the Student *t*-test (i.e., *S*), the effect size is given by Cohen's *d*; for the Wilcoxon test (i.e., *W*), effect size is given by the matched rank biserial correlation. For all one-sided tests the hypothesis was that the threatening condition (i.e., T) would be greater than the non-threatening condition (i.e., C). *Df* = degrees of freedom; *p* = *p*-value, *ES* = effect size, *M* = Mean; *SD* = standard deviation.

Repeated-measures analyses of covariance / main analyses

The outcomes of the within-subjects effects for the RM-ANCOVA are provided in Table 4, and a graphical representation of the outcomes is provided in Figure 4. As expected, there was a large effect of condition (Cohen, 1992); participants more often reported feeling the presence of agents (as indicated by the Button Press Task) in the threatening as opposed to the non-threatening condition. In addition, we observed a medium effect size for the type of cue. Post-hoc tests revealed that participants reported more agents after auditory cues than after multimodal cues ($M\Delta = -0.96$, $t = -6.11$, $p < .001$, $d = .60$), and that they reported more agents after multimodal cues than that they spontaneously reported agents ($M\Delta = 0.77$, $t = 3.42$, $p = .002$, $d = .35$). We further observed a significant interaction between the condition and type of cue. In the threatening condition, participants reported more agents after multimodal cues and they reported more agents spontaneously than in the non-threatening condition. There was no difference for agent reports after auditory cues.

With regard to the covariates, we observed significant between-subject effects for the Negativity Bias Scale, $F(1,90) = 3.25$, $MSE = 14.31$, $p = .038$, $\eta^2 = .03$, general anxiety, $F(1,90) = 10.37$, $MS = 14.31$, $p = .002$, $\eta^2 = .09$, and the White Christmas Task, $F(1,90) = 10.07$, $MS = 14.31$, $p = .002$, $\eta^2 = .09$, but not for the scales related to supernatural beliefs, all p’s > .619. Thus, the higher the scores on these significant scales, the more participants in general reported agents. We further observed very small interactions between all covariates (apart from the Supernatural Belief Scale) and condition that were close to significance (see Table 4).

We also observed a two-way interaction between type of cue and the White Christmas Task. More importantly, these effects are qualified by the three-way interactions between the type of cue and condition on the one hand, and general anxiety and the White Christmas Task (see Figure 5 left graph and right graph) on the other hand. The interpretation of the three-way interaction was similar for both the White Christmas Task and general anxiety. For people scoring low on the White Christmas Task or on general anxiety, participants reported more agents in the threatening condition than in the non-threatening condition. This difference disappeared for people scoring high on either one of the scales, but then, participants reported more agents in the threatening than in the non-threatening condition in the spontaneous condition. As is evident from Table S1 in the supplementary material, it is not the case that the comparable effects of the White Christmas Task and general anxiety were due to high correlations (i.e., shared variance).

Table 4. *Within-subjects effects of the RM-ANCOVA for Experiment 1, with number of agency reports as dependent variable, condition and type of cue as within-subject factors, and the questionnaires as covariates.*

Within Factor	***df***	***MS***	***F***	***p***		**η²**
C	1.00	128.39	36.99	< .001	***	0.27
C ∗ SBS	1.00	2.65	0.76	.192		0.01
C ∗ SAE	1.00	9.12	2.63	.054		0.02
C ∗ NB	1.00	10.74	3.09	.041	*	0.02
C ∗ Anxiety	1.00	6.55	1.89	.087		0.01
C ∗ WCT	1.00	13.19	3.80	.027	*	0.03
Residual	90.00	3.47				
ToC	1.50	189.10	22.31	< .001	***	0.18
ToC ∗ SBS	1.50	14.65	1.73	.095		0.01
ToC ∗ SAE	1.50	2.08	0.25	.359		0.00
ToC ∗ NB	1.50	2.41	0.28	.344		0.00
ToC ∗ Anxiety	1.50	3.96	0.47	.286		0.00
ToC ∗ WCT	1.50	62.66	7.39	.002	**	0.06
Residual	134.85	8.48				
C ∗ ToC	1.67	14.16	5.07	.006	**	0.05
C ∗ ToC ∗ SBS	1.67	0.21	0.07	.450		0.00
C ∗ ToC ∗ SAE	1.67	1.86	0.67	.245		0.01
C ∗ ToC ∗ NB	1.67	4.14	1.48	.116		0.01
C ∗ ToC ∗ Anxiety	1.67	13.57	4.86	.007	**	0.04
C ∗ ToC ∗ WCT	1.67	24.46	8.76	< .001	***	0.08
Residual	149.97	2.79				

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. C = condition (threatening vs non-threatening); ToC = type of cue (multimodal vs auditory vs spontaneous); SBS = Supernatural Belief Scale; SAE

= Survey of Anomolous Experiences (i.e., percentage of paranormal interpretations); NB = the Negativity Bias Scale; Anxiety = general anxiety; WCT = the White Christmas Task.

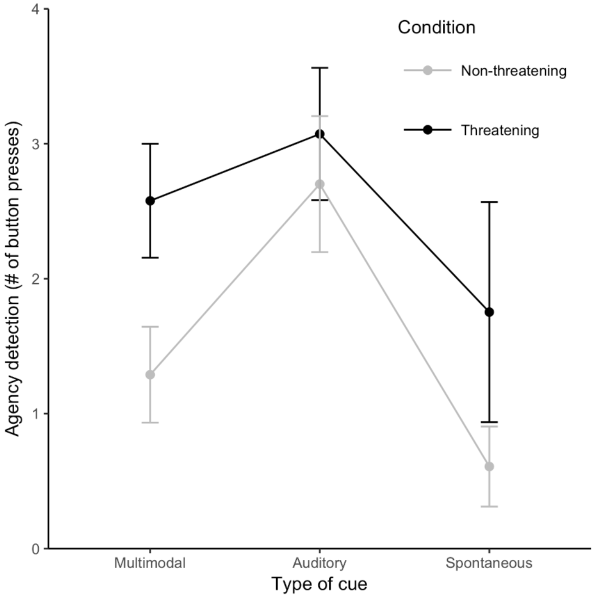

Figure 4. Graphical representation of the outcome of the RM-ANCOVA in Experiment 1.

Note. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the type of cue associated with the agency reports (i.e., multimodal or auditory triggered agency reports, or spontaneous agency reports). The black line represents the threatening condition; the white line represents the non-threatening control condition. Error bars represent 95% confidence intervals.

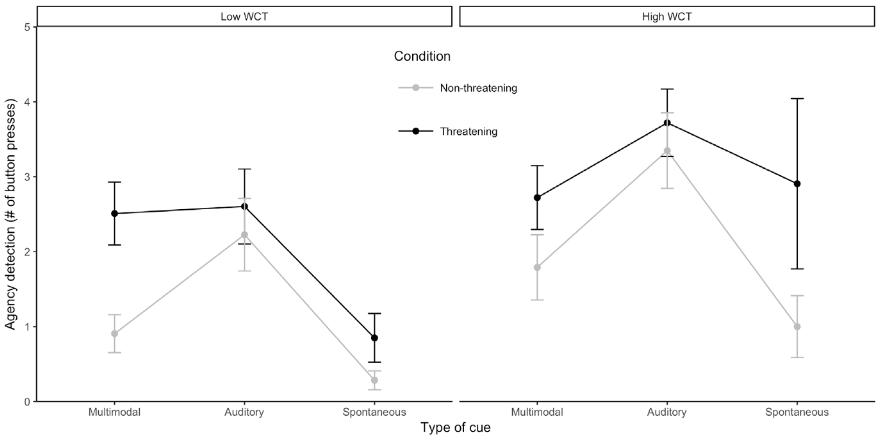

Figure 5. Graphical representation of the three-way interactions between the White Christmas Task, condition and type of cue for the RM-ANCOVA in Experiment 1.

Note. WCT = White Christmas Task; Low and High refer to participants scoring low or high on the White Christmas Task respectively, which were derived by conducting a media-split analysis. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the type of cue associated with the agency reports (i.e., multimodal or auditory triggered agency reports, or spontaneous agency reports). Black lines represent the threatening condition; white lines represent the non-threatening control condition. The error bars represent 95% confidence intervals.

Type of agents

A classification table of the type agents that people reported after each condition is presented in Table 5. Participants generally reported more agents in the threatening than in the non-threatening condition, $\chi^2(6) = 21.58$, $p = .001$, Cramer's $V = 0.33$. In the threatening condition, agents were more often considered to be humans, $\chi^2(6) = 33.80$, $p < .001$, Cramer's $V = 0.41$, and to have a threatening affect, $\chi^2(2) = 8.76$, $p = .013$, Cramer's $V = 0.30$, than in the control condition. In the control condition, agents were more often considered to be animals, $\chi^2(6) = 13.26$, $p = .039$, Cramer's $V = 0.26$, and to have a non-threatening affect, $\chi^2(1) = 8.74$, $p = .003$, Cramer's $V = 0.30$, than in the threatening condition. All other comparisons did not reach statistical significance, all *p*'s > .118.

Table 5. *Classification table and inter-rater reliabilities for the type of agents reported in Experiment 1 for each of the conditions.*

	Threatening		**Non-threatening**			
	Nr	**%**	**Nr**	**%**	***κ* T**	***κ* C**
Total agents	93.5		77			
Animals	62	66.3	65	84.4	.96	.96
Humans	18	19.3	4	5.2	.96	.88
Creatures	3	3.2	2	2.6	.74	1
Something	10	10.7	5	6.5	.81	.64
Total affect	80.5		74			
Threatening	14	17.4	1	1.4	.91	.66
Non-threatening	4	5.0	9	12.2	1	.94
Unclear	64	79.5	64	86.5	.89	.91

Note: κ = Cohen's Kappa inter-rater reliability; T = threatening condition; C = control non-threatening condition; *N* = the average number of occurrences for the two raters, % = the average number of occurrences expressed in percentages.

Discussion

Participants reported more agents in the threatening than in the non-threatening condition, and characterized these agents as being more threatening. The outcomes of the manipulation checks indicated that participants felt more threatened in the threatening condition than in the non-threatening condition. This suggests that the increased agency detection may be attributed to threat, but the correlations between the perceived threat measures and agency detection were mixed. General anxiety was only related to button presses in the control condition and perceived anxiety was only related to button presses in the threatening condition. Further, both conditions differed somewhat on luminance (i.e., the threatening condition was darker than the control condition), and as a consequence it remains unclear to what extent the observed differences between the conditions were the result of the threat manipulation, or rather the result of differences in luminance (i.e., ambiguity). Therefore, we adjusted the luminance in Experiment 2. Specifically, the luminance of the threatening condition was made brighter.

The difference in luminance could potentially provide an explanation for why multimodal-triggered and spontaneous agency reports differed between the conditions, whereas auditory-triggered agency reports did not. Multimodal and spontaneous agency reports likely rely more strongly on visual information. For instance, in the case of tumbleweed (i.e., a multimodal cue), people might just be more confident that it was not caused by an agent as tumbleweed is typically moved by the wind. Therefore, in Experiment 2, we also wanted to know how confident participants were about their decisions. We expected that people might be more confident after multimodal and spontaneous than auditory agency reports.

We made six changes in Experiment 2 as opposed to Experiment 1. First, the luminance of the threatening condition was increased. Second, a measure was added reflecting the confidence of participants' agency judgements. Third, we changed the moment in which we asked participants to guess the hypothesis. in Experiment 1, we asked participants to guess the hypothesis of the study. However, this question was asked after all questionnaires were filled in. Due to the nature of the questionnaires, almost all participants thought that the experiment had something to do with 'supernatural beliefs'. What we were actually more interested in was whether participants figured out that we expected them to detect more agents in the threatening as opposed to the non-threatening virtual reality scenario. Therefore, in the follow-up study, we asked participants to guess the hypothesis immediately after the virtual reality paradigm, before completing the questionnaires. Fourth, the vocal responses of people addressing the type of agents they perceived were audio recorded to increase transparency. Fifth, we pre-registered to test 30 participants using a within-subjects design, as we were mostly interested in whether the main results of our threat manipulation remained similar with decreased luminance. Sixth, we no longer recruited participants who had affiliation with supernatural beliefs, as there were no indications that supernatural beliefs were related to agency detection. The hypotheses remained the same, and we again pre-registered these on the Open Science Framework (https://osf.io/sjnv3/).

Experiment 2: keeping the luminance constant

Methods

Participants

Thirty participants were recruited via the website of the University of Amsterdam and via social media. Two participants were dropped from the analyses. One of them indicated to not have understood the task (the participant also had Autism Spectrum Disorder), another literally guessed the hypothesis (i.e., that we expected participants to press more often in the threatening condition as opposed to the non-threatening condition). This left 28 participants (*M* age = 24.1, *SD* age = 6.1, 64.3% female). Further, due to technical failure, the second block of one of the participants was not recorded, and for five participants the heart rate was not recorded.

Experimental manipulation

The experimental manipulation was similar to Experiment 1. The only difference was that the luminance (i.e., ambiguity) from the threatening condition was made more constant with the non-threatening condition. Specifically, the threatening forest was made brighter. Note, that it is impossible to keep the luminance completely constant, as the shadows in the virtual reality environments are calculated automatically.

Experimental paradigms

Agency detection, suggestibility and demand effects were all the same as in Experiment 1.

Questionnaires

Manipulation checks. The manipulation checks were the same as in Experiment 1. Thus, we included ecological validity, presence of agency, attention, acquaintance with forests and heart rate. The following reliability scores were obtained: feeling the presence of agency in the threatening and non-threatening condition, α = .73; feeling the presence of agency in the threatening condition, α = .73. One additional measure was obtained. We measured how confident participants were on a 7-point Likert scale (1 = not at all confident, 7 = very confident) after each agency report. This scale appeared within the VR scenario, each time the participants reported agency (i.e., by means of a button press).

Qualitative data. Similar as in Experiment 1, participants had to say aloud what type of agents they thought were present. However, this time the responses were recorded with Quick Time Player (Version 10.2, Apple Inc., CA: USA).

Covariates. As in Experiment 1, we measured the following covariates and observed the respective reliability scores: the Supernatural Belief Scale, α = .91; the Survey of Anomalous Experiences, α = .64; the Negativity Bias Scale, α = .61; the PANAS in the threatening condition, α = .85; the PANAS in the non-threatening condition, α = .81; general anxiety (1 item).

Procedure

The procedure was similar to Experiment 1. The only change was that participant were also instructed to report how confident they were about their agency reports.

Data analysis

We analyzed the data in a similar way as in Experiment 1. With regard to the RM-ANCOVA, the only change was that based on the findings of Experiment 1. Further, we aimed to analyze the confidence ratings in a similar way; with within-subject factors condition (threat vs. non-threatening) and type of cue (multimodal vs. auditory vs. spontaneous). However, participants frequently did not press after agency cues, so they also did not have to give a confidence rating. Per cell, only five observations were available. To be able to interpret all available observations, we only reported the averages. Finally, the outcomes of the correlation (see Table S2) and mediation analyses can be found in the supplementary material (see Figures S3 and S4). They have to be interpreted with caution, considering the small sample size.

Results

Manipulation checks

The descriptive statistics and the outcomes of the manipulation checks are shown in Table 5. The higher PANAS scores reflected that participants wore more anxious in the threatening as opposed to the non-threatening condition, while the heart rate scores did not reflect that this was the case. Further, participants were more attentive to sound and more strongly felt the presence of agents in the threatening as opposed to the non-threatening condition. They did not feel more attentive in general in the threatening condition. The means of the ecological validity measures indicated that participants generally found the VR environment to be realistic and they generally felt more present in the VR environment than in the lab. We did not observe differences between the conditions on these ecological validity measures. Further, participants were slower in the threatening than in the non-threatening condition. Finally, there were no differences between the conditions with regard to head movements or confidence ratings.

Table 5. *Paired Samples t-Test for the manipulation checks in experiment 2.*

Variable	**Test**	**Statistic**	***df***	***P***		***ES***	**Condition**	***N***	***M***	***SD***
One-sided tests										
PANAS							T	27	2.91	0.78
	S	6.49	26	< .001	***	1.25	C	28	1.91	0.60
Heart rate							T	23	85.64	16.58
	S	0.45	22	.327		0.10	C	23	85.29	15.76
Attention							T	27	0.78	0.17
	W	196	26	.526		0.04	C	28	0.78	0.13
Attention to sound							T	27	0.76	0.19
	S	2.86	26	.004	**	0.55	C	28	0.69	0.22
Presence							T	27	3.04	0.26
	S	2.99	26	.003	**	0.58	C	28	2.89	0.21
Two-sided tests										
Walking time							T	28	219.54	83.51
	W	359		< .001	***	0.77	C	29	175.41	49.66
Head movements							T	28	4.10	0.82
	S	-6.34	27	.920		1.20	C	28	4.68	0.93
Realism							T	27	0.73	0.17
	S	-0.12	26	.548		0.02	C	28	0.74	0.19
Feeling in lab							T	27	0.80	0.12
	S	0.50	26	.312		0.10	C	28	0.78	0.14
Confidence							T	25	4.40	1.18
	S	1.25	19	.113		0.28	C	22	4.16	1.48

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. For the Student *t*-tests (i.e., *S*), the effect size is given by Cohen's *d*; for the Wilcoxon test (i.e., *W*), effect size is given by the matched rank biserial correlation. For all one-sided tests the hypothesis was that the threatening condition (i.e., T) is greater than the non-threatening condition (i.e., C). *Df* = degrees of freedom; *p* = *p*-value, *ES* = effect size, *M* = Mean; *SD* = standard deviation.

Repeated-measures analyses of covariance

The outcomes of the within-subjects effects for the RM-ANCOVA are provided in Table 6, and a graphical representation of the outcomes is provided in Figure 6. In contrast to expectations, there was no longer a statistical significant effect of condition. Participants did not more frequently report the presence of agents (as indicated by the Button Press Task) in the threatening as opposed to the non-threatening condition. We did observe a large effect size for the type of cue. Post-hoc tests revealed that participants reported more agents after auditory cues than after multimodal cues ($M\Delta$ = 1.35, t = 4.173, p < .001, d = .80), more agents after multimodal cues than that they spontaneously reported agents ($M\Delta$ = 1.69, t = 5.28, p < .001, d = 1.02), and more agents after auditory cues than that they spontaneously reported agents, ($M\Delta$ = 3.04, t = 8.29, p < .001, d = 1.60). We no longer observed a significant interaction between condition and type of cue.

With regard to the covariates, we observed a large significant between-subject effect for the White Christmas Task, $F(1,23) = 15.02$, $MSE = 7.45$, $p < .001$, $\eta^2 = .39$ (see Figure 7). The stronger the response bias or demand characteristics of participants, the more agents they reported. We did not observe between-subject effects for the Negativity Bias scale, $F(1,23) = 0.30$, $MSE = 7.45$, $p = .294$, $\eta^2 = .01$, or general anxiety, $F(1,23) = 0.01$, $MSE = 0.06$, $p = .931$, $\eta^2 < .01$. We further observed a strong significant interaction effect between condition and the Negativity Bias Scale (see Figure 8).

Table 6. *Within-subjects effects of the RM-ANCOVA for Experiment 2, with number of agency reports as dependent variable, condition and type of cue as within-subject factors, and the questionnaires as covariates.*

	df	*MS*	*F*	*p*		η^2
C	1	2.58	2.32	.071		0.06
C ∗ NB	1	13.36	12.03	.001	**	0.32
C ∗ Anxiety	1	0.35	0.31	.291		0.01
C ∗ WCT	1	0.01	0.01	.460		0.00
Residual	23	1.11				
ToC	2	143.08	37.31	< .001	***	0.54
ToC ∗ NB	2	0.11	0.03	.486		0.00
ToC ∗ Anxiety	2	0.54	0.14	.434		0.00
ToC ∗ WCT	2	33.60	8.76	< .001	***	0.13
Residual	46	3.84				
C ∗ ToC	2	0.58	0.37	.345		0.02
C ∗ ToC ∗ NB	2	3.03	1.96	.077		0.08
C ∗ ToC ∗ Anxiety	2	0.67	0.43	.327		0.02
C ∗ ToC ∗ WCT	2	0.02	0.01	.494		0.00
Residual	46	1.55				

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. C = condition (threatening vs non-threatening); ToC = type of cue (multimodal vs auditory vs spontaneous); NB = the Negativity Bias Scale; Anxiety = general anxiety; WCT = the White Christmas Task.

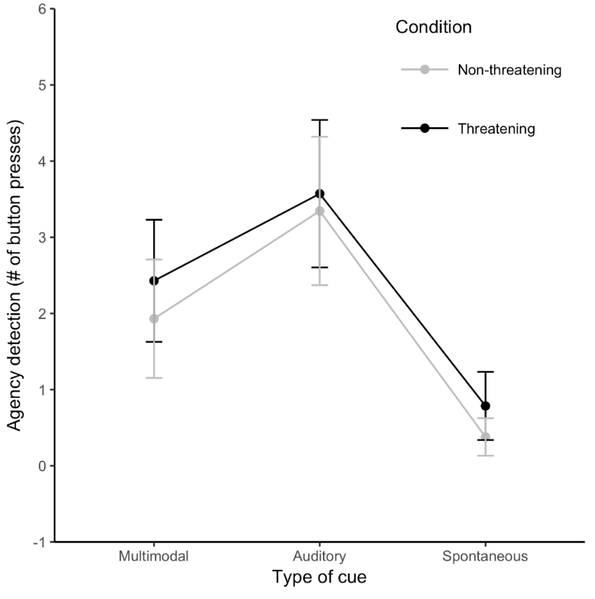

Figure 6. Graphical representation of the outcome of the RM-ANCOVA in Experiment 2.

Note. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the type of cue associated with the agency reports (i.e., multimodal or auditory triggered agency reports, or spontaneous agency reports). The black line represents the threatening condition; the white line represents the non-threatening control condition. The error bars represent 95% confidence intervals.

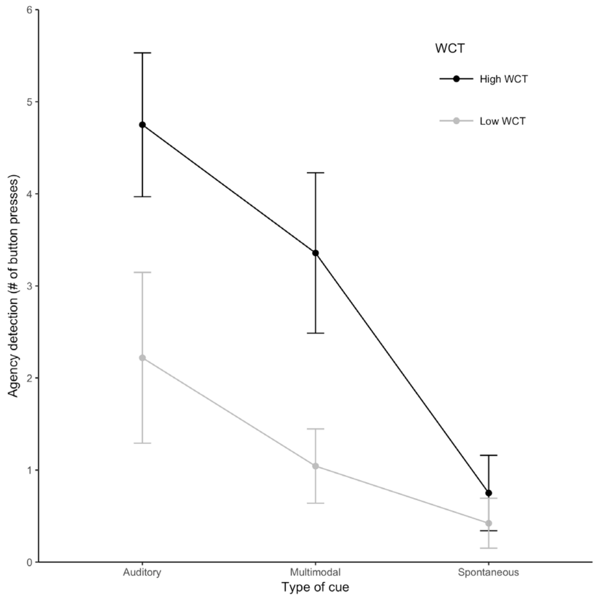

Figure 7. Graphical representation of the significant interaction between type of cue and scores on the White Christmas Task of the RM-ANCOVA in Experiment 2.

Note. WCT = White Christmas Task; Low and High refer participants scoring low (grey line) or high (black line) on the White Christmas Task, and these were derived by conducting a media-split analysis. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the type of cue associated with the agency reports (i.e., multimodal or auditory triggered agency reports, or spontaneous agency reports). The error bars represent 95% confidence intervals.

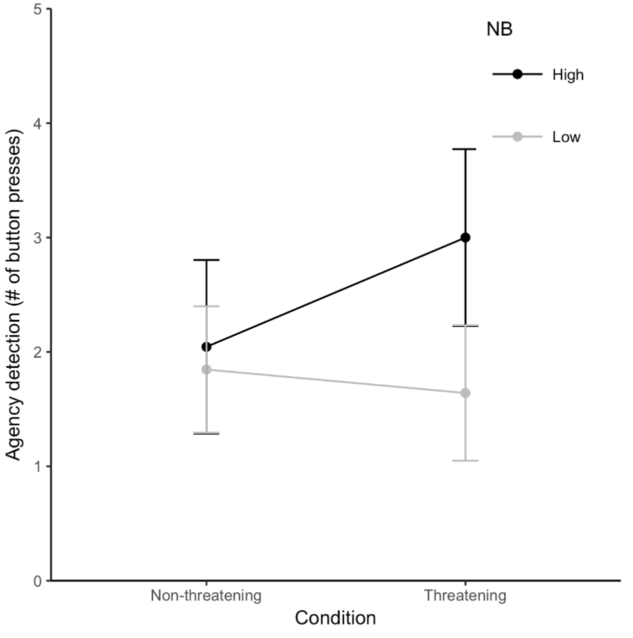

Figure 8. Graphical representation of the significant interaction between condition and scores on the White Christmas Task of the RM-ANCOVA in Experiment 2.

Note. NB = Negativity Bias Scale; Low and High refer participants scoring low (grey line) or high (black line) on the Negativity Bias Scale respectively, and these were derived by conducting a media-split analysis. The vertical axis represents the number of button presses in the Button Press Task (i.e., agency reports). The horizontal axis represents the type of cue associated with the agency reports (i.e., multimodal or auditory triggered agency reports, or spontaneous agency reports). The error bars represent 95% confidence intervals.

Confidence ratings

In Table 7, descriptive statistics are provided of the confidence rations. We expected participants to be the least confident of auditory cues. As it was not possible to conduct a RM-ANCOVA (see above) we have to be extra careful to interpret the data. We expected participants to be the least confident about the auditory agency cues, but in fact in absolute ratings, participants were the most confident about auditory ratings in the non-threatening condition.

Table 7. *Average confidence ratings as a function of type of cue and condition.*

	Threatening condition			Non-Threatening condition		
Type of cue	M	A	S	M	A	S
# Observations	20	12	21	20	7	21
M	4.3	4.1	4.7	3.7	5.2	4.5
SD	1.4	1.8	1.3	1.8	1.6	1.5

Note: M = multimodal, A = auditory, S = spontaneous.

Type of agents

A classification table of the type agents and its inter-rater reliabilities are presented in Table 8. Participants did not generally report more agents in the threatening than in the non-threatening condition, $\chi^2(4) = 7.36$, $p = .811$, Cramer's $V = 0.29$. In the threatening condition, agents were more often considered to be humans, $\chi^2(4) = 31.83$, $p < .001$, Cramer's $V = 060$, and to have a threatening affect, $\chi^2(4) = 31.83$, $p < .001$, Cramer's $V = 060$. The other comparisons did not reach statistical significance, all *p*'s > .181.

Table 8. *Classification table and inter-rater reliabilities for the type of agents reported in Experiment 2 for each of the conditions.*

	Threatening		Non-threatening			
	Nr	**%**	**Nr**	**%**	***κ* T**	***κ* C**
Total agents	38.5		37.5			
Animals	32	83.1	32	85.3	.95	1
Humans	2	46.8	2	5.3	1	1
Creatures	1.5	7.8	0	0.0	1	-
Something	3	7.8	3.5	9.3	1	.85
Total affect	37		36			
Threatening	9	24.3	1	2.8	.87	.76
Non-threatening	1.5	4.1	7.5	20.8	.67	.90
Unclear	26.5	71.6	27.5	76.4	.77	.92

Note: κ = Cohen's Kappa inter-rater reliability; T = threatening condition; C = control non-threatening condition; *N* = the average number of occurrences for the two raters, % = the average number of occurrences expressed in percentages.

Discussion

In Experiment 2, the most important objective was to control the luminance (i.e., ambiguity) between the two conditions. As a result of controlling the ambiguity, the threat manipulation appeared to be less effective than in Experiment 1. While participants still explicitly self-reported to be more anxious in the threatening condition than in the non-threatening condition, there was no longer a difference between the conditions on the more implicit heart rate level. With regard to the outcomes, similar to Study 1 participants self-reported to have more strongly felt the presence of agents, and they reported more threatening humans in the threatening condition as opposed to the non-threatening condition. However, they did not report more threatening animals in the threatening condition and there was no longer a statistical significant difference on the Button Press Task. Further, anxiety was no longer related to agency detection (see supplementary material). Finally, almost 60% of the variance on the Button Press Task was explained by demand characteristics or response expectancies.

General Discussion

Across one pilot study and two experiments we assessed the effects of threat on agency detection. We found that threat manipulations indeed made people feel more anxious and also caused them to detect more agents, as measured by means of a button press task. However, the effect of threat on perceived agents appeared to be mainly driven by the ambiguity of the threatening scenarios. Below, we will further discuss: 1) whether ambiguity is an inherent aspect of threat and its influence on agency detection; 2) to what extent the operationalization of agency detection can be considered an authentic instance of agency detection more generally; 3) how the observations relate to the different theoretical frameworks; 4) the relationships between the covariates and agency detection; 5) the limitations of the study.

An important concern is that ambiguity and feeling of threat may be two sides of the same coin, as darkness in general can make people feel unsafe (e.g., Fabiansson, 2007). Thus, by increasing the ambiguity of the threatening condition, we might have unintentionally decreased the perceived threat. This was, however, not reflected in the average anxiety scores between the threatening conditions of Experiment 1 and 2, as these were similar. Thus, it would be advisable to more thoroughly disentangle threat from ambiguity in future experiments. This can be done by keeping the virtual reality environment constant between the conditions, while manipulating threat in other ways, such as by showing people a horror movie that is situated in a forest environment (e.g., the Blair Witch Project) before the threatening condition[22].

Leaving aside this concern, it is evident that the influence of ambiguity on agency detection was more pronounced than the influence of threat on agency detection. The relationships between subjective and objective measures of anxiety on the one hand and different operationalizations of agency detection on the other hand, were non-significant (previously we also did not find any relationship, Chapter 2) or inconsistent. We observed a weak relationship between general anxiety and agency detection in the control condition of Experiment 1, and a moderate relationship between perceived threat and agency detection in the threatening condition of that experiment. In the latter case it cannot be ruled out that agency detection resulted in increased anxiety and the relationship is also likely to be confounded with ambiguity. Nevertheless, these corrrelations and the fact that the effect of threat was close to significance while controlling for ambiguity and demand characteristics could indicate a weak causal effect from threat on agency detection. Our future work will provide a more definite answer[10].

In contrast, the finding that ambiguity increases agency detection replicates findings of ourselves (Chapter 2; van Elk, Rutjens, van der Pligt, & van Harreveld, 2014; van Elk, 2013) and others (Andersen et al., 2017). The latter research group further observed that agency detection was strongly influenced by people's prior expectations. Several of our findings also show that prior expectancies may have contributed to the effects that we observed. First, participants reported more threatening agents in the threatening forest, such as wolves and humans, than in the non-threatening forest, where participants often reported birds and squirrels. Second, participants frequently interpreted the agency cues as agents and they also sometimes spontaneously reported to infer the presence of agents. Third, on the White Christmas Task, participants often heard the song they were expecting to hear. Thus, apart from ambiguity and to a smaller extent threat, prior expectations likely increased instances of agency detection.

An obvious concern is to what extent the button presses and subjective agency reports are reflecting authentic agency experiences. The high correlations between the White Christmas Task and the button presses indicate that to a large extent, the button

[22] Please note that at the moment of writing, we are still running a third pre-registered experiment (osf.io/9eb4h) with a large sample of participants (i.e., 100). The aim of this experiment is to manipulate threat between the conditions, while keeping ambiguity constant. We planned to include this experiment in the dissertation, but due to two unfortunate events (1. The data of the second condition was recorded over the first condition; 2. The virtual reality headset broke) this was no longer feasible.

presses were likely the result of demand characteristics or response expectancies. We asked participants to press the button when they perceived the presence of a person, animal or creature and to not think to long before responding. So, quite a few button presses are likely to be attributable to demand characteristics, probably especially the first button presses. However several observations indicate that some button presses reflected genuine agency interpretations. Participants sometimes spontaneously reported agents, participants' confidence ratings sometimes reflected the maximum score of the scale, participants sometimes reported fairly specific agents (e.g., smeagol, dementors), participants subjectively reported to have felt more presence of agents in the threatening than in the non-threatening condition and some participants were surprised to learn that Bing Cosby's White Christmas was actually not present in the White Christmas task. Nevertheless, in future studies it would be advisable to have a baseline condition in which people are asked to walk through the forest with the same agency cues but without any specific instructions. Subsequently, it would be interesting to interview participants to learn whether they still interpreted several cues in an agentic fashion.

Now the question is, which of the theories outlined in the introduction can most adequately explain the agency detection interpretations that were authentic? On basis of HADD theorizing (e.g., Barrett, 2000; Barrett, 2004; Barrett & Burdett, 2011) and error management theory (i.e., the idea that cognitive biases evolved by favoring false positives above false negatives in threatening situations, Haselton & Nettle, 2006; Johnson, Blumstein, Fowler, & Haselton, 2013), we predicted that ambiguity and especially threat would increase agency detection. We observed the opposite; it was mainly ambiguity that increased agency detection, as shown by the absence of an effect of threat on the number of button presses in Experiment 2 in which we controlled for the ambiguity between the different scenarios.

Further, on basis of HADD theorizing we expected a relation between supernatural beliefs and agency detection. We did observe a significant correlation between agency detection and religiosity in the pilot study, but also learned that this relationship gave a distorted picture. There was an absence of religious believers and the relationship was caused by the only three individuals that scored 2 on the 7-point Likert scale. The sample was also small, which can lead to an overestimation of effect sizes (Button et al., 2013). In a larger sample, of which half of the participants had some affiliation with supernatural beliefs, using standardized measures of supernatural beliefs, we no longer observed a relation between supernatural beliefs and agency detection. In contrast, on the basis of the predictive processing account (e.g., Friston, 2005; Friston & Kiebel, 2009), we predicted that agency detection interpretations result from a combination of strong expectations about agency and ambiguous sensory input, while threat would predominantly affect the nature of the interpretations that people gave to their experiences. Indeed we found that pre-dominantly ambiguity affected agency detection and that participants where strongly influenced by expectancies, as was evident from the White Christmas Task and the type of agents participants reported. Thus overall, the findings are evidently more in line with predictive processing than with HADD theorizing.

With regard to the covariates, we did not observe a relation between general attentiveness and agency detection, in contrast to our expectation that attention would mediate the relationship between threat and agency detection. In the case that we did observe a relationship between perceived threat and agency detection (i.e., Experiment 1), neither general attentiveness nor attention to sound mediated this relationship. Attention to sound was, however, related to agency detection in both conditions (i.e., Experiment 2). Nevertheless, the fact that we observed the relation in the less ambiguous environment, contrasts with our idea that increased ambiguity results in more attention to sound. To get a more thorough understanding of the effect of agency detection on attention, attention should be more objectively controlled and measured (e.g., by means of eye-tracking).

We further observed, similarly as in previous work (Chapter 2), that the negativity bias was related to agency detection. What complicates matters is that the findings were inconsistent. In the pilot study, the negativity bias was unrelated to agency detection. In Experiment 1 they were related to each other, while in Experiment 2, high scores on the negativity bias were related to agency detection, but only in the threatening condition. In other work, it has been found that participants scoring high on the Negativity Bias Scale more often believed that other players were humans when they received negative outcomes of other players, that could also be algorithms, during a computer game (Morewedge, 2009). It seems as though people with a higher negativity bias more easily attribute intentionality or agency to negative phenomena. To explore this hypothesis, it could be investigated whether people scoring high on the negativity bias ascribe more intentionality to geometrical figures that move as if they have negative intentions (e.g., as if one figure is 'teasing' or 'chasing' the other; (Heider & Simmel, 1944)).

We acknowledge several limitations of our studies. First, the nature of the agency cues likely influenced why people more often interpreted auditory cues as agents than multimodal cues. For example, rolling tumbleweed (i.e., a multimodal cue in our study) is intuitively more likely to be caused by wind than by an agent. Also thunder might be intuitively less likely to be caused by an agent, although according to HADD theorizing, the belief in thunder Gods started with the agentic interpretation of thunder, so theoretically it should trigger the HADD. We tried addressing this issue by taking into account the confidence ratings of the different types of agency cues. However, in contrast to our expectations, participants seemed not more confident about multimodal cues than auditory cues, although we had to rely on average scores that could not be interpreted statistically. To more adequately address this issue, the types of cues should be kept constant over the different modalities in future studies. Second, although we could compare the outcomes of the studies to the different theories, the experiment was not purposefully designed to disentangle predictive processing from HADD theorizing. In future studies, this could be done by providing an alternative cover story for the study. For example, by instructing participants that a snowstorm recently hit the forest and by using only auditory cues it could be investigated whether…. According to HADD theorizing, people would still interpret the agency cues as agents, whereas according to the predictive processing framework, people would be more likely to interpret the cues as melting snow.

To summarize, we tested in a more ecologically valid situation than in previous studies (Chapter 2), whether threat increases agency detection and whether agency detection was related to supernatural beliefs. Contrary to HADD theorizing and in line with predictive processing, we observed that false agency interpretations are likely to be the result of strong prior expectations and reduced bottom-up sensory processing due to ambiguous information. Further, these studies add to the accumulating empirical evidence (Andersen et al., 2017; van Elk et al., 2014; Chapter 2) that at least for explaining which factors foster supernatural beliefs in contemporary societies, agency detection does not appear to play a central role. Nevertheless, false agency detection instances may still provide an elegant explanation for why a common element among the wide variety of supernatural beliefs is that people always seem to believe in some type of agent.

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SUPPLEMENTARY MATERIAL

Pilot study

Intolerance of Uncertainty Scale. Intolerance of Uncertainty Scale was measured by a short version of the Intolerance of Uncertainty Scale (Carleton, Norton, & Asmundson, 2007). Participants had to rate 11 items (e.g., '*I can't stand being surprised'*) by indicating to which degree a statement was applicable to them on a 5- point scale (1 = totally disagree, 5 = totally agree). The reliability was adequate, α = .75.

Anthropomorphism. Individual differences in the tendency to anthropomorphize were measured with the Anthropomorphisation scale (Waytz, Cacioppo, & Epley, 2010). Participants had to rate 14 items (e.g., *'the ocean has a conscious*') by indicating the degree to which they agreed with the statements on a 9-point scale (1 = totally disagree, 9 = totally agree). The reliability was adequate, α = .93.

Experiment 1

Correlations. The pre-registered Spearman correlations are provided in Table S1. The subjective anxiety measures were related with each other, but they were not related to the normalized heart rate. Further, there were weak to moderate positive correlations between the Button Press Task on the one hand and the White Christmas Task and subjective anxiety measures on the other hand (Cohen, 1992). There was a weak inverse relationship between the Button PressTask and acquaintance with forests. Further, there was a strong relationship between the Negativity Bias Scale and general anxiety. Finally, the scales relating to supernatural beliefs are strongly related to each other and moderately to subjective anxiety in the threatening condition.

Table S1. *Spearman correlations for Experiment 1.*

	1	2	3	4	5	6	7	8	9	10
1. BP C	—									
2. BP T	.62 ***	—								
3. SBS	.03	.08	—							
4. SAE	-.02	.13	.49 ***	—						
5. NB	.00	-.10	.05	.11	—					
6. WCT	.31 **	.30 **	.00	-.08	.03	—				
7. Anxiety	.24 *	.17	.13	.15	.50 ***	.13	—			
8. zHR	-.17	.05	.11	.11	.11	-.04	-.02	—		
9. Forest	-.23 *	-.22 *	-.04	-.05	.02	.02	-.21 *	.03	—	
10. PANAS C	.07	.16	.18	.10	.03	.02	.37 ***	-.07	-.13	—
11. PANAS T	.18	.34 ***	.37 ***	.36 ***	.17	.05	.43 ***	.14	-.19	.56 ***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$, based on two-sided tests. BP C and T = number of button presses on the Button Press Task in the non-threatening control and threatening condition respectively; SBS = Supernatural Belief Scale; SAE = Survey of Anomalous Experiences; NB = the Negativity Bias Scale; WCT = the White Christmas Task; Anxiety = general anxiety; zHR = the normalized heart rate (i.e., T-C/ T+C); Forest = acquaintance with forests; PANAS C and T = the anxiety subscale on the Positive and Negative Affect Scale in the non-threatening control and threatening condition respectively.

Mediation analyses. To investigate whether there was a relationship between anxiety and agency detection, and if this was mediated by attention to sound we conducted a mediation analysis for each condition. In the threatening condition (see Figure S1), we observed significant relationships between anxiety on the one hand, and agency detection and attention to sound on the other hand. The higher participants' self-report anxiety was on the positive and negative affect scale, the higher they scored on attention to sound and the more agents they reported. However, since there was no significant relationship between attention to sound and agency detection, the relationship between anxiety and agency detection was not mediated by attention. A different pattern emerged for the non-threatening condition (see Figure S2). In this condition, none of the relationships was statistically significant.

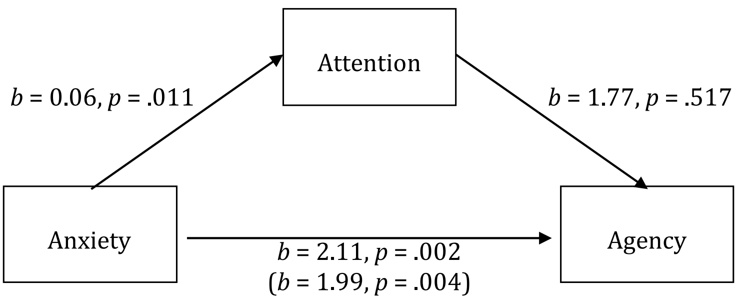

Figure S1. Mediation analysis for the relationship between threat and agency detection, mediated by attention to sound in the threatening condition. *b*-values indicate unstandardized regression coefficients.

Note. Direct effect between brackets. Attention refers to people's attention to sound.

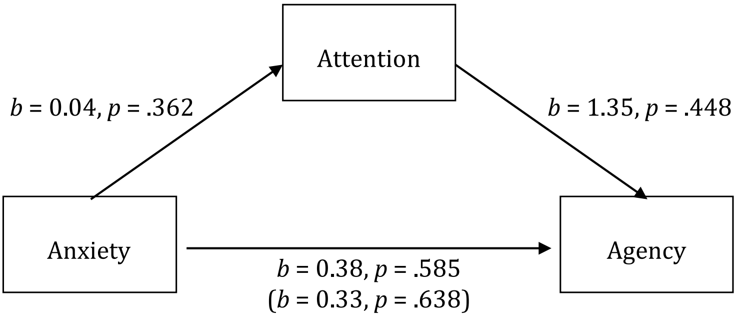

Figure S2. Mediation analysis for the relationship between threat and agency detection, mediated by heart rate in the non-threatening condition. *b*-values indicate unstandardized regression coefficients.

Note. Direct effect between brackets.

Experiment 2

Correlations. The pre-registered Spearman correlation table is provided in Table S2. There were strong correlations between the Button Press Task in both conditions and the White Christmas Task. Further, paranormal interpretations (i.e., the Survey of Anomalous Experiences) were significantly related to agency detection (i.e., the Button Press Task), but only in the non-threatening condition. Finally, there was a significant relation between acquaintance with forests and paranormal interpretations. No further statistically significant relationships were observed.

Table S2. *Spearman correlations for Experiment 2.*

	1	2	3	4	5	6	7	8	9	10
1. BP C	—									
2. BP T	.77 ***	—								
3. SBS	.07	.21	—							
4. SAE	.22	.21	.50 **	—						
5. NB	-.09	.21	.32	.05	—					
6. WCT	.72 ***	.57 **	.17	.34	-.10	—				
7. Anxiety	.06	.07	-.04	.04	.34	.13	—			
8. zHR	-.08	-.20	-.16	.02	.01	.12	.18	—		
9. Forest	.26	.01	.10	.41 *	.15	.22	-.10	-.14	—	
10. PANAS C	-.03	.02	.20	-.15	.14	-.01	.33	.12	-.18	—
11. PANAS T	.02	.08	.30	.29	.17	.11	.17	-.10	-.20	.28

Note. * $p < .05$, ** $p < .01$, *** $p < .001$, based on two-sided tests. BP C and T = number of button presses on the Button Press Task in the non-threatening control and threatening condition respectively; SBS = Supernatural Belief Scale; SAE = Survey of Anomalous Experiences; NB = the Negativity Bias Scale; WCT = the White Christmas Task; Anxiety = general anxiety; zHR = the normalized heart rate (i.e., T-C/ T+C); Forest = acquaintance with forests; PANAS C and T = the anxiety subscale on the Positive and Negative Affect Scale in the non-threatening control and threatening condition respectivel

Mediation analysis. To investigate whether there was a relationship between anxiety and agency detection, and if this was mediated by attention to sound, we conducted a mediation analysis for each condition. In both the threatening condition (see Figure S4), and the non-threatening condition (see Figure S5), we observed that attention to sound was positively significantly positively related to agency detection (as operationalized by the Button Press Task). In contrast to our expectations however, we did not observe that anxiety was related to attention or agency detection

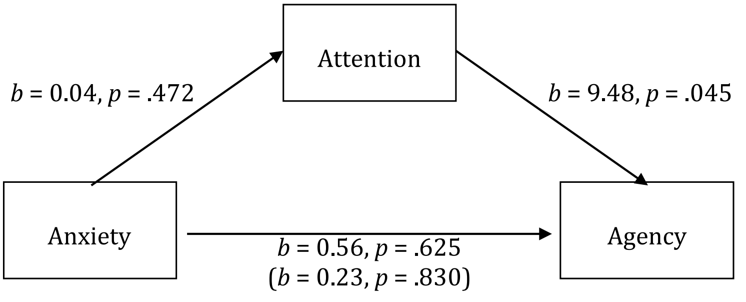

Figure S3. Mediation analysis for the relationship between threat and agency detection, mediated by attention to sound in the threatening condition. *b*-values indicate unstandardized regression coefficients.

Note. Direct effect between brackets. Attention refers to people's attention to sound.

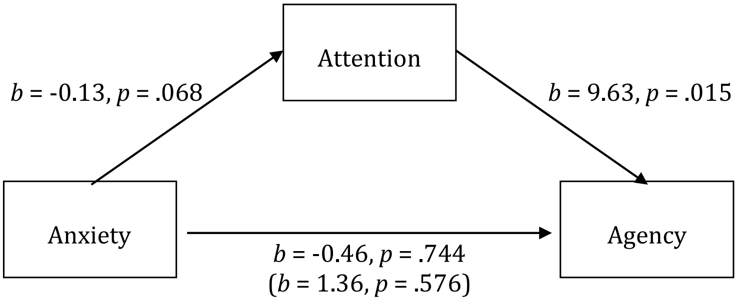

Figure S4. Mediation analysis for the relationship between threat and agency detection, mediated by heart rate in the non-threatening condition. *b*-values indicate unstandardized regression coefficients.

Note. Direct effect between brackets

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Chapter 4

GETTING ABSORBED IN EXPERIMENTALLY INDUCED EXTRAORDINARY EXPERIENCES:

Effects of placebo brain stimulation on agency detection

This chapter is currently under revision at Consciousness & Cognition:
Maij, D. L. R. & van Elk, M. (under revision). Getting absorbed in experimentally induced extraordinary experiences: Effects of placebo brain stimulation on agency detection. Consciousness & Cognition.

Abstract

Previous work demonstrated that placebo brain stimulation can function as a powerful tool to elicit mystical and quasi-mystical (i.e., extraordinary) experiences. However, it has not yet been investigated whether these effects result from mere sensory deprivation and individual differences in suggestibility, or whether expectancy manipulations are crucial in eliciting these effects. In this study, we showed that extraordinary experiences could be systematically manipulated by means of an expectancy manipulation using a within-subjects design, while controlling for suggestibility effects. We further observed that absorption, an individual difference measure reflecting people's propensity to get immersed in external stimuli or internal mental processes, predicts the frequency and intensity of such experiences. Finally, we investigated the relationship between extraordinary experiences and agency detection, which has been hypothesized to be associated to supernatural beliefs and experiences. The experimental induction of extraordinary experiences did not result in increased agency detection in an Auditory Agency Detection Task.

Scholars interested in the foundations of supernatural beliefs and experiences have for long sought methods aimed at manipulating supernatural beliefs and experiences in a systematic manner. Such methods include sensory over-stimulation (Glicksohn, 1991), sensory deprivation (Kjellgren, Lindahl, & Norlander, 2009), mind altering substances (Griffiths, Richards, McCann, & Jesse, 2006; Griffiths, Richards, Johnson, McCann, & Jesse, 2008; Griffiths et al., 2011; MacLean, Johnson, & Griffiths, 2011; Maij, Schjoedt, & van Elk, 2018; Pahnke & Richards, 1966), magic tricks (Benassi, Singer, & Reynolds, 1980; Mohr, Koutrakis, & Kuhn, 2015; Olson, Landry, Appourchaux, & Raz, 2016; Subbotsky, 2004), extreme rituals (Fischer et al., 2014; Xygalatas et al., 2013), meditation practices (Deikman, 1963), trying to recall memories of past mystical experiences (Beauregard & Paquette, 2006), expectancy manipulations (Collins & Persinger, 2013; Cook & Persinger, 1997; French, Haque, Bunton-Stasyshyn, & Davis, 2009; Irwin, Dagnall, & Drinkwater, 2013; Lange & Houran, 1997; Persinger, Tiller, & Koren, 2000; Tinoca & Ortiz, 2014) and by means of a so-called 'God Helmet' (Collins & Persinger, 2013; Cook & Persinger, 1997; Persinger et al., 2000).

The Koren helmet or Shakti helmet (Tsang, Koren, & Persinger, 2004, it was later termed 'God Helmet' in popular media) was originally devised as a transcranial brain stimulation device (Persinger, 1987). It supposedly stimulates the brain region (i.e., the temporal lobe) that underlies the subjective 'feeling of a presence' (i.e., the feeling that an intentional agent is spatially close to one's own body). The proposed efficacy of the helmet is controversial (see Granqvist et al., 2005; Schjoedt, 2009 for critical discussions), as the magnetic field generated by the helmet is comparable to that of a wristwatch. To the best of our knowledge, only a single "successful" independent replication has been published outside the Persinger-lab (Tinoca & Ortiz, 2014). Yet, there are numerous methodological issues with that specific study (e.g., expectancy was not controlled, insufficient power N = 20, no correction for multiple comparisons and a p-value of .10 was considered significant). Moreover, in a double blind randomized controlled trial, researchers did not observe differences between the helmet on and helmet off condition. Importantly, a minority of the participants in both conditions reported authentic mystical and quasi-mystical (i.e., extraordinary) experiences (Granqvist et al., 2005; Granqvist & Larsson, 2006). So even though Persinger has argued that methodological shortcomings in the experimental setup used by Granqvist et al. (2005) could explain the absence of a difference between the experimental and the control condition (Pierre & Persinger, 2006), the God Helmet was capable of eliciting authentic extraordinary experiences irrespective of whether an electromagnetic field was applied or not.

The observations of Granqvist et al. (2005; 2006) suggested that the God Helmet is a specific instance of placebo brain stimulation, and could potentially be used to investigate extraordinary experiences and their consequences in a non-invasive laboratory setting (Andersen, Schjoedt, Nielbo, & Sørensen, 2014). Several research groups have now successfully shown that placebo brain stimulation is a powerful manipulation capable of inducing extraordinary experiences (Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006; Chapter 5). Crucially, it is as of yet unclear to what extent these extraordinary experiences are driven by mere sensory deprivation (i.e., participants were blind-folded and listened to white noise, e.g., Rossi, Sturrock, & Solomon, 1963), individual differences in suggestibility (e.g., Granqvist et al., 2005; Granqvist & Larsson, 2006), expectancy effects triggered by the contextual manipulation (e.g., French et al., 2009), or a combination of these different factors (Zuckerman & Cohen, 1964). The main purpose of the present study was to disentangle these factors. In addition, there are no studies in which extraordinary experiences are manipulated by means of placebo brain stimulation to investigate the consequences of these experiences on decision-making. Thus, the second purpose was to provide a proof of concept of how placebo brain stimulation could be used to investigate research questions that so far have been mostly restricted to the domain of individual differences approaches. We will discuss each of these aims in a more detailed fashion below.

Expectancy manipulations and extraordinary experiences

Expectancies about extraordinary experiences were already manipulated in the context of sensory deprivation in the sixties and seventies of the last century (see for reviews, Jackson & Pollard, 1962; Solomon, Leiderman, Mendelson, & Wexler, 1957; Zuckerman & Cohen, 1964). At first, researchers investigated the consequences (e.g., cognitive) of long-term sensory deprivation (i.e., longer than 24 hours). During these sessions, participants reported hallucinations and extraordinary experiences. Later, researchers observed that similar although less intense extraordinary experiences could be elicited with short-term sensory deprivation manipulations (i.e., 1 hour). Researchers agreed on the notion that due to the absence of external sensory input, internal stimuli were experienced as more intense (Jacobson, 1966; Ktjbie, 1961; Robertson, 1961; Zuckerman & Cohen, 1964). They heavily disagreed, however, upon the role of expectancy effects. Several studies were conducted to systematically investigate the influence of expectancies. The outcomes of these studies differed widely (see for a review, Zuckerman & Cohen, 1964). Some researchers observed that the extraordinary experiences were strongly influenced by participants' expectancies (Jackson & Kelly, 1962; i.e., telling participants that specific extraordinary experiences could be expected resulted in these specific experiences). Yet others found the exact opposite (i.e., telling participants that a placebo pill would enhance extraordinary experiences did not result in stronger experiences than mere sensory deprivation, Short & Oskamp, 1965). On the basis of these conflicted findings, it was concluded that the type of suggestions and individual differences influenced the effects (Zuckerman & Cohen, 1964). More recently, in two comparable studies participants were led to believe that a building was either haunted or not. In one study the expectancy manipulation resulted in increased extraordinary interpretations (Lange, Houran, Harte, & Havens, 1996), whereas in the other it did not (Dagnall, Drinkwater, Denovan, & Parker, 2015), thereby rendering the precise role of expectancies on extraordinary experiences unclear.

Individual differences and extraordinary experiences

Two individual differences that seem to be especially relevant in the context of experimentally induced extraordinary experiences are supernatural beliefs and the personality trait of 'absorption'. With regard to supernatural beliefs, in a sensory deprivation floatation tank study controlling for demand characteristics (Hood Jr & Morris, 1981) and in three placebo brain stimulation studies (Andersen et al., 2014; Granqvist & Larsson, 2006; Chapter 5), it has been observed that supernatural beliefs were associated with increased extraordinary experiences. With regard to absorption, it is interesting that this measure consistently predicted induced extraordinary experiences in all placebo brain stimulation studies in which it was included (Granqvist & Larsson, 2006; Van Elk, 2014). Absorption is the tendency to get fully immersed in external sensory events or in internal mental processes (Tellegen & Atkinson, 1974). Thus, the more strongly people indicated on the Tellegen Absorption Scale to agree with statements such as "I can be greatly moved by eloquent or poetic language" or "If I wish I can imagine (or daydream) some things so vividly that they hold my attention as a good movie or story does", the more frequently they reported extraordinary experiences (Granqvist et al., 2005; Van Elk, 2014). The relationship between absorption and extraordinary experiences has mostly been explained in terms of proneness to hallucination and suggestibility (Andersen et al., 2014; Granqvist et al., 2005; Van Elk, 2014). An alternative explanation follows from the older sensory deprivation studies, were researchers suggested that due to the absence of external sensory input, internal processes were experienced as more intense (Jacobson, 1966; Ktjbie, 1961; Robertson, 1961; Zuckerman, Albright, Marks, & Miller, 1962). People who get easily immersed into such internal processes (i.e., people scoring high on absorption) may just be especially responsive to interpret their bodily sensations and thoughts as extraordinary events in the context of placebo brain stimulation.

Extraordinary experiences and agency detection

Placebo brain stimulation studies have so far mainly been restricted to the use of subjective measures and reports. Therefore, apart from systematically investigating the roles of expectancies and individual differences, the aim of this study was to use placebo brain stimulation to investigate the proximate effects of induced extraordinary experiences on behavioral decision-making. One research question that lends itself readily, considering that a frequently reported extraordinary experience in the God Helmet studies is 'the feeling of presence' (Andersen et al., 2014; Cook & Persinger, 1997; Granqvist et al., 2005), is whether such beliefs are causally related to agency detection. Agency detection is the tendency to interpret events as the consequence of actions of intentional agents (Barrett, 2000). Scholars have hypothesized that a universal agency detection bias may facilitate beliefs in supernatural agents (Barrett, 2012; Barrett, 2000; Barrett & Lanman, 2008; Norenzayan, Hansen, & Cady, 2008) and that supernatural agent beliefs in turn can reinforce agency experiences (Barrett & Lanman, 2009). This proposal stems from the idea that in an evolutionary sense, the quick detection of intentional agents is vital to survive. Therefore, it would be adaptive to have a bias towards inferring the presence of agency in ambiguous or threatening situations. On its turn, this bias to detect intentional agents is thought to encourage the belief in intentional supernatural agents

In most studies investigating the relationship between agency detection and supernatural beliefs, researchers have looked at individual differences in supernatural beliefs and related these to agency detection (Chapter 5; van Elk, Rutjens, van der Pligt, & van Harreveld, 2014; van Elk, 2013). In one other study, participants were primed with supernatural agents, leading people to interpret nature events (e.g., thunder) as having more agency than nature events when they were not primed (Nieuwboer, van Schie, & Wigboldus, 2014). However, this difference was not found for animal agents, and the researchers attributed this to the difference between agent detection (i.e., animals) and intentionality detection (i.e., nature events). It may be more ecologically valid to investigate the relationship between agency detection and supernatural beliefs, if one of these could be convincingly manipulated. As placebo brain stimulation holds the potential to experimentally manipulate extraordinary experiences and beliefs, it becomes possible to investigate whether this increases agency detection. Further, it allows us to investigate whether extraordinary experiences affect performance on a behavioral decision making task, that is less likely to be influenced by expectancy effects than subjective reports.

The present study

To summarize, our aims were to systematically investigate the influence of a placebo brain stimulation expectancy manipulation on extraordinary experiences, to investigate the relationship with individual differences (i.e., supernatural beliefs and absorption), and to investigate the effects of extraordinary experiences on agency detection. In a pilot study, we used a between-subjects design whereby one group of participants was told that the God Helmet was turned on, while the other group was told that the God Helmet was turned off (similar as Van Elk, 2014)[23]. In the main study, we used a within-subjects design whereby the helmet was literally taken off in the helmet off condition, to increase the contrast between both conditions. For both experiments, we expected that: 1) the helmet on condition would result in more extraordinary experiences than the helmet off condition, as reflected by higher scores on the Mysticism Scale (Hood Jr, 1975) and more extraordinary reports on the open question, 2) the individual differences measures related to suggestibility and spirituality would be positively related to the frequency of extraordinary experiences, and that 3) participants would more frequently report the presence of agency responses during the helmet on than during the helmet off condition.

Pilot Study

Method

Participants. Forty-two participants (*M* age = 22.7, *SD* = 4.6, 24 females) were recruited; twenty-one for the helmet on condition and twenty-one for the helmet off condition. We used a between-subjects design to decrease skepticism[1]. Participants were recruited via a participant pool website and were generally highly educated (i.e., 72,5% were

[23] This pilot study was conducted at the same time as the study of Van Elk, 2014 discussed in the introduction. Therefore, we did not yet know that a between-subject design in which both groups wear a helmet could lead to the ironical effect that the experimental group believed to be in the control condition and vice versa.

bachelor university students, 25% were applied sciences university students, 2,5% were college students). Exclusion criteria were 1) epilepsy, 2) easy fainting, 3) claustrophobia and 4) any form of brain damage. These criteria were assessed verbally as the main goal of these criteria was to increase the credibility of the study, but participants who did not meet one of the criteria could not participate in the study. Data of two participants from the helmet on condition could not be analyzed. One of the participants misunderstood the instructions and used the mouse instead of the keyboard, for another there was a technical failure. Testing took place in the physiological lab of the University of Amsterdam and participants received course credits for participating. The ethics committee of the University of Amsterdam approved the study and all procedures were conducted in accordance with the understanding and written informed consent of the participants.

Expectancy manipulation. A placebo brain stimulation device (i.e., the God Helmet) was used to manipulate expectancies (for similar procedures see Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006; Chapter 5; van Elk, 2014). The helmet was a transformed scooter helmet (see Figure 1) with wires directed to the back of a computer as well as to a bogus analog to digital converter (ADC)-box which had a flickering light. The helmet was not attached to electrical current. The credibility of the helmet manipulation was increased in three ways. First, participants were screened on the exclusion criteria. Second, participants read a short review of research claiming that the helmet reliability elicits extraordinary experiences (Cook & Persinger, 2001; Persinger, Tiller, & Koren, 2000; Pierre & Persinger, 2006). Third, electrophysiological measures were obtained to 'keep track of their health', but were not analysed. To decrease bottom-up sensory input, participants were sensory deprived by means of an eyeshade and they listened to white noise presented through earphones.

Figure 1. Image of the placebo God Helmet; an adapted scooter helmet used as placebo brain stimulation.

Measures. ***Experimental Paradigm.*** The auditory agency detection task (AADT) was a modified version of the auditory signal detection task used by Barkus et al. (2007). Participants listened to 120 randomized trials of 5-second epochs of white noise. In half of these stimuli agent voices were embedded, which consisted of a male voice pronouncing the numerals one to eight. The 1-second voice fragments were recorded and normalized regarding their pitch- and dB-levels with Audacity (2.0.5, Boston, USA). Subsequently, we filtered the voices within the Dutch telephone frequency range - Low pass filter 3400 Hz, high-pass filter 300 Hz. We varied both the position of the voice within the white noise – starting after 1, 2 or 3 seconds of the white noise – as well as the percentage of the loudness of the noise – attenuated to 10, 15, 20, 25 or 30% of the original sound level. The sound and voice stimuli were combined in MatLab (R2013b, Mathworks, Natick, Massachusetts, U.S.A.) and the experiment was programmed in Presentation (V.16.2, Neurobehavioral systems, Albany, CA, USA). In total, 240 sound fragments were used (i.e., 8 voices, agent embedded vs. agent not embedded, 3 positions in time, 5 attenuation levels) and participants semi-randomly listened to 120 of those (i.e., each of the 5 levels was presented 8 times on each of the 3 positions).

The mapping of the response buttons (i.e., using the left or the right button to indicate the presence of an agent) was counterbalanced between subjects. Half of the participants had to press on the left arrow keyboard button when they heard an agent in the white noise and on the right arrow when they did not hear an agent in the white noise, and vice versa for the other half of participants. To gain high attention of the participants and to ensure that participants made intuitive responses, it was stressed that they only had three seconds after each stimulus to indicate whether they had detected an agent voice or not. After they had pressed a button, or after the maximum response time ended, a variable inter stimulus interval between 500 and 1000 ms was presented. The stimuli were presented with in-ear headphones, as the participants were wearing the placebo God-helmet during the experiment. We presented 10 practice trials before the God-helmet manipulation was started.

Manipulation checks. Two manipulation check questions were obtained to determine to what extent participants believed the manipulation: 1) 'To what extent did you have the idea that your brain was being stimulated', and 2) 'To what extent do you think the helmet is capable of inducing feelings of spirituality?'). These items were measured on a 5-point Likert scale (1 = not at all, 5 = absolutely). It is important to note that in later studies, it turned out that these questions triggered skepticism regarding the experimental manipulation (Chapter 5).

Dependent measures. *Frequency and types of extraordinary experiences.* The frequency and types of extraordinary experiences were measured by means of the Mysticism Scale (MS; Hood, 1975). The scale consists of 32 items from which 20 load on a general mystical experience factor (e.g., "I have had an experience in which I became aware of a unity to all things") and 12 on a religious interpretation factor (e.g., "I have had an experiences that seemed holy to me")[24]. The scale's reliability was adequate, $\alpha = .84$.

Nature of the experience. To investigate more thoroughly what participants experienced while wearing the helmet, we asked in an open question: "Please describe what thoughts and feelings came to mind during the experiment". We classified these experiences according to a categorization scheme with eight categories of sensations (auditory, visual, mental, weak bodily, strong bodily, events in surrounding, time / space distortion, distraction / skepticism) that we discussed extensively elsewhere (Chapter 5).

Individual difference measures. In this pilot study, several questionnaires were included for explorative purposes. In order to limit the number of multiple comparisons, to be consistent with the main study and to prevent a 'fishing expedition' (we did not pre-register the study considering that the data was collected in 2014), in this study we only report the analyses for the measures that were of primary interest following our other

[24] Differentiating between the two subscales did not result in different results or the interpretations thereof, so for reasons of brevity, the results from the overall scale is reported.

studies (i.e., the frequency and types of extraordinary experience, supernatural beliefs, Chapter 5, and absorption, van Elk, 2014). However, for completeness we included the data from all the different measures that were included in the supplementary online material.

General supernatural beliefs. General supernatural beliefs were assessed with a single continuous scale item with a range from 0 to 100 (0 = I believe in nothing, 50 = I believe in something, 100 = I believe in one almighty God or multiple almighty Gods).

The Revised Paranormal Belief Scale. Supernatural beliefs were measured with the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004). The scale includes items referring to spiritual (e.g., *'Reincarnation exists'*) as well as more general religious beliefs (e.g., *'I believe in God'*). Participants had to rate the 26 statements by indicating to what extent they believed the statement was true on a 7-point scale (1 = strongly disagree, 7 = strongly agree). The reliability was adequate, α = .89.

Absorption. Absorption was measured with the modified Tellegen Absorption Scale (Jamieson, 2005), which is an adapted version of the Absorption Scale (Tellegen & Atkinson, 1974). Absorption is defined as a disposition for moments of total attention or engagement into one's internal experiences (e.g., perceptual or imaginative). The scale consists of 34 items and people can respond by agreeing or disagreeing with an item. Examples of items are 'The sound of a voice can be so fascinating to me that I can just go on listening to it' and 'I can sometimes recollect certain past experiences in my life with such clarity and vividness that it is like living them again or almost so'. The reliability of the scale was adequate, α = .84.

Procedure. Participants were contacted via telephone in order to check the exclusion criteria. Before the participants entered the lab, they were already semi-randomly assigned to either the helmet on or helmet off condition. We matched the groups in terms of gender, as in general women tend to score somewhat higher on supernatural beliefs (e.g., Collett & Lizardo, 2009). Participants were told that we were investigating the effects of extraordinary experiences on perception. They were given the information voucher in which background information was given on Persinger's work on the God Helmet. The voucher ended with information about the experimental paradigm. After reading the voucher, participants filled in the survey questions on demographics and supernatural beliefs. For the agency detection paradigm, participants were instructed to listen to white noise fragments and they were told that sometimes a voice was embedded within the white noise and that they had to press a button according to whether they had heard a voice in the noise fragment or not. Then, the participants were attached to the physiological equipment (i.e. skin conductance and heart rate measures). The AADT started with ten practice trials in which feedback was given about the correctness of their answers.

After finishing the practice trials, the experimenter placed the placebo God Helmet on the head of the participant. In the 'helmet on condition', participants were led to believe that triggers were send from an ADC-box towards the helmet. A screen was presented which stated '*ready for stimulatio*n?' and as soon as the enter-button was pressed the sentence '*active pulses sent to helmet'* appeared on screen, which was accompanied by a flickering light on the ADC-box. Then participants were blindfolded. In the helmet off condition, the cables of the helmet were plugged out of the ADC-box in full sight of the participants. Subsequently, all participants were blindfolded and they had to wait for five minutes to get used to the helmet and the stimulation while white noise was presented, until a voice was presented through the headphones that said '*the experiment starts no*w'. Participants were told that blindfolding was necessary in order to focus their attention on the sound. Finally, they were told that if they did not feel well due to the helmet, they could raise their hand, as an experimenter would watch them throughout the experiment via a camera.

Data analyses. Manipulation checks and between-group differences were analyzed with independent Welch sample *T*-tests, as the number of participants differed between the groups. To analyze the AADT, a signal detection analysis was used (Green & Swets, 1966; Macmillan & Creelman, 2005). As a measure of response bias, the response criterion (i.e., *c*) was used. This represents the response strategy of the participants (i.e., saying easily yes or no). It was calculated by the sum of the normalized false alarm rate and the normalized hit rate, multiplying the outcome by minus 1 and subsequently dividing it by 2. A response bias higher than 0 indicates a response bias towards not detecting voices, a response bias lower than 0 indicates a response bias towards detecting voices. As a measure of perceptual sensitivity, the difference of the *z*-transforms (using a normal cumulative distribution function) of the hit and false alarm rates was calculated for each of the different attenuation levels (i.e., *d'* or *d*-prime) with MatLab (The Mathworks inc.). As discussed in Stanislaw and Todorov (1999), we added the value of 1 to the number of hits, misses, false alarms and correct rejections to prevent that *Z*-scores became infinite.

Repeated measurement analyzes of variance (RM-ANOVAs; with Greenhouse-Geisser adjusted *p*-values if Mauchly's test of sphericity was violated) were conducted to analyze whether the perceptual sensitivity was lower and the response bias was higher in the helmet on condition than in the helmet off condition. We included the within-subjects factors noise level (10, 15, 20, 25 or 30% attenuation of sound level) and condition (helmet on vs. helmet off). To investigate which individual differences best predicted to what extent participants had extraordinary experiences, we conducted three analyses of covariance (ANCOVA). Condition was included as between-subject factor, while the RPBS and absorption were included as centered (score – mean) covariates (Chen, Adleman, Saad, Leibenluft, & Cox, 2014). To remain consistent with the main study and for brevity, we only report the ANCOVA in which the Mysticism Scale was used as dependent variable. Two other ANCOVA's can be found in the supplementary material in which we used the Persinger Exit Questionnaire and the visual analog scale as dependent variables. A correlation table with all the variables used in the ANCOVA's, as well as other variables relating to supernatural beliefs can be found in the supplementary material (Table S1). Significance levels were always set at p = .05 (two-tailed). The answers to the open question were described in a qualitative manner and analyzed according to the categorization scheme. Data processing was done in R (R Development Core Team 2017, Version 3.3.3.) and analyses were conducted in JASP (JASP Team, 2017, Version 0.8.3.1.).

Results

The descriptive statistics of the pilot study and the outcomes of the independent samples *t*-tests for the differences between the helmet on and the helmet off condition (see Table 1) indicate that there were no significant differences between the groups on any of the variables. Further, the gender distribution did not differ between the conditions, $\chi^2(1)$ = 0.08, p = .775. There seems to be an absolute difference, although non-significant, on general supernatural beliefs. This did not result from the manipulation as the questionnaire was filled in at home, prior to the manipulation.

Table 1. *Descriptive statistics and independent samples t-tests for between-subject variables of the pilot study between helmet on and helmet off condition.*

	Helmet on (*N* = 19)	Helmet off (*N* = 21)	*t*	*df*	*p*	*d*
Age	23.6 (5.9)	22.0 (3.1)	1.00	25.03	.326	0.34
Education	2.7 (0.6)	2.7 (0.5)	-0.18	34.36	.859	-0.06
GSB	46.2 (33.0)	32.5 (24.1)	1.49	32.68	.147	0.48
RPBS	2.6 (1.2)	2.7 (0.8)	-0.33	31.83	.743	-0.11
Absorption	14.4 (7.3)	17.7 (5.0)	-1.63	31.25	.113	-0.53

Note. Welch's *T*-test. *M* and *SD* between brackets (except for Absorption, which is a sum score). Age (range = 17 - 43), Education (range = 1 – 3), GSB = General supernatural beliefs (range = 0 – 100), RPBS = Revised Paranormal Beliefs Scale (range = 1.1 - 5.2), Absorption (range = 0 – 29).

With regards to the manipulation checks, participants in the helmet on condition ($M = 2.2$, $SD = 1.0$) did not think that their brains were stimulated to a greater extent than participants in the helmet off condition ($M = 2.1$, $SD = 1.4$), Welch's $T(1,35.8) = 0.19$, $p = .669$. Ironically, participants in the helmet on condition ($M = 2.0$, $SD = 0.9$) believed to a *lesser* extent that the helmet was capable of eliciting extraordinary experiences than participants in the helmet off condition ($M = 2.8$, $SD = 1.3$), Welch's $T(1,35.8) = 4.98$, $p = .032$.

Auditory Agency Detection Task. With regard to the AADT, the placebo brain stimulation manipulation did not affect the response bias, $F(1,38) = 0.14$, $MSE = 0.60$, $p = .866$, $\eta^2 < 0.01$, $\omega^2 < 0.01$, whereas the attenuation level did, $F(4,152) = 34.24$, $MSE = 0.02$, $p < .001$, $\eta^2 = 0.47$, $\omega^2 = 0.46$ (see Figure 1, left graph). This means that with increased levels of attenuation of the agent voice, participants had a stronger bias to judge that there were no voices embedded in the white noise. Further, the interaction between the manipulation and attenuation level was not significant, $F(4,152) = 0.14$, $MSE = 0.02$, $p = .967$, $\eta^2 < .01$, $\omega^2 < 0$ .01, indicating that the response bias as a function of the attenuation level did not differ between the two conditions.

The placebo brain stimulation manipulation did also not affect the perceptual sensitivity, $F(4,152) = 0.10$, $MSE = 0.84$, $p = .754$, $\eta^2 < 0.01$, $\omega^2 < 0.01$. We again observed a main effect of attenuation level, $F(4,152) = 34.24$, $MSE = 0.10$, $p < .001$, $\eta^2 = 0.47$, $\omega^2 = 0.46$, indicating that the experiment provoked the intended result. With increased levels of attenuation of the agent voice, the perceptual sensitivity (d') decreased (see Figure 1, right graph). No significant interaction between condition and attenuation level was observed, $F(4,152) = 0.14$, $MSE = 0.10$, $p = .967$, $\eta^2 < 0.01$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the attenuation level did not differ between the two conditions.

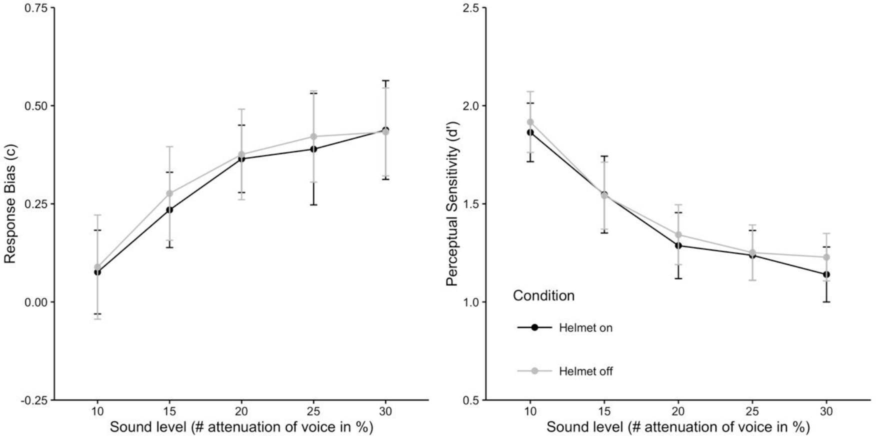

Figure 1. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the level of attenuation of the voice in the pilot study. The dark lines represent the helmet on condition and the light line represents the helmet off condition. Error bars represent 95% confidence intervals.

Explorative analyses. With regard to the ANCOVA predicting the outcome of the Mysticism Scale, there was no significant effect of condition when controlling for the RPBS and absorption, $F(1,36) = 1.91$, $MSE = 17.78$, $p = .175$, $\eta^2 = 0.03$, $\omega^2 = 0.02$, indicating that the frequency and type of extraordinary experiences did not differ between the two conditions (helmet on $M = 5.6$, $SD = 4.6$; helmet off $M = 5.5$, $SD = 5.6$). Importantly, absorption was significantly related to the frequency and type of extraordinary experiences, $F(1,36) = 18.11$, $MSE = 17.78$, $p < .001$, $\eta^2 = 0.32$, $\omega^2 = 0.29$. Participants scoring higher on absorption reported more frequent extraordinary experiences (Pearson's $r = .56$, $p < .001$). Further, the RPBS was not significantly related to the frequency and type of extraordinary experiences, $F(1,36) = 1.32$, $MSE = 17.78$, $p = .259$, $\eta^2 = 0.02$, $\omega^2 = 0.01$.

Nature of the Experiences. Regarding the nature of the experiences as reported in response to the open question, Table 2 indicates that most of the reported comments were relatively minor sensations, such as everyday thoughts or people reporting tingling sensations. We refrained from trying to statistically compare these categories due to the small number of participants per category. The absolute numbers indicate that if there were any differences at all, they are very small, which converges with the non-significant between condition comparisons above. Several reports of experiences are worth mentioning (see Table 3), as they indicate that some participants did experience sensations that could be considered ‘extraordinary’ or because they shed light on what participants thought during the manipulation. The comments have been translated from Dutch and for brevity the comments have been reduced in length or paraphrased.

Table 2. *Inter-rater reliability scores and average number of occurrences of the categorization scheme categories.*

	κ	***N* Helm on**	***N* Helm off**
Auditory	0.87	6.5	3.5
Visual	0.62	4.5	1.5
Mental	0.74	11	13.5
Weak bodily sensations	0.93	5.5	4
Strong bodily sensations	1	2	0
Events in surrounding	1	1	1
Time / Space distortion	1	0	1
Distraction / Skepticism	0.81	2.5	3.5

Note: κ = Cohen’s Kappa; *N* = the average number of occurrences for the two raters. In the helmet on condition, participants were led to believe that the helmet was on and vice versa in the helmet off condition.

Table 3. *Quotes of participants following the placebo brain stimulation in both conditions.*

	Helmet on condition
A	“Immediately from the start of the stimulation I felt as if I was floating. I was very aware of it. Now and then I saw imagery of myself floating. It was very pleasant”.
B	“I felt like I was dreaming or meditating, I had no control over my thoughts and feelings, like a feeling of unconsciousness.”
C	“I was in doubt whether I heard something and whether I was in the control group or not.”
D	“I felt dizzy and noxious and sometimes felt as if I was under the table and at other times I felt being far above the table.”

E	"I had a strong feeling that some other being was present who was watching me. I also felt very angry."
	Helmet off condition
F	"I saw a face with very bright, almost white, eyes. I also saw dark trees and a purple cloud passing by."
G	"I heard strange singing voices with a high pith. It made me think of a horror movie with TV noise."

Note: Comments have been translated from Dutch and for brevity the comments have been reduced in length or paraphrased.

Discussion

The expectancy manipulation did not result in differences between the helmet on and the helmet off condition on the Mysticism Scale, suggesting that the expectancy manipulation may have failed. This may also explain why the manipulation did not affect the agency detection task. However, the scores on the Mysticism Scale, the Persinger Exit questionnaire (supplementary material) and the visual analog scale (supplementary material) in combination with comments of the participants revealed that participants did occasionally have extraordinary experiences, but that these experiences were distributed relatively evenly across both conditions (similar as in Granqvist et al., 2005; Van Elk, 2014). One explanation is that the experiences were solely the result of sensory deprivation effects, and were, in contrast to our expectations, not driven by our suggestions (e.g., Short & Oskamp, 1965; Zuckerman & Cohen, 1964). Another explanation (similar as provided by van Elk, 2014) is that participants in the helmet on condition sometimes ironically thought that they were in the placebo condition and vice versa (e.g., participant C, who expressed to be in doubt whether he or she was in the control group or not; see Table 3). We think that especially blindfolding the participants to sensory deprive participants may have had the unwanted effect that it increased suspicion towards the manipulation. This may explain why participants in the helmet off condition believed to a greater extent that the helmet was capable of eliciting extraordinary experiences. From later studies (Chapter 5) we also learned that the manipulation checks themselves caused people to become skeptic of the study, which may have led participants to answer even more skeptic after the helmet on condition.

To be able to disentangle these alternative explanations for the absence of an effect, we made four changes in the main study. First, we used a within-subjects manipulation, to convince each participant that there was an experimental condition with a working helmet and a control condition in which no helmet was used. This procedure is similar to studies on the effects of placebo analgesia, in which expectations about the effects of a placebo are manipulated in advance (see for a review, Büchel, Geuter, Sprenger, & Eippert, 2014). Second, we took off the helmet in the helmet off condition to make the distinction between the conditions very clear and to avoid skepticism or doubts about the potential possibility that we secretly turned on the brain stimulation device while participants were blindfolded. Participants in the helmet off condition were still sensory deprived, so we could contrast the effects of sole sensory deprivation with the expectancy manipulation. Third, we increased the time of the manipulation from 5 to 15 minutes, as the frequency of reports has been found to increase with time – especially in the second half participants reported extraordinary experiences (Andersen et al., 2014). Third, we recruited participants who were critical of supernatural beliefs (i.e., students) as well as participants who strongly endorsed supernatural beliefs (i.e., spiritualists), to increase variation in suggestibility and in supernatural beliefs in general.

To obtain more insight in the frequency with which people report sensations, we measured the frequency of extraordinary experiences by means of a Button Press Task (e.g., Andersen et al., 2014; Chapter 5). During this behavioral measure, participants had to press a response button each time they experienced something extraordinary that they attributed to the God Helmet. In order to be able to control for a response bias or demand characteristics driving the effects during the God Helmet session, we included the White Christmas Task at the end of the experiment (Merckelbach & van de Ven, 2001). During this task, participants are presented with white noise and they have to press a response button each time they think they hear Bing Crosby's 'White Christmas'. This task has been related to fantasy proneness and hallucinatory reports (Merckelbach & van de Ven, 2001) and it provides a behavioral proxy of a general response bias (Perinelli & Gremigni, 2016). The logic behind the White Christmas Task is comparable to that of the Button Press Task used during placebo brain stimulation, in the sense that participants had to respond to subjective events or experiences that are not externally triggered. However, the tasks are framed in completely different ways.

Further, in the three ANCOVA's that were conducted in the pilot study (of which two are reported in the supplementary material), a consistent pattern occurred showing that absorption was predictive of the extent to which people reported extraordinary experiences. This could suggest that especially people who get immersed into or pay particular attention to internal processes are prone to report extraordinary experiences. Further, the RPBS was not related to any of the dependent variables, but this may have been caused by the general low level of supernatural beliefs among the participants in the pilot study. This issue will also be addressed in the main study by recruiting spiritualist as well as more skeptical participants. For the main study, we predicted that: a) participants would report more extraordinary experiences in the helmet on than in the helmet off condition, as indicated by both behavioral and self-report measures, b) participants would report more agent voices in the helmet on than in the helmet off condition (in the main study, we reduced the number of attenuation levels from five to three levels), c) suggestibility and response bias measures (i.e., the Absorption Scale and the White Christmas task) would be predictive of the intensity and frequency of extraordinary experiences.

Main study

Method

Participants. Sixty-three participants (*M* age = 30.7, *SD* = 13.2, 41 females) were recruited. We recruited skeptical participants (i.e., students) and participants who had affiliation with spirituality in order to increase the variability on supernatural beliefs. Spiritual participants were recruited by stating that only participants who had affiliation with spirituality could participate in the study. Participants were recruited via social media, by handing out flyers at a psychic fair, and via a participant pool website. Participants were generally highly educated (61.9% pre-university or university, 23.8% senior general secondary education or college, 9.5% lower secondary education or vocational education college, 4.8% other).

The same exclusion criteria were used as in the pilot study. The response button data of the first four participants was not recorded due to a programming error. Testing took place in the behavioral lab of the University of Amsterdam and participants received a financial reimbursement of €20,- (60 participants) or course credits (3 participants) for participating. The Ethics Committee of the University of Amsterdam approved the study and all procedures were conducted in accordance with the understanding and written informed consent of the participants.

Expectancy manipulation. The expectancy manipulation was similar to the manipulation in the pilot study. Importantly, we used a within-subjects design in the main study. In the helmet on condition participants were told that the helmet was on, in the helmet off condition the helmet was literally taken off, to prevent that participants thought that we turned the helmet on when they were blindfolded - as some participants thought in the pilot study. In het helmet off condition, participants were still sensory deprived and they were told that this condition would function as a control condition to allow a comparison with the effects of placebo brain stimulation. Each helmet session lasted 15 minutes. In order to increase the credibility of the manipulation further, four measures were taken. First, two experimenters conducted the experiment. Second, the experimenters wore lab coats. Third, participants were guided past a Mock scanner – a non-functioning brain scanner, used to get participants accustomed to a real brain scanner (Andersen et al., 2014). Fourth, participants were shown parts of a Youtube video in which professor Susan Blackmore explains what happened to her when she wore the helmet in Persinger's lab[25].

Dependent measures. ***Experimental paradigm.*** Again, the AADT was used to operationalize agency detection. The AADT was slightly adapted. Instead of five attenuation levels, three attenuation levels of the human voice were used (i.e., 10%, 20% and 30% attenuation of the sound level) as the pilot study indicated that three levels were sufficient to obtain insight in the effects of different levels of ambiguity. The number of trials (i.e., 120) was kept constant, half of these were again white noise stimuli, 10 different numbers were spoken by a male agent, and each number was named 6 times.

Frequency of extraordinary experiences. The frequency of extraordinary experiences was measured by means of a Button Press Task. During this behavioral task, participants had to press on a response button box each time they experienced 'something extraordinary' during the helmet on or the helmet off condition. This task was programmed and responses were recorded using Presentation software (V.16.2, Neurobehavioral systems, Albany, CA, USA).

Frequency and types extraordinary experiences. As in the pilot study, we used the Mysticism to measure the frequency and types of extraordinary experiences. The reliability of the scale was adequate, Cronbach's $\alpha = .84$.

Nature of the experience. The nature of the experiences was measured by asking participants to describe what they experienced when they pressed the button – if they

[25] https://www.youtube.com/watch?v=Zo-achedLMs

pressed it at all. We classified the experiences perceived in both the helmet on and the helmet off condition on the basis of the same categorization scheme used in the pilot study. The frequency of occurrences and the inter-rater reliabilities can be found in Table 7. The inter-reliabilities are the result of authors (DLRM and MvE) scoring each of the experiences independently.

Response bias or demand characteristics. We used a 'White Christmas Task' (Merckelbach & van de Ven, 2001) as a behavioral measure of response bias. In this task, participants are asked to press a button on a response box when they heard Bing Crosby's 'White Christmas' in white noise while in fact only white noise was presented for 3 minutes. Before white noise was presented, participants had to listen to the song for 30 seconds, so that they remembered what the song was like. Participants were told that the task provides a measure of auditory sensitivity, which we needed to know for analyzing the AADT. We stressed that there were no correct or false answers.

Questionnaires. ***Manipulation checks.*** The same two manipulation checks as in the pilot study were used, but this time participants could respond on a Likert-scale from 1 (not at all) to 5 (to a strong extent). Two manipulation checks were added. First, we asked participants if they had an extraordinary experience and if so, how this was caused. Participants were given three answer options: 1) They did not have an extraordinary experience, 2) They did have an extraordinary experience that was caused by electrical brain stimulation, 3) They did have an extraordinary experience that was caused by something that scientists think they can explain, but which may have a cause that science cannot explain. Second, participants were asked when they thought that their brains were stimulated. Here, participants were given four answer options: 1) In the condition in which you were wearing the helmet 2) When the helmet was taken off, 3) In neither of the conditions, 4) In both conditions.

Religiosity. Religiosity was measured with four questions. 1) To what extent do you consider yourself to be religious? 2) To what extent do you belief in the existence of God? 3) How often do you visit a religious institution such as a church or mosque? 4) How often do you pray? All questions were answered on an 8-point Likert scale (1 = Not at all/ Never – 8 To a strong extent / very often). The reliability was adequate, Cronbach's α = .89.

Spirituality. Spirituality was measured with four questions. 1) To what extent do you consider yourself to be spiritual? 2) To what extent do others consider you as spiritual? 3) To what extent do you believe in a higher power? 4) To what extent do you believe that there is more between heaven and earth? (This is literally translated from Dutch, this is comparable to the English saying: Is there more than meets the eye?). All questions were answered on an 8-point Likert scale (1 = Not at all/ Never – 8 To a strong extent / very often). The reliability was adequate, Cronbach's α = .81.

The Revised Paranormal Belief Scale and the Absorption Scale. Finally, similar as in the pilot study, the RPBS and the Absorption scale were included. Both reliabilities were adequate, Cronbach's α = .96 and .89 respectively.

Procedure. The procedure for the AADT was similar to Study 1, although changes had to be made considering that we used a within-subjects design with a counterbalanced order. First, participants were screened on the exclusion criteria via telephone. If they met the criteria, they were sent an online survey with the religiosity, spirituality, RPBS and absorption scale, which they could fill in at home. When participants arrived in the lab, they read the information voucher and signed an informed consent. Then, they were shown the video, explaining the working of the helmet. Subsequently, the AADT was further explained and the participants conducted the practice trials. The experimenters checked whether the participants conducted the task correctly. After the practice trials, participants were attached to the physiological measures, and the sleeping mask as well as the earphones were put in place.

Depending on the condition, the helmet was also put on or not and the Button Press Task was initiated. After 15 minutes, the AADT started. Afterwards, in the placebo brain stimulation condition the helmet was taken off. Participants filled in the Mysticism Scale and the manipulation checks. Then, the same procedure with a different experimental condition was repeated once more. Finally, participants conducted the White Christmas Task.

Statistical analyses. The manipulation checks were described in terms of means and percentages, as asking the manipulation checks in between conditions would have likely resulted in suspicion. The statistical analyses were kept similar to the pilot study. For analyzing the AADT, RM-ANOVA's were used. We included the within-subjects factors noise level (10, 20, or 30% attenuation of sound level) and condition (helmet on vs. helmet off). We also included the between-subjects variable counterbalance order to investigate whether this had a significant influence on the results. For conciseness, the RM-ANOVA without counterbalance order is reported in case the between-subjects factor was non-significant. Exploratively, we added the White Christmas task (centered; scores – mean) as a covariate (i.e., a RM-ANCOVA).

To investigate whether we succeeded to experimentally manipulate extraordinary experiences and to investigate which individual differences best predicted to what extent participants had extraordinary experiences, we conducted a RM-ANCOVA. Condition was included as within-subjects variable, and the RPBS and absorption were included as centered (score – mean) covariates. We also included a correlation table with all the variables used in the RM-ANCOVA as well as variables related to supernatural beliefs and experiences. The answers to the open question were expressed in frequencies and described in a qualitative manner. Further, to test whether some of the categories defining the nature of the experience were mentioned more often in either one of the conditions, participants were given a score of 1 if either of the raters observed this category in the comment of the participant. Subsequently, a paired-samples *t*-test was conducted for each of the eight categories. To correct for multiple comparisons, we divided the significance level (p = .05), by the number of categories (i.e., 8): .05/8 = .00625. For all other tests, significance levels were always set at p = .05 (two-tailed).

Results

Manipulation checks. When asked to what extent participants thought that their brains were stimulated, they on average scored 2.9 (SD = 1.3; 1 = not at all – 5 = to a strong extent). Visual inspection of a frequency histogram indicated that there was a bimodal distribution, with around half of the participants indicating that their brains were not stimulated or stimulated to a weak extent, and the other half indicating that their brains were stimulated to a moderate or strong extent. When asked to what extent participants thought that the helmet was capable of eliciting extraordinary experiences a similar pattern emerged, the average score was 2.8 (SD = 1.3). Further, 52.4% of the participants reported to not have had an extraordinary experience, 27.0% of the participants thought the extraordinary experiences they had were due to electrical stimulation of the brain, and 20.6% of the participants thought the experiences were caused by something that science cannot explain. When asked when their brains were stimulated, 60.3% of the participants reported that their brains were stimulated in the helmet on condition, 4.8% in the helmet off condition, 14.3% in neither of the conditions and 20.6% in both conditions.

The Shapiro-Wilk test of normality indicated that both on the Button Press Task as well as on the Mysticism Scale the assumption of normality was violated, W = 0.73, p < .001 and, W = 0.88, p < .001 respectively. Hence, Wilcoxon's signed rank tests are reported. Participants reported more frequent extraordinary experiences, as indicated by the Button

Press Task, in the helmet on (M = 5.3, SD = 9.0) as opposed to the helmet off condition (M = 2.4, SD = 6.3), W = 509.5, p < .001, d = 0.46. Similarly, participants had higher scores on the Mysticism Scale in the helmet on (M = 7.9, SD = 8.1), than in the helmet off condition (M = 5.2, SD = 6.8), W = 1096.0, p < .001, d = 0.38. These results indicate that the manipulation was successful; participants reported more frequent and a wider range of extraordinary experiences when they were told that the helmet was on than when the helmet was taken off.

Descriptive Statistics and Correlations. The descriptive statistics of participants' scores on religiosity, spirituality, the RPBS, the Absorption Scale and the White Christmas Task can be found in Table 4. A correlation table with all the variables used in the RM-ANCOVA as well as variables relating to supernatural beliefs and experiences is provided in Table 5. With regard to the self-report measures, it becomes evident from this correlation table that the questionnaires Religiosity, Spirituality, RPBS and Absorption Scale have weak to strong significant correlations. These questionnaires were however not consistently related to scores on the Mysticism Scale. Only the Absorption Scale and the RPBS were related to the Mysticism Scale, in the helmet on condition. With regard to the behavioral measures, scores on the button press task in the helmet off condition were related to scores on the White Christmas Task. Finally, the self-report measures were not consistently related to the behavioral measures. Only the Absorption Scale was related to all measures, except for the White Christmas Task.

Table 4. *Descriptive statistics of the individual difference measures used in the main study.*

	Religiosity	Spirituality	RPBS	Absorption	WCT
M (SD)	3.3 (2.3)	4.8 (1.9)	3.6 (1.4)	20.2 (7.4)	7.8 (22.1)
Range	1-8	1-8	1.2-6.4	2-33	0-68

Note: RPBS = Revised Paranormal Belief Scale; Absorption = Absorption Scale; WCT = White Christmas Task. Scores on Religiosity, Spirituality and the RPBS reflect average scores on the scales. Absorption and WCT reflect average scores of sum scores.

Table 5. *Spearman correlation table of all measures related to supernatural beliefs and experiences in the main study.*

	1	2	3	4	5	6	7	8	9
1. R	—	.55 ***	.58 ***	.44 ***	.16	.24	.22	.20	.22
2. S		—	.74 ***	.52 ***	.27 *	.23	.28 *	.10	.26 *
3. RPBS			—	.59 ***	.25	.37 **	.33 **	.23	.26 *
4. AS				—	.32 *	.31 *	.32 *	.29 *	.23
5. H On					—	.59 ***	.63 ***	.29 *	.24
6. H Off						—	.52 ***	.59 ***	.39 **
7. MS H On							—	.56 ***	.27 *
8. MS H Off								—	.35 **
9. WCT									—

Note: * $p < .05$, ** $p < .01$, *** $p < .001$. H On/Off = number of button presses during the helmet on and helmet off condition respectively, MS H On/Off = score on the Mysticism Scale during the helmet on and helmet on condition respectively, R = religiosity, S = spirituality, RPBS = Revised Paranormal Belief Scale; AS = Absorption Scale; WCT = White Christmas Task. Scores on Religiosity, Spirituality and the RPBS reflect average scores on the scales. Absorption and WCT reflect average scores of sum scores.

Auditory Agency Detection Task. With regard to the AADT, counterbalance order neither had an effect on the response bias, $F(1,61) = 0.04$, $MSE = 0.73$, $p = .835$, $\eta^2 < 0.01$, $\omega^2 < 0.01$, nor on the perceptual sensitivity, $F(1,61) = 0.04$, $MSE = 1.12$, $p = .842$, $\eta^2 < 0.01$, $\omega^2 < 0.01$. The placebo brain stimulation manipulation (i.e., helmet on vs. helmet off) did not affect the response bias, $F(1,62) = 0.12$, $MSE = 0.14$, $p = .727$, $\eta^2 < 0.01$, $\omega^2 < 0.01$, whereas the attenuation level did, $F(2,124) = 43.50$, $MSE = 0.06$, $p < .001$, $\eta^2 = 0.41$, $\omega^2 = 0.40$ (see Figure 2, left graph). This means that with increased levels of attenuation of the agent voice, participants had a stronger bias to judge that there were no voices embedded in the white noise. Further, the interaction between the manipulation and attenuation level was not significant, $F(1,124) = 0.96$, $MSE = 0.05$, $p = .386$, $\eta^2 = .02$, $\omega^2 < 0.01$, indicating that the response bias as a function of the amount of noise did not differ between the two conditions.

The placebo brain stimulation manipulation did also not affect the perceptual sensitivity, $F(1,62) = 0.31$, $MSE = 0.50$, $p = .580$, $\eta^2 = 0.01$, $\omega^2 < 0.01$. We again observed a main effect of attenuation level, $F(2,124) = 41.88$, $MSE = 0.21$, $p < .001$, $\eta^2 = 0.40$, $\omega^2 = 0.39$, indicating that the experiment provoked the intended result. With increased levels of attenuation of the agent voice, the perceptual sensitivity (d') decreased (see Figure 2, right graph). No significant interaction between condition and attenuation level was observed, $F(2,124) = 0.67$, $MSE = 0.16$, $p = .505$, $\eta^2 = 0.01$, $\omega^2 < 0.01$, indicating that the perceptual sensitivity as a function of the attenuation level did not differ between the two conditions.

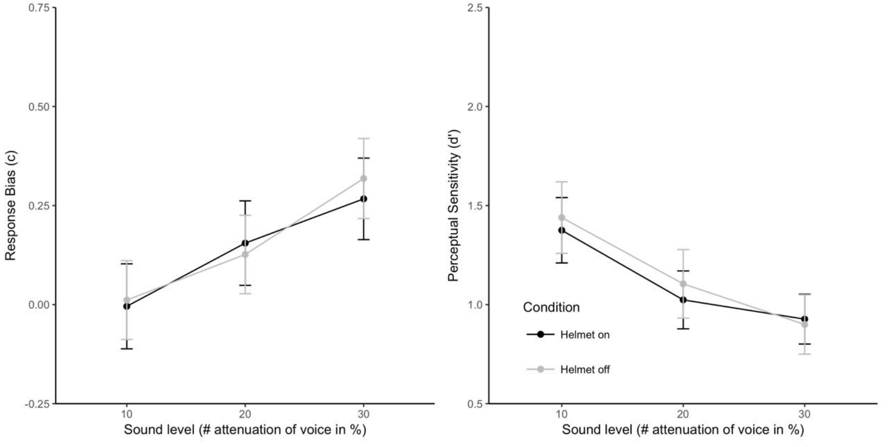

Figure 2. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the level of attenuation of the voice in the pilot study. The dark lines represent the helmet

on condition and the light line represents the helmet off condition. Error bars represent 95% confidence intervals.

Explorative analyses. The scores on the White Christmas Task were included as covariate in the RM-ANOVA of the AADT, as the White Christmas Task is a behavioral measure possibly reflecting a response bias. The between-subjects effect of the White Christmas Task was significant, $F(1,61) = 8.64$, $MSE = 0.64$, $p = .005$, $\eta^2 = .12$, $\omega^2 = 0\ .11$; participants with higher scores on the White Christmas Task also had a higher response bias for detecting agent voices[26]. We further observed a weak interaction between condition and scores on the White Christmas Task, $F(1,61) = 4.10$, $MSE = 0.53$, $p = .047$, $\eta^2 = .06$, $\omega^2 = 0\ .05$. Correlation analyses revealed that the relationship between the response bias (c) on the AADT and scores on the White Christmas Task were somewhat more consistently related in the helmet on (10% $r = .35$, $p = .005$; 20% $r = .32$, $p = .010$; 30% $r = .35$, $p = .005$) than in the helmet off condition (10% $r = .18$, $p = .150$; 20% $r = .38$, $p = .002$; 30% $r = .27$, $p = .032$). No other interactions were observed, all F's < 1, all p's > .390, all η^2's < .02.

Counterbalance order did not affect the scores on the Mysticism Scale, $F(1,59) = 0.17$, $MSE = 12.10$, $p = .681$, $\eta^2 < 0.01$, $\omega^2 < 0.01$. The outcomes of the RM-ANCOVA with scores on the Mysticism Scale as dependent variable, condition as independent variable and the revised paranormal belief scale, absorption and the White Christmas Task as covariates are presented in Table 6. As mentioned above, the scores on the Mysticism Scale differed significantly. There were no significant interactions between condition and any of the covariates. Further, absorption was significantly related to scores on the Mysticism Scale irrespective of the experimental condition. Higher scores on absorption were correlated to higher scores in both the helmet on and helmet off condition (see Table 5).

[26] As can be see from the descriptive statistics in Table 2, the range of scores on the White Christmas Task was 0-68. This large range was mostly due to a participant who pressed the button 68 times. As we did not specify removal criteria a-priori, we did not remove this participant. Nevertheless, to investigate whether this participant could explain the large between-subjects effect of the White Christmas Task, we removed it, but the between-subjects effect became even larger, $F(1,60) = 16.98$, $MSE = 0.65$, $p < .001$, $\eta^2 = .22$, $\omega^2 = 0\ .21$.

Table 6. *Outcomes of the repeated measures analysis of covariance (N = 63) with scores on the Mysticism Scale as dependent variable, condition as within-subjects variable and the revised paranormal belief scale, absorption and the White Christmas Task as covariates.*

		df	*MS*	*F*	*p*	η^2	ω^2
Within-subject effects	C	1	227.21	8.71	.005	0.13	0.11
	C ∗ RPBS	1	19.11	0.73	.396	0.01	<0.01
	C ∗ Absorption	1	0.09	<0.01	.953	<0.01	<0.01
	C ∗ WC	1	0.34	0.01	.910	<0.01	<0.01
	Residual	59	26.10				
Between-subject effects	RPBS	1	113.70	1.59	.213	0.02	0.01
	Absorption	1	302.96	4.23	.044	0.06	0.05
	WC	1	187.00	2.61	.111	0.04	0.02
	Residual	59	71.58				

Note: C = condition, MS = mean square. All scales were centered; RPBS = Revised Paranormal Belief Scale, WC = White Christmas Task.

The outcomes of the RM-ANCOVA with scores on the Button Press Task as dependent variable, condition as independent variable and the RPBS, Absorption Scale and the White Christmas Task as centered covariates are presented in Table 7. Counterbalance order did not affect the scores on this task, $F(1,57) = 1.13$, $MSE = 19.07$, $p = .170$, $\eta^2 = 0.02$, $\omega^2 = 0.02$. As mentioned above, the scores on the Button Press Task differed significantly between the conditions. There were no significant interactions between condition and any of the covariates and the covariates were not significantly related to the Button Press Task.

Table 7. *Outcomes of the repeated measures analysis of covariance (N = 59) with scores on the Button Press Task as dependent variable, condition as within-subjects variable and the revised paranormal belief scale, absorption and the White Christmas Task as covariates.*

		df	*MS*	*F*	*p*	η^2	ω^2
Within-subject effects	C	1	239.21	11.77	.001	0.18	0.16
	C ∗ RPBS	1	0.57	0.03	.868	<.01	<.01
	C ∗ Absorption	1	4.83	0.24	.628	<.01	<.01
	C ∗ WC	1	0.02	<.01	.973	<.01	<.01
	Residual	55	20.33				
Between-subject effects	RPBS	1	175.98	1.92	.172	0.03	0.02
	Absorption	1	121.85	1.33	.254	0.02	0.01
	WC	1	45.69	0.50	.484	0.01	<.01
	Residual	55	91.88				

Note: C = condition, MS = mean square. All scales were centered; RPBS = Revised Paranormal Belief Scale, WC = White Christmas Task.

Nature of the Experiences. In Table 8, the frequency of the different types of experiences are reported in percentages, accompanied by the inter-rater reliabilities. This table indicates that after correcting for multiple comparisons, participants report significantly more strong bodily sensations and events in the surrounding in the helmet on than in the helmet off condition. With regards to the sub-categories within strong bodily sensations, participants often reported involuntary movements, paralyzing and heavy or light limbs or head. With regards to the sub-categories within events in the surrounding, participants often reported the effect of strong forces, such as a strong magnetic force pulling them. This means that all other sub-categories, as reported elsewhere (Chapter 5), did not differ between the conditions. In addition, the results in the table suggest that participants most frequently report mental and bodily sensations and that time and space distortions are least frequently mentioned. In Table 9, quotes are reported that were reported during the conditions and after the experiment.

Table 8. *Inter-rater reliability scores and average number of occurrences of the categorization scheme categories.*

	Helmet on			Helmet off			Statistics		
	κ	***N***	**%**	**κ**	***N***	**%**	***t***	***p***	***d***
Auditory	.95	13.5	20.8	.76	12.5	19.2	-0.23	.821	0.03
Visual	.96	15.5	23.8	1	13	20.0	0.90	.370	0.11
Mental	.78	28.5	43.8	.88	36	55.4	-1.00	.321	0.12
Weak bodily sens.	.74	41	63.1	.82	30	46.2	2.26	.027	0.28
Strong bodily sens.	1	24	36.9	1	7	10.8	4.76	<.001	0.59
Events in surrounding	.79	16.5	25.4	1	6	9.2	3.00	.004	0.37
Time / space distortion	.48	4	6.2	.90	4	6.2	0.63	.531	0.08
Distraction / skepticism	.83	10.5	16.2	.90	13	20.0	-0.50	.621	0.06

Note: κ = Cohen's Kappa; *N* = the average number of occurrences for the two raters. In the helmet on condition, participants were led to believe that the helmet was on and vice versa in the helmet off condition. % = the average number of occurrences expressed in percentages; N/65.

Table 9. *Quotes of participants following the placebo brain stimulation in both conditions.*

	Helmet on condition
H	"…I felt like a different substance. I know this sounds weird, but while wearing the helmet it felt natural and relaxing. Sometimes I felt like tipping over, somewhat comparable to the feeling of falling asleep but I was fully conscious…"
I	"I completely lost sense of my body size. One moment I felt extremely small, another moment I felt like I was blown up and another moment my eyes felt larger than my head. These changes occurred vary rapidly. At the end, I felt like I was leaving my body and was floating through the room".
J	"I was in doubt whether I heard something and whether I was in the control group or not."

K	"I felt coming loose from my body. I saw Yahshuah (Jezus) who told me he was there for me to protect me. I saw light creatures who had intense love for me. It all felt really pleasant..."
L	"I constantly had the feeling that there were people present around me…"
M	"I felt an energy around my eyes and my eyes started pounding… At a certain moment, everything in the surrounding started to spin, shake and move. It made me really dizzy…"
	Helmet off condition
N	"Now I was in the control condition, my attention was far less focused on my feelings and my bodily sensations."
O	"It is as if the helmet makes everyday sensations just far more strong and vivid."
	After the study
I	"Participant wrote us an email after having participated in the study. The participant wrote that due to a concussion several years ago, she had been having tinnitus ever since. Yet, from the moment that she wore the God Helmet, the tinnitus was gone. She wanted to know whether it was possible to wear the helmet again as she thought it helped getting over the symptoms of her concussion."

Note: Comments have been translated from Dutch and for brevity the comments have been reduced in length or paraphrased.

General Discussion

Using a placebo brain stimulation manipulation, we predicted that: 1) participants would report more extraordinary experiences during the helmet on than during the helmet off condition while controlling for individual differences in suggestibility; 2) participants' score on supernatural beliefs and absorption would be predictive of the intensity and frequency of extraordinary experiences; 3) participants would detect more agent voices in white noise during the helmet on than during the helmet off condition. The observed data were in line with the first hypothesis, partially in line with the second and deviated from the third hypothesis. We will discuss each of these findings in more detail and we will also critically discuss limitations such as demand characteristics.

Expectancy effects

First, we observed that in both a between- and within-subjects design participants reported extraordinary experiences, as indicated by self-report and behavioral measures.

This again confirms that placebo brain stimulation is a powerful manipulation to induce extraordinary expectancies in participants (Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006; van Elk, 2014). In the within-subjects design, participants reported more extraordinary experiences in the helmet on than in the helmet off condition. Importantly, this is the first study in which placebo brain stimulation was used in a within-subject design, similar to procedures that are typically used in placebo analgesia studies (Büchel et al., 2014). By doing so, we make a significant contribution to the placebo brain stimulation (Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006; Chapter 5) and sensory deprivation literature (Jackson & Pollard, 1962; Zuckerman & Cohen, 1964), by providing evidence that the effects of placebo brain stimulation cannot be accounted for by mere sensory deprivation effects. The experiences participants reported are strongly expectancy-driven. These conclusions are further strengthened by another study of one of the co-authors, in which participants of a psychic fair more often reported sounds when wearing a 'sound' helmet and more visual imagery when wearing a 'visual' helmet (Van Elk, in preparation). The fact that we did not observe differences between the conditions in the between-subjects pilot study (similar as in previous studies, Granqvist et al., 2005; Van Elk, 2014) can have several causes. There was insufficient power due to the small sample size, the students were skeptic of the condition and they were skeptic in general towards supernatural experiences and beliefs. This does not mean that is impossible to investigate between-group differences by means of placebo brain stimulation, but efforts should be taken to increase the credibility of both the experimental and the control condition as has been done in the main study.

Individual differences

Second, with regard to absorption, we replicated that participants' score on the Tellegen Absorption Scale was a predictor of the frequency and types of extraordinary experiences people reported in both the pilot and the main study, as operationalized by the Mysticism Scale (Granqvist et al., 2005; Van Elk, 2014). In addition, the Absorption Scale was significantly correlated to the Button Press Task, reflecting that participants scoring higher on absorption more frequently pressed the button during placebo brain stimulation. The relationship between absorption and extraordinary experiences may suggest that people who become more easily immersed into internal mental processes (and external stimuli) are more likely to interpret their sensations in light of the expectancy manipulation. This relates to findings of Luhrmann, who found that absorption was predictive of whether people can come to ascribe internal thoughts as coming from God (Luhrmann, 2006; Luhrmann, Nusbaum, & Thisted, 2010; Luhrmann, 2012). Comments of two of the participants in the helmet off condition further support our view: one participant noted to be less attentive of his bodily sensations; another noted that the helmet made everyday sensations more strong and vivid. What is especially interesting is that several experiences spontaneously reported by participants bear close resemblance to the items on the Absorption Scale (e.g., “At times I somehow feel the presence of someone who is not physically there”; “I can sometimes recollect certain past experiences in my life with such clarity and vividness that it is like living them again or almost so”; “If I wish, I can imagine that my body is so heavy that I could not move it if I wanted to”; “Sometimes thoughts and images come to me without the slightest effort on my part”).

A more skeptic interpretation that follows is that the relation between the Absorption Scale and the Mysticism Scale is merely the result of overlap between items of both questionnaires (i.e., a common method bias Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Specifically, items from both questionnaires were framed in terms of experiences (e.g., “My thoughts don’t occur as words but as visual images” from the Absorption Scale and “I have had an experience that was timeless and spaceless” from the Mysticism Scale). Do note, however, that the Absorption Scale was filled in at home, while the Mysticism Scale was filled in the lab, making it unlikely that participants were primed (Granqvist et al., 2005) or tried to be consistent on both questionnaires. Nevertheless, researchers should try to investigate more thoroughly whether the Absorption Scale is an important individual difference that could be considered a causal factor of extraordinary experiences or whether it rather reflects a resemblance between different methodological operationalizations (e.g., absorption relates to all supernatural belief measures in Table 1 of the supplementary material).

With regard to the other individual differences measures, supernatural beliefs were relatively unrelated to extraordinary experiences, although we did observe correlations between the Revised Paranormal Belief Scale and extraordinary experiences. This contrasts somewhat with recent observations from our own lab, where we found that participants who considered themselves to be spiritual best predicted whether participants had extraordinary experiences (Chapter 5) and from other research groups who observed comparable results (Andersen et al., 2014; Granqvist & Larsson, 2006; Hood Jr & Morris, 1981). In the pilot study, the absence of a relationship between supernatural beliefs and extraordinary experiences could be attributed to the lack of variance of supernatural beliefs.

In the main study, however, nearly half of the participants indicated to have some affiliation with spirituality. It is also not the case that the lack of a relationship was due to multicollinearity problems between absorption and supernatural beliefs. Possible explanations for the differences with previous findings may be attributable to power problems, that we were unlucky, or that the influence of worldview is less important than we previously thought.

Agency detection

Third, in contrast to our expectations, we did not observe that participants reported more agent voices in white noise during the helmet on than during the helmet off condition. However, failing to observe a difference between the conditions may be the result of conflicting cognitive processes that were activated during the placebo brain stimulation and the AADT. The extraordinary experiences perceived by participants during placebo brain stimulation were likely caused by interpreting random internal mental imagery and thoughts in light of the suggestion of the placebo brain stimulation manipulation (Andersen et al., 2014; Jackson & Pollard, 1962; Jackson & Kelly, 1962; Van Elk, 2014; van Elk & Aleman, 2016 and participants N and O from Table 9). This task requires that the attention of participants was focused on internal processes. The AADT, on the other hand, requires that the attention of participants is focused on external events (i.e., sounds). These different types of processes have different effects on signal detection tasks (Mirams, Poliakoff, Brown, & Lloyd, 2012) and may have interfered with each other. More specifically, as soon as the placebo brain stimulation was followed by the AADT, attentional focus shifted from an internal focus on extraordinary experiences, to an external focus on detecting agent voices within white noise.

Further, similar as we argued elsewhere (Chapter 2), the AADT is a perceptual and objective signal detection task whereby participants are forced each trial to respond to a discrete external event. In contrast, in the White Christmas Task and the Button Press Task participants themselves have to decide whether and when to respond to continuous internally generated sensations and experiences. Nevertheless, this is the first study in which the effects of placebo brain stimulation induced extraordinary experiences on behavioral decision tasks were investigated. In future studies, efforts should be made to bring the manipulation of extraordinary experiences closer to the operationalization of the subsequent measure. For example, by manipulating extraordinary experiences externally by means of virtual reality (e.g., hallucinogenic 3D-experiences), decision tasks could be integrated within the manipulation. Thereby, the conflict between internal and external processes, and subjective experiences and objective measures could be minimized.

Limitations and conclusion

Some limitations should be addressed. First, a skeptical reader may question the authenticity of the responses and may attribute the effects to demand characteristics (i.e., participants responding in a manner that is consistent with their perceived request by the experimenter). We (Chapter 5), and others (e.g., Andersen et al., 2014), have discussed this issue extensively elsewhere. In the present study we also tried to control for an overall response bias (i.e., some participants could be more prone to having a 'yes-saying' tendency on the different measures that we included) by means of a White Christmas Task, which was included as a behavioral measure that was conceptually similar to the Response Button Press Task used during the God helmet session. This showed that response bias could only at the maximum explain 15% of the variance (see Table 5, $.39^2 = .15$). Second, in the open comments of pilot study, participants were asked to comment on the entire experiment and it became apparent that when participants mentioned for example voices in white noise, they often referred to the AADT. This may have artificially heightened the frequency of agent voice reports and possibly some other categories. However, this should have affected both the helmet on and the helmet off condition to a similar extent and only in the pilot study. Third, the raters were not blind of the condition, and in future studies, more objective analysis of the comments are to be preferred (e.g., by means of language recognizing algorithms).

Summing up, we provide evidence that the effects of placebo brain stimulation are strongly influenced by expectancies and cannot be exclusively attributed to sensory deprivation. This has important implications for researchers investigating extraordinary experiences in the lab, but also for researchers using 'fancy' brain stimulation devices, such as transcranial magnetic stimulation and transcranial direct-current stimulation, where participants' expectancies can also strongly contribute to the observed effects. In addition, we highlighted absorption as an interesting personality trait to be taking into account in future research, as this individual difference measure robustly predicts extraordinary experiences. Finally, our findings seem to contrast with the hypothesized relationship between supernatural beliefs and agency detection, although we stress that the subjective nature of agency experiences may be difficult to capture by more objective experimental agency measures.

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SUPPLEMENTARY MATERIAL

Measures Pilot study

Dependent Measures. ***Intensity of the experience.*** The intensity of the mystical experience was captured by means of a slider with a scale from 0 to 100 (0 = no experience, 100 = strong mystical/spiritual experience).

Persinger Exit Questionnaire. To capture the type and frequency of mystical experiences, the Persinger Exit Questionnaire (Cook & Persinger, 1997) was used. The Persinger Exit Questionnaire consists of 20 statements (e.g., "I had the feeling that I was somewhere else" or "I felt as if I separated from my body"), with which participants could agree or disagree. The questionnaire had an adequate reliability, α = .75.

Covariates. ***The Spiritual Transcendence Scale.*** The Spiritual Transcendence Scale (Piedmont, 1999) was developed to reflect a personality trait that complements the five-factor model of personality. Spiritual transcendence was defined as "the capacity of individuals to stand outside of their immediate sense of time and place to view life from a larger, more objective perspective" (Piedmont, 1999, p. 988). The questionnaire consists of 24 items with which participants could agree or disagree. Example items are "I believe that death is a doorway to another plane of existence" and "I have had at least one "peak" experience". The reliability of the scale was adequate, α = .81.

The Magical Ideation Scale. The Magical Ideation Scale (Eckblad & Chapman, 1983) measures forms of causation that are considered invalid from a natural metaphysical worldview. Participants scoring high on this scale show are thought to have a predisposition to psychosis. It consists of 30 items with which participants could agree or disagree. Example items are "Horoscopes are right too often for it to be a coincidence" and "I have occasionally had the silly feeling that a TV or radio broadcaster knew I was listening to him". The reliability was adequate, α = .73.

The Dualism Scale. The Dualism Scale (Stanovich, 1989) captures to what extent people hold dualistic (mind/body) or materialistic beliefs. The scale consists of 27 statements such as "The mind is not part of the brain but it affects my brain" and "Minds are inside brains but are not the same as brains". Participants indicated to what extent they believed these statements were true on a 5-point scale (1 = strongly disagree, 5 = strongly agree). The reliability was adequate, α = .77.

Emotions. The types of emotions felt by participants were measured with the Positive and Negative Affect Scale (Watson & Clark, 1999), which has a subscale for positive (e.g., "happy") and negative (e.g., "sad") emotions. Participants had to respond to what extent they felt each of 20 emotions during the experiment on a 5-point Likert scale (1 = very slightly or not at all, 5 = extremely). Both the positive, $\alpha = .87$, and negative subscale, $\alpha = .88$ had adequate reliability.

Feeling of control. Feelings of control were measured with a 5-item scale (e.g., '*How much control did you experience during the experiment?*'), adapted from (Rutjens, Van Der Pligt, & Van Harreveld, 2010).

Self-other connectedness. To investigate whether participant's felt connected to others, self-other representations were measured by means of a visual representation. Participants had to indicate which of seven images they thought best described the relationship between themselves and others. In each of the seven images two circles were depicted – one circle read 'self' the other read 'other'. In the first image the circles were completely independent from each other and then in the subsequent images they overlap slightly more until the last image where the circles completely overlap. Participants could choose one of the seven image making the images comparable to a 7-point Likert scale.

Physiological measures. Biophysical responses were measured with an amplifier developed by the technical support group of the UvA psychology department. For skin conductance the amplifier uses a 50Hz, sine-shaped excitation voltage with an amplitude of 1Vpp. A pair of curved Ag/AgCl electrodes (20 x 16 mm) were connected to the medial phalanxes of the middle and index finger of the non-dominant hand. ECG was measured using a set of three Ag/AgCl electrodes (3M Red Dot disposables). Both signals were sampled with Vrssp98 version 8.5 software (developed by UvA's technical support group) and a NI-6224 A/D converter with a sample speed of 1000S/s. Due to technical failure, no recordings were made for the second half of the experiment – the last 22 participants. The study involved two baseline conditions. The first baseline condition was from the time the participants were attached to the physiological measures until the start of the practice trials. The second baseline condition was from the start of the practice trials until the end of the practice trials. The experimental part began at the start of the experiment and went on until the end of the experiment.

Results pilot study

With regard to the analysis of covariance for predicting the outcome of the intensity of the extraordinary experiences as measured with the slider, there was no effect of condition, $F(1,36) < 0.01$, $MSE = 498.76$, $p = .997$, $\eta^2 < 0.01$, $\omega^2 < 0.01$. Participants in the helmet on condition ($M = 3.8$, $SD = 3.2$) reported more Persinger Exit Questionnaire extraordinary experiences than participants in the helmet of condition, $t(1) = 2.17$, $p_{\text{tuckey}} = .037$. The Revised Paranormal Belief Scale, $F(1,36) = 0.23$, $MSE = 498.76$, $p = .637$, $\eta^2 = 0.01$, $\omega^2 < 0.01$ was not significantly related to scores on the intensity slider. The effect of absorption, $F(1,36) = 3.74$, $MSE = 498.76$, $p = .061$, $\eta^2 = 0.09$, $\omega^2 = 0.07$, was close to significance, with people scoring higher on absorption also having higher scores on the intensity slider.

With regard to analysis of covariance for predicting the outcome of the Persinger Exit Questionnaire, there was a significant effect of condition when controlling for the Revised Paranormal Belief Scale and absorption, $F(1,36) = 4.70$, $MSE = 6.98$, $p = .037$, $\eta^2 = 0.10$, $\omega^2 = 0.08$. Participants in the helmet on condition ($M = 3.8$, $SD = 3.2$) reported more extraordinary experiences on the Persinger Exit Questionnaire than participants in the helmet of condition, $t(1) = 2.17$, $p_{\text{tuckey}} = .037$. The Revised Paranormal Belief Scale, $F(1,36) = 0.58$, $MSE = 6.98$, $p = .452$, $\eta^2 < 0.01$, $\omega^2 < 0.01$ was not significantly related to scores on the Persinger Exit Questionnaire. Again, the effect of absorption was close to significance, $F(1,36) = 3.70$, $MSE = 6.98$, $p = .062$, $\eta^2 = 0.08$, $\omega^2 = 0.06$, with people scoring higher on absorption reporting higher Persinger Exit Questionnaire scores.

Correlation Tables

Table 1S. *Spearman correlation table of all measures related to supernatural beliefs in the pilot study.*

	1	2	3	4	5	6	7
1. STS	—	.41 **	-.05	.52 ***	.16	.39 *	.19
2. Dualism		—	.09	.29	.12	.36 *	-.02
3. Persinger Exit Questionnaire			—	.35 *	.62 ***	.38 *	.52 ***
4. Absorption				—	.50 ***	.56 ***	.29
5. MS					—	.46 **	.59 ***
6. MIS						—	.32 *
7. SE							—

Note: Spearman correlations. * $p < .05$, ** $p < .01$, *** $p < .001$. STS = Spiritual Transcendence Scale; Dualism = Dualism Scale; Persinger Exit Questionnaire = Persinger Exit Questionnaire; Absorption = Absorption Scale; MS = Mysticism Scale; MIS = Magical Ideation Scale; SE = Spiritual Experience Slider.

Table 2S. *Spearman correlation table of all measures related to supernatural beliefs in the main study.*

	1	2	3	4	5	6	7	8	9
1. Reli	—	.55 ***	.58 ***	.44 ***	.16	.24	.22	.20	.22
2. Spiri		—	.74 ***	.52 ***	.27 *	.23	.28 *	.10	.26 *
3. RPBS			—	.59 ***	.25	.37 **	.33 **	.23	.26 *
4. Abso				—	.32 *	.31 *	.32 *	.29 *	.23
5. H On					—	.59 ***	.63 ***	.29 *	.24
6. H Off						—	.52 ***	.59 ***	.39 **
7. MS H On							—	.56 ***	.27 *
8. MS H Off								—	.35 **
9. WCT									—

Note: Spearman correlations. * $p < .05$, ** $p < .01$, *** $p < .001$. H On = number of button presses in the helmet on condition; Off = number of button presses in the helmet off condition; MS H On = Mysticism Scale score in the helmet on condition; MS H Off = Mysticism Scale score in the helmet off condition; RPBS = Revised Paranormal Belief Scale; Absorption = Absorption Scale; WCT = White Christmas Tas

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Chapter 5

THE ROLE OF ALCOHOL IN EXPECTANCY-DRIVEN MYSTICAL EXPERIENCES:

A pre-registered field study using placebo brain stimulation

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Abstract

We explored the effects of alcohol on expectancy-driven mystical and quasi-mystical experiences by manipulating participants' expectations. By using the so-called God Helmet suggestion, participants were led to believe that a placebo brain stimulation could elicit mystical experiences. In this pre-registered field study, we set out to test whether alcohol could increase participants' susceptibility to the God Helmet suggestion in a large sample (*N* = 193) at a Dutch festival. Participants reported a wide range of extraordinary experiences associated with mysticism, including out-of-body experiences, involuntary movements, and the felt presence of invisible beings. Regression analyses revealed that self-identified spiritualism predicted extraordinary experiences, but neither objective nor subjective measures of alcohol intoxication increased participants' susceptibility to the God Helmet. Methodological limitations that may explain the lack of an effect for alcohol are discussed, while we explore the usefulness of the God Helmet in the study of extraordinary experiences.

"The sway of alcohol over mankind is unquestionably due to its power to stimulate the mystical faculties of human nature…" - William James, pp. 307, 1902/1985

Psychoactive substances have been frequently used in the context of religious rituals (de Rios & Winkelman, 1989; Ellens, 2014; Fuller, 2000). For instance, in many indigenous religions in the Peruvian Amazon, tribes use ayahuasca during religious ceremonies to get into contact with ancestor spirits (McKenna, 1999; Tupper, 2009). One specific psychoactive substance that has received little attention in the context of religious rituals is alcohol. Alcohol has been consumed by humans for several thousands of years (McGovern, 2013), and the link between alcohol and religion is well-documented but complex (Boyle, 2013; Dietler, 2006; Fox, 2000; Hanson, 1995). In some cultures, the ritual experts use alcohol as part of their rituals, while other religions allow alcohol to be consumed by the ritual participants (e.g., Catholic Christians, Native Americans, and the ancient Greeks, Hinduism, Judism and Chinese). Several sects of religions restrict alcohol use (e.g., Protestant Christians and Buddism), while other religions prohibit the use of alcohol altogether (e.g., Islam and Jainism; Dietler, 2006; Royce, 1985).

The specific effects of alcohol consumption in religious rituals are poorly understood. Some researchers have proposed that alcohol fosters social cohesion among participants (for reviews see Kuntsche, Knibbe, Gmel, & Engels, 2005; Kuntsche, Knibbe, Gmel, & Engels, 2006), while others suggest that alcohol could facilitate extraordinary religious experiences (James, 1902; Smith, 1964). This latter idea is particularly interesting because extraordinary experiences in rituals may reinforce participants' belief in supernatural worldviews (James, 1902). It could be for instance that in the right suggestible ritual context, alcohol intoxication facilitates mystical and quasi-mystical (i.e., extraordinary) experiences. Alternatively, ritual experts such as shamans and witch doctors may benefit from the liberating and mind-altering effects of alcohol as they often display interactions with the supernatural realm following alcohol consumption. Alcohol may also enable ritual spectators to be less critical when they witness supernatural events suggested to them by ritual leaders (e.g., spirit travels or communication with deceased ancestors). Stories about such events are likely to spread quickly and thereby foster endorsement of supernatural beliefs[27] (Blackmore, 1999; Hardy, 1979; James, 1985; Lang, 1900). Ideas about the potential involvement of alcohol in fostering extraordinary experiences, however, have remained hypothetical. In fact, it remains unclear if and to what extent alcohol can facilitate extraordinary experiences at all.

William James was one of the first to describe a link between alcohol and extraordinary religious experiences (1902/1985, p. 307), but he did not describe the potential underlying mechanism through which alcohol could exert its effects. Modern scientific evidence hints at two potentially interrelated causal pathways from alcohol to extraordinary experiences: by impaired executive functioning and by increased suggestibility.

Alcohol, executive function, and increased suggestibility

Alcohol affects the information processing capacities of the brain (e.g., Bjork & Gilman, 2014), including motor control, which is subserved by the primary/supplementary motor areas, the basal ganglia, and the cerebellum. Alcohol also affects the motivational processes, mediated by the ventrial striatum and the nucleus accumbens, and a host of executive functions supported by the dorsolateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC; see for a review Bjork & Gilman, 2014). Alcohol reliably impairs basic executive functions like attentional control, motor control, working memory and inhibitory control (Zoethout, Delgado, Ippel, Dahan, & Van Gerven, 2011).

The effect of alcohol on the brain's executive processing is interesting because impaired executive functioning has been associated with increased suggestibility (see for a review, Parris, 2016). Suggestibility is the extent to which people are influenced by suggestions, such as the suggestions of a hypnotist or shaman. Suggestibility seems to be increased through alcohol consumption (e.g., Van Oorsouw, Merckelbach, & Smeets, 2015). Although the general effects of alcohol and psychoactive substances differ strongly, there are some indications that the effects of alcohol on suggestibility may be at least somewhat similar to

[27] By belief in the supernatural (Latin: *supranaturalis*), we refer to all beliefs that are said to exist beyond (*supra*) nature (*naturalis*). They are cultural specific beliefs about phenomena that do not coincide with a naturalistic worldview and are therefore invisible and immeasurable.

psychoactive substances such as lysergic acid diethylamide (LSD, Carhart-Harris et al., 2015; Sjoberg & Hollister, 1965; Weitzenhoffer, 1980), mescaline (Weitzenhoffer, 1980) and nitrous oxide (Whalley & Brooks, 2009). For example, alcohol-intoxicated participants seem more prone to follow leading questions (Van Oorsouw et al., 2015) and alcohol consumption appears to increase participants' susceptibility to hypnotic suggestions (Semmens-Wheeler, Dienes, & Duka, 2013). However, the literature on alcohol and suggestibility is scarce, and some studies show no effect (Dienes et al., 2009) or even a negative relationship (Santtila, Ekholm, & Niemi, 1999). Based on the evidence presented above, alcohol may impair the brain's executive processing to the extent that people become more susceptible to the suggestions by ritual leaders, and this may facilitate extraordinary experiences in participants of rituals. Yet, empirical support for this possible relation between alcohol and mystical experiences is still missing.

Suggestion, beliefs, and the God Helmet

The power of suggestion has recently been explored in a series of studies that use both verbal and contextual suggestion to elicit extraordinary experiences (Andersen, Schjoedt, Nielbo, & Sørensen, 2014; French, Haque, Bunton-Stasyshyn, & Davis, 2009; Granqvist et al., 2005; Granqvist & Larsson, 2006; Tinoca & Ortiz, 2014; van Elk, 2014). One particularly suggestive manipulation for eliciting extraordinary experiences is the so-called God Helmet suggestion. The God Helmet suggestion is a placebo brain stimulation manipulation combined with sensory deprivation, which generates strong expectations in participants who are instructed that the helmet stimulates their brain electromagnetically to elicit various types of extraordinary experiences. The God Helmet was originally designed to test the effects of weak electromagnetic transcranial brain stimulation on paranormal experiences (Persinger, Tiller, & Koren, 2000; Pierre, & Persinger, 2006), but the transcranial effect of the device is highly controversial (Granqvist et al., 2005). Despite this controversy, the placebo brain manipulation itself has proven to be an effective and powerful tool for manipulating participants' expectancies to elicit extraordinary experiences (Andersen et al., 2014; Granqvist et al., 2005; Chapter 4; van Elk, 2014; van Elk, in preparation).

The placebo brain stimulation effects induced by the helmet may best be understood in light of the predictive processing framework (Andersen et al., 2014; Büchel, et al., 2014; Schjoedt et al., 2013; van Elk & Aleman, 2016). According to proponents of this framework, life-long interactions with the environment result in models with which the brain tries to predict what sensory input it can expect (Clark, 2013; Friston, 2005; Friston & Kiebel, 2009). The brain's predictions are compared to sensory input, and detection of mismatches between predictions and sensory input (i.e., prediction errors) are used to correct and update predictive models. The God Helmet may induce strong predictions about extraordinary experiences, while sensory deprivation may prevent participants from updating their models based on sensory input (see Figure 4 in the supplementary material for a schematic representation of the working of the God Helmet in terms of predictive processing). With limited access to sensory information, randomly fluctuating bodily sensations and internal thoughts may be interpreted in light of the kind of experiences predicted by the God Helmet suggestion.

Importantly, the God Helmet suggestion appears to be most effective for people who already believe in the possibility of having the kind of experiences suggested to them by the experimenter. For example, spiritualists seem particularly prone to suggestions about so-called 'felt presence experiences' because they believe in the possibility of connecting with spirits, while New Age practitioners seem more prone to experience holistic experiences (Andersen et al., 2014; Granqvist & Larsson, 2006). The least susceptible participants either reject the possibility of a supernatural realm, or simply remain skeptical of the suggestions made about the God Helmet. Whether alcohol can strengthen the power of the God Helmet suggestion by reducing skepticism is therefore an interesting question.

Based on previous findings, we set out to test whether alcohol consumption (measured objectively and subjectively) predicted increased susceptibility to expectancy-driven mystical experiences (self-report measures of extraordinary experiences and frequency of experiences), by using placebo brain stimulation, while controlling for demographics (i.e., gender, age and education) and cultural learning (i.e., whether participants themselves or their parents were supernatural believers). We adopt a correlational approach, so no control group was included intentionally.

The specific aim was to investigate whether susceptibility to the God Helmet suggestion increases with alcohol consumption, and to examine if such a correlation might be mediated by impaired executive processing (i.e., performance on a Stroop Task), and see if we could replicate whether self-identified spirituality is predictive of such experiences (e.g., Andersen et al., 2014). Briefly, we set up a controlled environment for the God Helmet suggestion at a large Dutch festival[28] and managed to recruit a sample of 199 participants who all received the same instructions and suggestions. All our hypotheses, materials and data analysis plans were pre-registered on the Open Science Framework (see https://osf.io/7u4wd/ and supplement https://osf.io/4m7n2/).

Methods & Materials

Participants

Participants were recruited at Lowlands, a large three-day Dutch music festival with over 50.000 visitors and a stage dedicated to science (i.e. Lowlands science). The study was advertised in the program booklet as 'Tripping with the God Helmet: Researchers of the University of Amsterdam will electromagnetically stimulate your brain to elicit spiritual experiences'. By conducting the study at a festival, we expected to observe variation in alcohol intoxication as well as in the types of worldviews people hold (i.e., spiritualists and sceptics). In total, 199 participants started the study. Six participants did not complete the study due to a variety of reasons (e.g., some participants took the helmet off after several minutes as they did not notice anything). Of the 193 participants who completed the study, 61.7% were male (N = 119) and the mean age was 26.2 years (SD = 9.6, range = 18 – 69). Participants were generally highly educated (41.7% pre-university or university, 38% senior general secondary education or college, 15.6% lower secondary education or vocational education college, 4.7% other). People participated voluntarily and were not compensated. However, to increase the response rate on a follow-up questionnaire, we did reward two participants with festival tickets for the upcoming year by means of a lottery. The ethics committee of the University of Amsterdam

[28] http://lowlands.nl/programma/ll-science/

approved the experimental protocol, all participants signed written informed consent and all participants were treated in accordance with the declaration of Helsinki.

Procedure

Upon arrival at the science booth, participants were screened on the inclusion criteria. Participants read an information voucher in which the supposed working of the God Helmet and other aspects of the study were explained (see supplementary material). Subsequently, objective alcohol intoxication was measured by means of an alcoholmeter, and a sticker was attached to the participant's shirt with an anonymous participation number and their blood alcohol (BAC) level.

Once participants were seated in an open cubicle behind a laptop (see Figure 1 of the supplementary material), they were required to fill out their demographic information and questions related to their religiosity and spirituality on a computerized survey. After these questions were completed, participants viewed a video in which the working of the helmet was explained. Next, the Stroop Task was explained, both verbally and with text on the computer screen. As soon as the Stroop task was completed, an experimenter placed the God-helmet on the participant's head and attached the participants to sham electrophysiological measures (i.e., apparatus that were not turned on), supposedly to keep track of their health. Their fingers were attached to a sham skin conductance apparatus and heart rate stickers and wires were attached on their breast under their shirt. Participants were provided with blindfolds, earphones with white noise and were given a response key (i.e., mouse button) to indicate with their index finger whether and when they had an extraordinary experience. After 15 minutes of sitting with the God Helmet, the helmet was taken off and the blindfolds and earphones were removed as well. Participants were asked to fill out questions on the laptop relating to the type of experiences they had had. In the final comment of the questionnaire, participants were asked to fill out their email address so we could send them the debriefing as well as some follow-up questions. Follow-up questions were sent within five days after the festival. A debriefing was sent by mail two weeks after the experiment, to prevent that the debriefing might influence the follow-up questions via (social) media exposure.

Testing site. It is important to note that organizational rules of the festival limited us to test the participants for a maximum of 45 minutes. Therefore, tasks and measures were used that took relatively little time, and only relevant items of existing scales were selected. In addition, although there was a specific stage dedicated to conducting scientific studies, the experimental conditions were suboptimal for the experimental procedure. The bass sound of a nearby stage could occasionally be heard, there were no closed cubicles and the wooden floor moved if people walked nearby. These distractions inevitably had an effect on the participants (see the Results section 'Nature of Experiences' and Discussion for more details). We made use of six open cubicles with experimental equipment, so that six participants could be tested simultaneously (see Figure 1 in the supplementary material for a schematic representation of the testing site).

Suggestibility manipulation

A placebo brain stimulation suggestion was used to manipulate participants' expectations. The helmet was a transformed metallic-colored skate helmet with wires attached to the back of a bogus ADC-box which had a flickering light (see Figure 2 in the supplementary material), but the helmet was not attached to any electrical generator. The credibility of the helmet manipulation was increased in five ways. First, participants were screened on four exclusion criteria: 1) epilepsy, 2) easy fainting, 3) claustrophobia and 4) any form of brain damage. Second, prior to the study participants read a short review of research claiming that the helmet reliably elicits extraordinary experiences (e.g., Persinger, Tiller, & Koren, 2000; Pierre & Persinger, 2006; the full instructions can be found in the supplementary material). Third, prior to the study participants watched a Youtube video of the Big Think (a Youtube channel in which science topics are discussed). In this video, author Steven Kotler explains how the helmet (supposedly) works (i.e., by means of electromagnetic stimulation) and describes the types of experiences that can be induced through the helmet[29]. Fourth, sham electrophysiological measures (i.e., skin conductance and heart rate) were used and we told participants that these were included to 'keep track of their health'. Fifth, a vomit bowl was placed on every table (see Figure 3 in the supplementary material for a picture of the experimental set-up). To decrease bottom-up sensory input, participants were sensory deprived by means of an eyeshade and they listened to white noise presented with in-ear earphones. To see if the manipulation raised suspicion, at the end of the experiment we asked participants to describe the side effects they experienced as a result of the stimulation with the helmet (for a similar procedure see, Andersen et al., 2014).

Measures

Nature of the experiences. The nature of the experiences was measured by asking participants what they experienced when they pressed the button – if they pressed it at all. To categorize the reported experiences, we classified all comments in a categorization scheme. First, all comments were read by one of the authors (DLRM) and a categorization scheme was proposed to a second author (MvE). The second author categorized half of the subjective reports on the basis of the categorization scheme and proposed some small adjustments. Subsequently, the first author tried to classify the comments on the basis of the renewed categorization scheme and some final adjustments were made. This resulted in eight types of reported experiences, which are presented in Table 4, and are accompanied by the inter-rater reliabilities and the frequency with which they were reported. The reliabilities indicate that we agreed to a sufficient extent on the categorization of the different types of experiences.

[29] http://bigthink.com/videos/religion-and-god-helmets

Table 1. *Inter-rater reliability scores and average number of occurrences of the categorization scheme categories.*

	κ	*N*	*%*
Auditory	0.87	30.3	16.1
Visual	1	27.5	14.6
Mental	0.74	24	12.8
Weak bodily sensations	0.87	147.5	78.5
Strong Bodily sensations	0.67	56.5	30.1
Events in surrounding	0.78	38.5	20.5
Time / Space distortion	0.78	10.5	5.6
Distraction / Skepticism	0.81	57	30.3

Note: κ = Cohen's Kappa; *N* = the average number of occurrences for the two raters, % = the average number of occurrences expressed in percentages; N/188.

Extraordinary experiences. ***Frequency.*** To measure the frequency of extraordinary experiences participants had to press the mouse button each time they felt 'something extraordinary' during the 15 minutes that they wore the helmet. This task was programmed and responses were recorded using Presentation software (V.16.2, Neurobehavioral systems, Albany, CA, USA).

Intensity. The intensity of extraordinary experiences was measured by a subjective rating question at the end of the 15-minute stimulation ("To what extent did you feel a mystical/spiritual experience as a result of the helmet?"*;* 0 = not at all - 100 = very much), combined with a shortened version of the Mysticism-scale (items 1, 9, 16, 22, 23, 25, 28, and 29; Hood, 1975), statements to which participants could agree or disagree. Based on previous work on the God Helmet (Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006) two additional items were included. One referred to the feeling of awe (i.e., "The helmet left me with a feeling of awe") another referred to the feeling of a presence (i.e., "I felt the presence of another being").

Alcohol and Drugs. ***Objective alcohol measure.*** Alcohol intoxication was objectively measured with a calibrated alcoholmeter (Alcoholtester Alcoscan ALC-1) – the manufacturer appoints the accuracy between 0.005% BAC and 0.050% BAC. BAC is the blood alcohol concentration content. A BAC of 0.1% means that there is 0.1 gram of alcohol for every liter blood. Mild euphoria and concentration problems start at around 0.03% BAC, Disinhibition and reasoning problems start around 0.06% BAC, possibility of nausea and motor control problems start above 0.1% BAC (Carp, 2015).

***Subjective alcohol and drug measure*.** Apart from objective alcohol intoxication, we measured the subjective index of their 'high' (Zoethout et al., 2011), by letting people indicate on a scale from 0 (= completely sober) to 100 (= very high of alcohol) how drunk they felt from alcohol. Participants were also asked how many units (i.e., glasses or cups) of alcohol and other type of drugs (to rule out effects of other intoxicants, see supplementary material) they had consumed on that day (i.e., since they were awake) on a scale from 1 to 20. Unfortunately, due to a programming error these subjective questions were not seen by the participants and had to be obtained retrospectively, in a follow-up questionnaire.

Executive functioning. A Stroop Task was used as a proxy of inhibitory control, which is part of the executive functioning processes (Mansouri, Tanaka, & Buckley, 2009). The task was derived from the Millisecond Software LLC[30] website, which provides an online database with cognitive tasks. The task was an adapted version of the one designed by Bauer and Cox (1998). In this task, words or squares were presented in four different colors (red, green, blue, and black). Participants had to indicate the color of the ink of the word or square by pressing one of four keyboard keys (d, f, j, or k for respectively the colors red, green, blue, and black). In

[30] http://www.millisecond.com/download/library/Stroop/

congruent trials, the color of the ink was consistent with the meaning of the word (e.g., the word 'blue' written in blue ink). In incongruent trials, the color of the ink was inconsistent with the meaning of the word. Therefore, participants had to inhibit an automatic behavior (i.e., reading). In control trials, a square with a color was presented. In the task, 94 trials were presented. The first 10 were practice trials so participants could get acquainted with which keyboard button corresponded to which color, and this information was also presented during each trial on top of the screen. The remaining 84 trials consisted of 12 different possibilities (i.e., 4 colors x 3 conditions) each presented 7 times. Each word was presented on the middle of a white screen and was presented for as long as the participants waited to respond. For incorrect answers a red cross was presented on screen for 400 ms. No feedback was given for correct trials. Between trials a 200 ms white screen inter stimulus interval was presented. As a measure of response inhibition, we subtracted the reaction time of the incongruent trials from the reaction time of the congruent trials (Bauer & Cox, 1998). We did not pre-register outlier criteria and none of the trials were deleted.

Spirituality and Religiosity. Spirituality and Religiosity were measured with the following questions with scales ranging from 0 (not at all) to 100 (very much). "How religious do you consider yourself?" and "How spiritual do you consider yourself?".

Spirituality and Religiosity of the parents. Participants who were brought up surrounded by credibility enhancing displays of a supernatural realm (Henrich, 2009; Lanman & Buhrmester, 2016), might be somewhat more open to the idea of supernatural experiences than participants without such upbringing. We addressed this issue with the following question ranging on a scale from 0 (not at all) to 100 (very much). "How religious and/or spiritual do you consider your parents/caretakers? (If you consider one of them very religious/spiritual but the other not at all, opt for 50)".

Exploratory measures. We piloted physiological measures of skin conductance and and heart rate variability in two out of six participant. However, response variability was overly sensitive to testing conditions and could not be used.

Data analysis

The nature of the experiences was described in a qualitative manner and the frequencies were reported. To predict the *frequency* of extraordinary experiences (i.e., the number of button presses) we used generalized linear models (GzLM). Considering that the count data followed a Poisson distribution with zeros, we used a negative binomial regression model (Zeileis, Kleiber, & Jackman, 2008). As predictors, gender, age, education, religiosity, spirituality, religiosity of the parents, objective alcohol intake and response inhibition were inserted. To predict the *intensity* of the extraordinary experiences we used hierarchical linear regression (HLR; Method = Enter). To combine the data of the subjective intensity item and the mysticism scale items, we used principal axis factoring (PAF) analyses with oblique (Promax) rotation (Russel, 2002). The regression weights were used as a combined measured of intensity of the experience. In the first step of the HLR we controlled for gender, age and education. As predictors religiosity, spirituality, religiosity of the parents, objective alcohol intake and response inhibition were used.

As outlined above, we treated the analyses in which we used retrospective subjective alcohol intoxication separately. Thus, we had two additional models for the retrospective follow-up data: one additional GzLM for the frequency of the extraordinary experiences and one additional HLR for the intensity of the extraordinary experiences. The only addition was that the subjective alcohol intake measures (i.e., feeling of 'high' and units consumed) were also included. Data pre-processing, principal axis factoring and the HLRs were run in R Studio (R Core Team, version 1.0.136). All other analyses were run in SPSS (IBM, version 23).

Results

Alcohol and Drugs data

Of all participants, 73.2% consumed alcohol on the day of testing, 16.8% consumed alcohol and at least one other type of drugs on the day of testing, 7.4% did not consume alcohol or drugs and 2.6% used at least one type of drugs without consuming alcohol.

Nature of experience

The entire study depends on the possibility of eliciting the kind of experiences that are of interest to the study of religion. We therefore start by quoting examples of the striking experiences reported by the participants before we reduce these reports to types and frequencies in our classification schema (below).

> Participant a: “It felt as if I was floating, as if I was no longer on the chair”.
>
> Participant b: “I had the feeling that the helmet was taking control over me. My head started turning around and my eyes were spinning.”
>
> Participant c: (this text is shortened and paraphrased) “I went into a dialogue with a dark circle, it sounded like my own voice yet also different. It was something ‘higher’. The voice told me that I was ready to get children, even though the circumstances were suboptimal. Deep down I already knew this and I became very emotional and started crying, but I was never afraid. I have never had such an experience, it was truly amazing”.
>
> Participant d: “I came loose from the chair, the chair fell and I was floating. The desk started to shake heavily and I felt the presence of a dark figure next to me. It whispered something in my ear that I could not understand.”
>
> Participant e: “A strong gravitation or magnetic force was pulling my head back. I wanted to move my head back but it was simply impossible”.
>
> Participant f: “Some force wanted let me know its presence and let me click the button”.
>
> Participant g: “‘It felt as if I was floating, like being slowly lifted. My heart slowed down and my breathing sometimes stopped, because of the floating feeling - similar to an MDMA experience. I felt stable and after a while it seemed like an external influence was affecting me. By brain heated up and I felt tingling sensations over my body and I got a pleasant goosebump feeling.”

Table 1 indicates that weak bodily sensations were mentioned most frequently, but several participants reported strong bodily sensations and distractions and skepticism were also relatively frequently reported. Time and space distortions were not reported often. The type of experiences covered by the different categories become apparent from Table 2, in which the sub-categories are also reported, in association with the frequencies with which they occur. Certain categories warrant some more detailed explanation. With ‘memories of past drug experience’ we mean that participants sometimes reported that their experiences were comparable to that of earlier drug experiences (e.g., with psychedelics, such as MDMA, LSD or magic mushrooms). With ‘ego dissolution’ we mean that participants reported that they felt as if their soul or spirit was slowly dissolving and that they felt no longer present. With ‘moving surroundings’ we mean that participants reported movements of objects in the environment such as a shaking desk or chair. With ‘forces’ we mean that participants reported that they noticed the influence of certain forces, such as the feeling of being pushed or pulled, that gravity changed or that they noticed the presence of energies or electricity. With ‘feeling of oneness’ we mean that participants reported to feel ‘one’ with the universe or with other beings.

As can be seen in Table 2, randomly fluctuating bodily sensations such as itches and tingles, sleepiness or heart rate increases were most frequently reported. Of the extra-ordinary experiences, agent voices, involuntary movements, forces, floating and out-of-body experiences were reported relatively frequently.

Table 2. *Categorization scheme with frequency of occurrences per category and sub-category.*

Category	**Sub-category**	***N***	**%**
Auditory	1. Agent voices	21.5	11.9
	2. Music/melody	17.5	9.7
	3. Other sounds	15.5	8.6
Visual	1. Flashes/light/light at end of tunnel	13	7.2

	2. Imagery/visuals/objects	22.5	12.5
	3. Agents/people/shadows	14	7.8
Mental	1. Feelings/emotions	5	2.8
	2. Self-referential Processing	6	3.4
	3. Mind-wandering	4	2.2
	4. Memories of past drug experiences	9	5.0
Weak bodily sensation	1. Cold/shivering/goose bumps	7	3.9
	2. Itch/tingeling/light pain	41	22.8
	3. Stress/heart rate increase/hot/sweat	29	16.1
	4. Light touches	10.5	5.8
	5. Dyziness	22.5	12.5
	6. Sleepiness/relaxation	37.5	20.8
Strong bodily sensations	1. Involuntary movements	18	10.0
	2. Out-of-body/ floating	15.5	8.6
	3. Ego dissolution	6.5	3.6
	4. Paralyzed	4	2.2
	5. Heavy arms/legs/head	12.5	6.9
Events in surrounding	1. Feeling of a presence	10	5.6
	2. Moving surroundings	8	4.4
	3. Forces	20.5	11.4
Time / Space distortion	1. Time distortion	3.5	1.9
	2. Space distortion	4	2.2
	3. Feeling of oneness	3	1.7
Distraction / skepticism	1. Distraction	25	13.9
	2. Doubts about helmet	9.5	5.3
	3. Felt bored	5.5	3.1
	4. Nothing happened	17	9.4

Note: N = the average number of occurrences for the two raters. % = the average number of occurrences expressed in percentages; N/188.

As we hypothesized that alcohol could facilitate extraordinary experiences by reducing executive functioning, we analyzed the relationship between alcohol and performance on the Stroop Task. The correlations between performance on the Stroop Task (i.e., response inhibition) and the objective as well as subjective alcohol measures are provided in Table 3. Although two out of three alcohol measures were statistically significant correlated to response inhibition, the correlations were weak.

Table 3. Correlation table for the relationship between alcohol and response inhibition performance of the Stroop Task.

	1. Alc obj (*N* = 193)	**2. Alc subj1 (*n* = 138)**	**3. Alc subj2 (*n* = 138)**	**4. RI (*n* = 187)**
1.	-	.58 ***	.43 ***	-.18 *
		(*n* = 138)	(*n* = 138)	(*n* = 187)
2.		-	.27 **	.09
			(*n* = 138)	(*n* = 138)
3.			-	-.20 *
				(*n* = 138)
4.				-

Note: * $p < .05$, ** $p < .01$, ***$p < .001$. Correlations represent Pearson correlations. Alc obj = blood alcohol concentration in percentages as measured with the objective alcohol meter, Alc obj = Blood alcohol concentration in percentages as measured with the objective alcohol meter (range = 0 – 2), Alc subj1 = subjective alcohol units consumed (range = 0 – 20), Alc subj2 = subjective alcohol high (range = 0 – 74), RI = response inhibition, Parents = religiosity / spirituality of the parents (range = 0 – 100).

Retrospective data

Of the 138 participants (69.3% response rate) who started the follow-up survey, 6 participants could not be linked to the first data collection, because they filled in another email address than the first time. Therefore, we had 130 participants for the frequency of extraordinary experiences (i.e., the number of times participants pressed on the button) and 132 participants for the intensity of extraordinary experiences (i.e., the combination of the subjective rating of the intensity and the Mysticism scale items). To investigate the consistency between the festival data and the retrospective data, we looked at the only question that occurred in both questionnaires (besides the email address), which was the question whether participants had used alcohol, drugs, a combination thereof or neither of both. A reliability analysis indicated that the participants were fairly consisted in their responses, Cronbach's alpha (α) = .82. Specifically, 12 participants filled in another answer than before. Although speculative, it may be the case that they could not specifically remember which of the three festival days they participated in the study.

Missing data

Data on the Stroop Task was missing for seven participants and data on the Response Button task was missing for three participants due to computer failure (if the battery cable was touched slightly, the laptop turned off). Table 4 shows the descriptive statistics of the measures included in the regression models. In general, participants were not very religious but did consider themselves to be somewhat spiritual and their parents were also considered somewhat religious. Alcohol intake was relatively low, the average score was indicative of 'mild euphoria and concentration problems' (Carp, 2015).

statistically significant more of the variance than an intercept only model, $\chi^2(15) = 41.17$, $p < .001$, Log-likelihood = -850.94. Both education and spirituality were statistical significant predictors. Specifically, an increase in education from lower general secondary education to higher general secondary education was associated with a decrease in the frequency of extraordinary experiences. Importantly, an increase in spirituality was associated with an increase in the frequency of extraordinary experiences, but objective alcohol intoxication was not associated with the frequency of extraordinary experiences.

The model in which retrospective data was included (see Table 5) also explained statistically significant more of the variance than an intercept only model, $\chi^2(17) = 44.51$, $p < .001$, Log-likelihood = -593.85. Both age and education were statistical significant predictors. Specifically, the effect of education remained the same. Further, increases in age were associated with decreases in the frequency with which extraordinary experiences were reported. Thus, younger participants had somewhat more frequent experiences. Finally, the effect of spirituality disappeared in the second model, and neither objective nor subjective alcohol intoxication were associated with the frequency of extraordinary experiences.

Table 5. Generalized linear models for predicting the frequency of extraordinary experiences.

GzLM1	*b*	*SE b*	*p*	**GzLM2**	*b*	*SE b*	*p*
Constant	2.16	0.53	<.001***	Constant	2.25	0.71	.002**
Gender2	0.07	0.25	.778	Gender2	0.01	0.30	.979
Age	-0.03	0.02	.056	Age	-0.04	0.02	.047*
Alcohol obj	-0.03	0.36	.929	Alcohol obj	0.12	0.59	.845
Education2	-0.86	0.35	.014*	Education2	-1.30	0.44	.003**
Education3	-0.54	0.34	.113	Education3	-0.80	0.43	.064
Education4	0.43	0.67	.522	Education4	0.49	0.77	.524
Religiosity	0.01	0.01	.170	Religiosity	0.01	0.01	.389
Spirituality	0.01	0.01	.034*	Spirituality	<.01	0.01	.409

Parents	<.01	<.01	.529	Parents	0.01	0.01	.131
RI	<.01	<.01	.250	RI	<.01	<.01	.887
				Alc subj1	0.01	0.05	.257
				Alc subj2	0.01	0.01	.261

Note: * p < .05, ** p < .01, ***p < .001. GzLM1 = generalized linear model without the retrospective data (N = 196), GzLM2 = generalized linear model including the retrospective data (N = 132). The dependent variable is the frequency with which participants responded on the Button Press Task. Alc obj = blood alcohol concentration in percentages as measured with the objective alcohol meter, Parents = extent to which the parents are religious / spiritual, RI = response inhibition score obtained with the Stroop Task, Alc subj1 = subjective alcohol high, Alc subj2 = subjective alcohol units consumed.

Intensity of extraordinary experiences. ***Principal Axis Factoring Analysis.*** To combine the data of the subjective intensity item and the mysticism scale items into one 'intensity of extraordinary experiences' measure, we used principal axis factoring (PAF) analyses with oblique (Promax) rotation (Russel, 2002). The Kaiser-Meyer-Olkin (KMO) measure was adequate; KMO = .50 (Field, 2009). Bartlett's test of sphericity; χ^2 = 144.66, p < .001, indicated that the correlations between the items were appropriate for doing PAF. An initial analysis was run in which eigenvalues were obtained for each of the components. Cattell's scree test (Cattell, 1966), a parallel analysis (Horn, 1965) and Eigenvalue is larger than mean test all indicated a clear one-factor solution. Therefore, one factor, explaining 86.7% of the variance, was retained in the final analysis. The overall internal consistency was theta = .87 (Armor, 1974). The regression weights were used as a combined measure of intensity of the experience.

General linear models. Visual inspection of the normal P-Plot of the standardized residuals and a scatterplot plotting the standardized residuals against the standardized predicted values indicated that the assumptions of normality and homoscedasticity were violated respectively, for both the intensity models with and without retrospective data. To account for these problems two measures were taken. First, a log transformation (i.e., LG10) was applied to the regression weights of the PAF plus a constant number (i.e., +1; to address the issue of negative values), increasing the normality of the distribution of the residuals (DiStefano, Zhu, & Mindrila, 2009). Second, a robust regression bootstrapping analysis with 2000 resamples was conducted to include a bias corrected confidence interval of the beta values (Efron & Tibshirani, 1994).

In Table 6, the outcomes of both HLRs predicting the intensity of the extraordinary experiences are presented (HLR1 = model without retrospective data, HLR2 = model including retrospective data). In the first step of the HLR, the demographical variables did not explain a statistical significant amount of the variance of the intensity of the experiences, $F(3, 183) = 1.81$, $p = .148$, $R^2 = .03$. In the second step, the predictors of the model did explain a statistical significant amount of the variance although the explained variance was small (Cohen, 1992), $F(8, 178) = 2.40$, $p = .017$, $R^2 = .10$. Both age and spirituality contributed statistical significantly to the model. As age increased, the intensity of the mystical experiences decreased. Importantly, the stronger participants considered themselves to be spiritual, the stronger they perceived the intensity of the extraordinary experiences. Contrasting our predictions, objective alcohol intoxication was not related the intensity of the extraordinary experiences.

In the first step of the HLR with the retrospective data (i.e., HLR2), the demographical variables did not explain a statistical significant amount of the variance of the intensity of the mystical experiences, $F(3, 128) = 1.95$, $p = .125$, $R^2 = .02$. In the second step, adding the residual predictors of the model did not explain a statistical significant amount of the variance, although the effect was close to significance, $F(10, 121) = 1.91$, $p = .051$, $R^2 = .07$. Again, spirituality was statistical significantly predictive of extraordinary experiences, while neither objective nor subjective alcohol intoxication was statistically significant.

Table 6. Hierarchical linear regression models for predicting the intensity of extraordinary experiences.

HLR 1	*b*	*SE B*	*β*	*p*
Step 1				
Constant	0.03 [-0.29/0.35]	0.16		.863
Gender	0.05 [-.08/.18]	0.07	.06	.448
Age	-0.01 [-.02/<.01]	<0.01	-.13	.075
Education	-0.05 [-0.13/0.03]	0.04	-.09	.212
Step 2				
Constant	-0.07 [-0.40/0.26]	0.17		.690
Gender	0.01 [-0.12/0.15]	0.07	.01	.862
Age	-0.01 [-0.02/0.00]	0.01	-.17	.021*
Education	-0.03 [-0.11/0.05]	0.04	-.06	.419
Religiosity	<0.01 [<0.01/0.00]	<0.01	.04	.630
Spirituality	0.01 [<0.01/0.01]	<0.01	.27	.001**
Parents	<-0.01 [<0.01/<0.01]	<0.01	-.08	.340
Alcohol	0.06 [-0.13/0.25]	0.10	.05	.525.

RI	<0.01 [<0.01/<0.01]	<0.01	-.02	.772

Table 6 continues

HLR 2				
	b	*SE B*	*β*	*p*
Step 1				
Constant	0.14 [-0.25/0.54]	0.21		.502
Gender	0.03 [-0.02/0.00]	0.08	.03	.696
Age	-0.01 [-0.12/0.17]	0.01	-.16	.074
Education	-0.07 [-0.15/0.03]	0.05	-.12	.174
Step 2				
Constant	-0.11 [-0.52/0.36]	0.22		.639
Gender	<0.01 [-0.02/<0.01]	0.10	-.01	.961
Age	-0.01 [-0.16/0.14]	0.01	-.14	.101
Education	-0.05 [-0.14/0.03]	0.05	-.10	.279
Religiosity	<0.01 [<0.01/0.01]	<0.01	.10	.301
Spirituality	0.01 [<0.01/0.01]	<0.01	.21	.032*
Parents	<0.01 [<0.01/<0.01]	<0.01	-.02	.845

Alc obj	-0.01 [-0.39/0.17]	0.16	-.07	.564
Alc subj1	0.01 [-0.01/0.03]	0.01	.11	.269
Alc subj2	<0.01 [<0.01/0.01]	<0.01	.16	.132
RI	<0.01 [<0.01/<0.01]	<0.01	-.05	.550

Note: * p < .05, ** p < .01, 95% CI between brackets. HLR1 = hierarchical linear regression model without the retrospective data (N = 193), HLR2 = hierarchical linear regression model including the retrospective data (N = 132). The dependent variable is the result of the log transformation of the regression weights of the principal component factor analysis conducted on the intensity scale and the mystical scale items. Parents = extent to which the parents are religious / spiritual, Alc obj = blood alcohol concentration in percentages as measured with the objective alcohol meter, Alc subj1 = subjective alcohol high, Alc subj2 = subjective alcohol units consumed, RI = response inhibition,, RI = response inhibition score obtained with the Stroop Task.

Discussion

The aim of the study was to investigate whether alcohol increases susceptibility to the God Helmet suggestion, and if such effects could result from impaired executive processing. We observed that 1) the placebo brain stimulation elicited a wide range of extraordinary experiences, 2) the data did not provide support for the hypothesized relation between objective and subjective alcohol measures, executive control and frequency and intensity of extraordinary experiences, and 3) successful induction of expectancy-driven mystical experiences was predicted by participants' self-reported spirituality. These three observations need further discussion.

First, the dependent measures as well as the open responses describing the nature of the experiences strengthened the proposition of previous researchers that placebo brain stimulation is a powerful manipulation to study extraordinary experiences (Andersen et al., 2014; French et al., 2009; Granqvist et al., 2005; Granqvist & Larsson, 2006; Tinoca & Ortiz, 2014; van Elk, 2014). The reported experiences relate to what people have reported in placebo conditions of studies on hallucinogens (Barrett & Griffiths, 2017) and to Hardy's (1981) seminal collection on spiritual experiences. The categorization scheme we developed bears resemblance to some items of Persinger's Exit Questionnaire (Persinger et al., 2000) and can be used as a helpful tool for future research as it extends previous work by indicating precisely what type of experiences may be induced, using expectancy manipulations of mystical experiences in combination with sensory deprivation. Building on this idea, one of the co-authors (MvE) already showed that the helmet could be framed as a 'sound-helmet', which led participants of a psychic fair to more often experience sounds, or a 'visual-helmet', which more often resulted in experiencing visuals (Van Elk, in preparation). This also makes clear that the expectancy manipulation adds to mere 'sensory deprivation' effects that have been frequently reported in past literature (e.g., Glicksohn, 1991; Hood & Morris, 1981; Rossi, Sturrock, & Solomon, 1963). That the suggestive context adds to sensory deprivation effects converges with another study of ours (Chapter 4), in which we observed that participants had more extraordinary experiences in a condition where they were wearing the God Helmet than a condition in which they the God Helmet was taken off - while they were sensory deprived in both conditions. Thus, we argue that the effects that we observed in our study cannot solely be explained by the fact that all participants were to some extent sensory deprived during the 'stimulation' with the God Helmet.

Scholars of religion who understand mystical experiences as happening only on rare occasions and in a very few people, may ask the important question: what kind of experiences do these self-reports in God Helmet studies actually refer to? Do they really resemble the vivid hallucinatory experiences reported by spiritual virtuosos like Teresa Avila (Starr, 2007) and Ignatius Loiyola (Gleason & Mottola, 1989)? Or are participants simply prone to report extraordinary experiences without experiencing anything (i.e., a strong demand effect) - a concern that has often been raised in response to M-scale surveys and other self-report studies on religious experiences (e.g., Allister Hardy's [1981] seminal collection on spiritual experiences).

Positioned somewhere between these two poles, the God Helmet may provide a unique context in which the combination of verbal suggestion, trust in modern science and technology, and sensory deprivation facilitate 'real' extraordinary experiences. Specifically, the level of detail conveyed in the subjective reports that we obtained in our study, provides convincing evidence that people were not merely confabulating, but reporting memorized experiences as if being real (Johnson, Foley, Suengas, & Raye, 1988). As explained in the introduction, the placebo brain stimulation effects induced by the helmet may best be understood in light of the predictive processing framework (Andersen et al., 2014; Büchel, et al., 2014; Schjoedt et al., 2013; van Elk & Aleman, 2016). Supporting this idea is the observation that several participants noticed that the God Helmet session was remarkably similar to previous drugs experiences they had (e.g., verbatim report by participant g). We argue that the contextual setting and expectations triggered them to remember or even 'relive' these experiences. Further, in line with the idea that randomly fluctuating bodily sensations are interpreted in a mystical fashion, is the observation that most participants reported weak bodily sensations (e.g., itches and tingling sensations, feelings of relaxation and stress). Some participants themselves occasionally related their sensations to rational causes (i.e., causes outside the God-Helmet). For example, one participant noticed: “My heart rate increased, but it may have been caused by tension”. Thus, comparable bodily sensations were interpreted differently on basis of participants’ prior models (e.g., spiritualistic vs skeptic models).

Secondly, we did not find that alcohol increased susceptibility to the God Helmet suggestion. Similarly, other researchers failed to observe an increase in suggestibility following alcohol intoxication (Dienes et al., 2009). This indicates that alcohol may not increase suggestibility among those participants who would naturally be less prone to have extraordinary experiences with the god-helmet (i.e., people who consider themselves non-spiritual or even atheist). On the other hand, suggestibility has been successfully manipulated with other substances such as LSD, mescaline and nitrous oxide (e.g., Carhart-Harris et al., 2015; Sjoberg & Hollister, 1965; Weitzenhoffer, 1980; Whalley & Brooks, 2009). These psychoactive substances have also been known to be used in the context of religious rituals (de Rios &

Winkelman, 1989; Ellens, 2014; Fuller, 2000). An important difference, however, is that the effects of these substances on bottom-up sensory processing are much stronger. Additionally, psychedelics are said to be consciousness expanders, whereas alcohol may have a reverse effect (i.e., narrowing of consciousness; Earleywine, 2005). Thus, it could well be that alcohol may not have such a powerful effect on the 'mystical faculties of human nature' as William James (1902) and others (e.g., Smith, 1964) once thought.

However, we ought to be cautious with dismissing the role of alcohol in facilitating extraordinary experiences. This is the first study on which the effects of alcohol on extraordinary experiences has been investigated, and this single study is not a definite answer to the question whether alcohol can increase people's susceptibility towards extraordinary experiences. Importantly, overall levels of alcohol intoxication were rather low. We frequently observed that participants deliberately did not drink (too much) alcohol, because they thought that this might be dangerous in combination with the God Helmet or that they were afraid to be excluded. The observation that alcohol intake was generally low was confirmed by the average BAC score on the objective alcoholmeter (i.e., around .03) and the relatively fast response inhibition scores (i.e., the mean was lower than observed in Bauer & Cox, 1998, on which the paradigm was based). We hypothesized that the effects of alcohol on extraordinary experiences would be mediated by executive functioning process. As expected, we did observe a statistical significant relationship relation between alcohol and executive functioning, similar to other studies (Finn, Justus, Mazas, & Steinmetz, 1999; Prada et al., 2012). The observed correlation was small (i.e., r = .20), but the environment was noisy, response inhibition is likely to be influenced by many other factors than alcohol and the general alcohol intoxication was relatively low.

Nevertheless, future researchers should note that strong alcohol intoxication in combination with sensory deprivation could be problematic. The few participants that were strongly intoxicated were more likely to experience dizziness, to fall asleep or to vomit, as they had to sit still with their eyes closed. A more fruitful way of investigating the effects of alcohol on extraordinary experiences may perhaps be to use a more ritualistic tribe-like context. For example, one could use a campfire setting with a shaman who supposedly gives a hallucinogen but provides the participants with alcohol. This could provide a more direct and more ecologically valid way of investigating the potential role of ritualistic alcohol use. Another possibility that should be considered is that people might have actively tried to compensate for the extent to which they were intoxicated by increasing attentional focus during the study (a similar explanation was given in a study on the effects of cannabis; Hester, Nestor, & Garavan, 2009). This would also explain the relatively weak correlation between alcohol and response inhibition of the Stroop Task. Further, based on the predictive coding framework and looking at the studies on the effects of alcohol, it becomes evident that alcohol may well affect different processes at the same time (Easdon, Izenberg, Armilio, Yu, & Alain, 2005; Marinkovic, Rickenbacher, Azma, & Artsy, 2012). That is, alcohol may increase susceptibility to suggestions of the context, but it may also reduce awareness of sensory input such as bodily sensations and external sounds. These different effects may differentially affect the sensitivity to self-induced mystical experiences, thereby potentially explaining the absence of an overall effect of alcohol ingestion.

In addition, there were several disadvantages of conducting the study at a festival, which may have prevented us from observing an effect of alcohol. First, we were given only limited time to test the subjects, while it has been shown that the number of perceived mystical experiences increases with time wearing the God Helmet (Andersen et al., 2014). Second, the testing conditions were not optimal, leading participants to become distracted by external events such as the moving floor of the stage or the bass-sound of other stages that could occasionally be heard. Third, although we initially hoped to acquire a more representative participant pool at the festival site than we usually recruit at our university, it is likely that the topic of the study (i.e., technology capable of inducing extraordinary experiences) resulted in a self-selection bias of participants, such as WEIRD (Western Educated Industrialized Rich Democratic) subjects, with a high ‘sensation seeking’ personality trait. Having outlined these limitations, this makes it all the more remarkable that extraordinary experiences were so frequently reported, again confirming that placebo brain stimulation is a powerful suggestibility manipulation. Finally, considering that the study was conducted at a music festival, it is good to elaborate on the possibility that participants underreported their drug use, although we do not think this was the case. First, we tried to guarantee the anonymity of the participants as much as possible. They wore a sticker with a participant number, which they had to fill in themselves on the computer survey. Further, the medical setting of the experiment (see also the pictures in the supplementary material) made participants cautious to be open about their medical conditions and use of alcohol and drugs. One of the most frequent questions we heard was: “Is it possible to do this with alcohol?”. Participants also inquired whether it was possible to participate under the influence of ‘drugs’ several times. Thus, although we cannot exclude under-reporting of actual drug use, the circumstances and informal observations make this possibility not very likely. In response to suggestions of reviewers, we investigated whether a nominal variable indicative of drugs and alcohol use (i.e., participants could indicate whether they used only alcohol, only drugs, both, or neither of both) explained some of the variance of the frequency or intensity of extraordinary experiences, but this was not the case.

Our last observation may explain why some people did report intense experiences. Like previous research (Andersen et al., 2014; Granqvist & Larsson, 2006), we found that reported experiences were predicted by participants’ self-reported spirituality, not by religiosity. What characterizes people who report to be spiritual? Previous research has shown that spirituality relates to a focus on individual experience instead of religious dogma or religious membership (Fuller, 2001; Koenig, 2008; Saucier, & Skrzypińska, 2006), openness to experience and absorption (Chapter 4), paranormal beliefs (Saroglou, & Antonio Muñoz-García, 2008) and cognitive biases such as making ontological confusions or increased mentalizing (Lindeman & Svedholm-Häkkinen, 2016; Lindeman, Svedholm-Häkkinen, & Lipsanen, 2015). For people who self-identify as spiritual, vivid concepts related to spirituality could be the most easily activated in the context of the suggestible setting. In terms of predictive processing, the expectancy manipulation proved especially effective for people whose worldview matched the prior expectations we manipulated (i.e., people scoring high on spirituality). In another study (Chapter 4), we have used different questionnaires relating to spiritual beliefs to investigate more precisely what individual differences could predispose participants for having extraordinary experiences. We observed that especially the personality trait ‘absorption’, i.e., the tendency of people to get immersed in everyday events (e.g., ‘The sound of a voice can be so fascinating to me that I can just go on listening to it’), strongly predicted whether people reported extraordinary experiences by using a God helmet manipulation. In short, extraordinary experiences are most likely to occur in participants who have a spiritual worldview that matches the expectations provided by the manipulation, and who are prone to get absorbed in spontaneous thoughts, bodily sensations or external stimuli, that become more salient because of the manipulation.

In conclusion, even with suboptimal testing conditions, a large variety of extraordinary experiences were reported. Setting aside the limitations of the study, we did not find evidence that objective or subjective alcohol intoxication increased people’s susceptibility to an expectancy-driven manipulation, but future studies can settle this matter by using higher dosages of alcohol in a more ecologically valid context.

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SUPPLEMENTARY MATERIAL

Controlling for the use of drugs

To investigate whether drugs use on the festival confounded the findings, we asked participants about there drug use and controlled for this in the HLR. As mentioned in the main paper, participants had to respond to the question whether they had used alcohol, drugs, both, or neither of both. This categorical predictor was entered in the first step of the exact same HLR1 described in the paper, but this predictor was not significant, t = 1.35, β = .10, p = .180. Also not when the other predictors were added, t = 1.01, β = .08, p = .288.

In addition, participants responded to the following questions: "How many units of the following substances have you consumed today (since you were awake)?" Scales ranging from 1 to 20 were available for the following drugs: Joints (i.e., marijuana cigarettes), 4-Fluoramfetamine (4fma-fmp), XTC/MDMA, Cocaine, Speed/amphetamine, GHB, ketamine, Mushrooms/truffles, LSD). As noted in the main paper, these questions were only viewed retrospectively in a follow-up questionnaire. However, in general, the number of times that drugs use was reported was so low that due to power problems only, no meaningful relationships could be established. The maximum amount of times that a drug was reported was marijuana (11 times).

Follow-up questions

Several other questions in which we got interested while conducting the study at the festival, were added in the follow-up questionnaire. Specifically, we asked whether participants experienced after-effects of the helmet on a scale from 0 to 100. "In the week after you wore the helmet, to what extend were you more conscious of a deeper reality?" and "In the week after you wore the helmet, to what extent did you experience feelings of unity with the world around you?". Further, we asked participants in an open question whether they experienced after-effects of the helmet (e.g., body or emotional sensations, or other effects that they attributed to the helmet). These data are not discussed here, but were taken into account in the classification scheme (i.e., Table 3). We also asked participants how many hours they slept the night before testing (on a scale from 0 to 12), as sleep deprivation has been related to hallucinatory experiences in previous research (e.g., Babkoff, Sing, Thorne, Genser, & Hegge, 1989). Finally, we investigated to what extent participants believed the helmet (i.e., "To what extent did you think that the helmet truly stimulated your brain?"). However, bear in mind that seeing this question raises suspicion, which is why we asked people to mention 'side-effects of the helmet' during the festival (a similar procedure was used by Andersen et al., 2015).

Table S1 shows the outcomes of the exploratory measures. Generally, the ratings were very low. Nevertheless, HLRs with the 'conscious' or 'oneness' as dependent measure in the same analysis as described for HLR1 showed similar results as in the main paper. With regard to the 'feeling of oneness' variable, the first step of the HLR, the demographical variables did not explain a significant amount of the variance of the intensity of the experiences, $F(3, 131) = 2.40$, $p = .071$, $R^2 = .03$. In the second step, the predictors of the model did explain a significant amount of the variance $F(11, 120) = 2.25$, $p = .016$, $R^2 = .10$. Both age, $t = -2.64$, $\beta = -.23$, $p = .009$, and spirituality, $t = 2.42$, $\beta = .24$, $p = .017$, significantly contributed to the model. As age increased the feeling of oneness with the world decreased, while it increased for spirituality. None of the other predictors was significant, including the 'amount of hours sleep'.

With regard to the 'conscious awareness' variable, the first step of the HLR, the demographical variables did not explain a statistical significant amount of the variance of the intensity of the experiences, $F(3, 131) = 0.82$, $p = .483$, $R^2 = .01$. In the second step, the predictors of the model did explain a statistical significant amount of the variance $F(3, 121) = 5.21$, $p < .001$, $R^2 = .30$. Both religiosity, $t = 3.60$, $\beta = .33$, $p < .001$, and spirituality, $t = 2.78$, $\beta = .25$, $p = .006$, contributed statistically significant to the model. As religiosity and spirituality increased, people were more conscious of a deeper reality in the week after the helmet. None of the other predictors was statistically significant, including the 'amount of hours sleep'.

Table S1. *Descriptive statistics of the measures included in the retrospective hierarchical linear regression models.*

	Sleep	Conscious	Oneness	MC
N	138	138	138	138
M	5.6	6.9	9.5	20.4
SD	2.0	17.0	22.2	26.6

Note: N = number of cases, *M* = Mean, *SD* = Standard deviation. Sleep = amount of sleep in hours; conscious = MC = manipulation check

Table S2. *Correlation table of the measures included in the generalized linear model predicting the frequency of extraordinary experiences.*

	2	3		4	5	6		7		8	
1. Gender	.02	.15	*	.09	.01	.16	*	.14	*	-.07	
2. Age	—	.08		.03	.00	.15	*	.01		.01	
3. Education		—		-.04	-.13	-.09		.00		-.10	
4. Alcohol obj				—	-.06	-.08		-.07		-.18	*
5. Religiosity					—	.34	***	.37	***	.07	
6. Spirituality						—		.34	***	-.10	
7. BeliefParents								—		-.05	
8. RI										—	

Note: * $p < .05$, ** $p < .01$, ***$p < .001$, $N = 196$, correlations represent Spearman correlations. The dependent variable is the frequency with which participants responded on the Button Press Task. Parents = extent to which the parents are religious / spiritual, RI = response inhibition score obtained with the Stroop Task, Alc obj = blood alcohol concentration in percentages as measured with the objective alcohol meter, Alc subj1 = subjective alcohol high, Alc subj2 = subjective alcohol units consumed, RI = response inhibition, Parents = religiosity / spirituality of the parents.

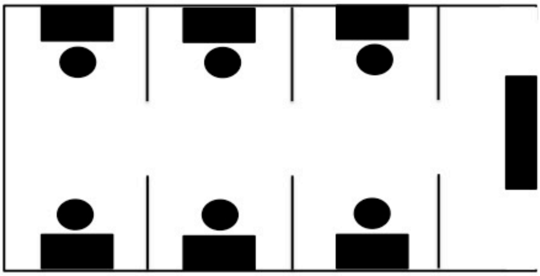

Figure 1. Experimental set-up of the six open cubicles at the testing site.

Note: The testing site consisted of six open cubicles and an entrance. Two experimenters walked in between to help the participants explain the experimental procedure.

Figure 2. Picture of the God helmet and experimental set up with sham physiological recording.

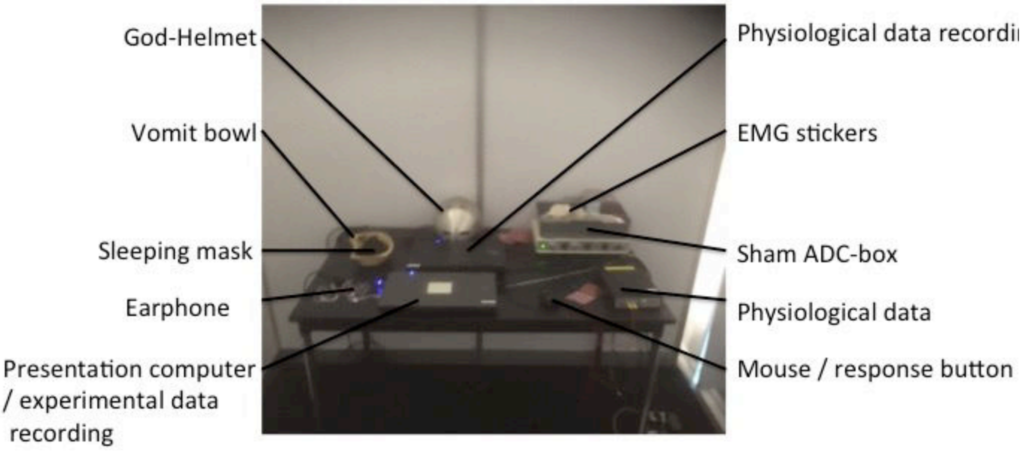

Figure 3. Picture of the God helmet with real physiological recording.

Note: EMG = electromyography, heart rate measure; ADC = analog-to-digital converter.

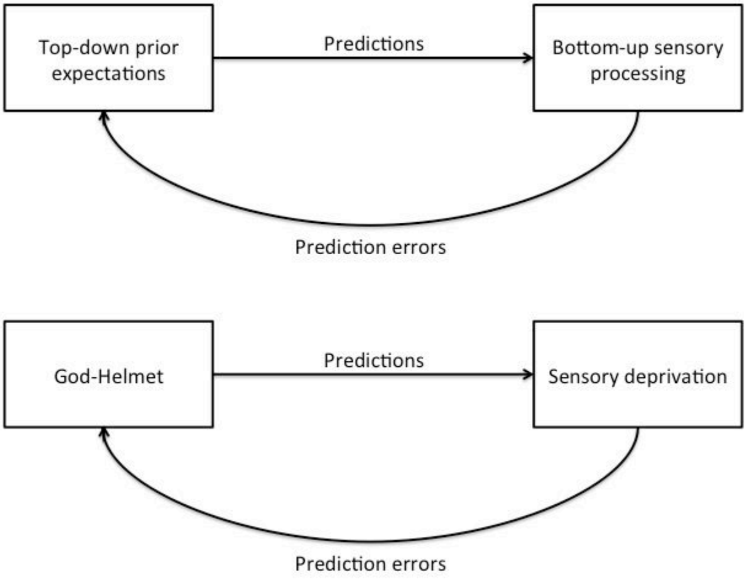

Figure 4. The working of the God helmet explained in terms of predictive coding processing. *Note:* The top image shows the basic premise of predictive processing. Top-down prior expectations result in predictions, which are compared to bottom-up sensory input. A mismatch between these processes results in a prediction error and this leads to adaptation of the prediction models. The bottom image shows how similar processes can explain the working of the helmet. The suggestible context of the God helmet results strong predictions about extraordinary experiences. Sensory deprivation restricts sensory input to bodily sensations and internal thoughts, which can be interpreted in light of the suggestible context at hand.

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Chapter 6

MENTALIZING SKILLS DO NOT DIFFERENTIATE BELIEVERS FROM NON-BELIEVERS, BUT CREDIBILITY-ENHANCING DISPLAYS DO

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Abstract

The ability to mentalize has been marked as an important cognitive mechanism enabling belief in supernatural agents. In five studies we cross-culturally investigated the relationship between mentalizing and belief in supernatural agents with large sample sizes (over 67,000 participants in total) and different operationalizations of mentalizing. The relative importance of mentalizing for endorsing supernatural beliefs was directly compared with credibility enhancing displays – the extent to which people observed credible religious acts during their upbringing. We also compared autistic with neurotypical adolescents. The empathy quotient and the autism-spectrum quotient were not predictive of belief in supernatural agents in all countries (i.e., The Netherlands, Switzerland and the United States), although we did observe a curvilinear effect in the United States. We further observed a strong influence of credibility enhancing displays on belief in supernatural agents. These findings highlight the importance of cultural learning for acquiring supernatural beliefs and ask for reconsiderations of the importance of mentalizing.

According to conservative estimates, at least 80% of the world population believes in intentional supernatural agents (P. Zuckerman, 2007). In this context, we refer to supernatural agents as an umbrella term for all intentional agents not conforming to a naturalistic worldview. Given this impressive number, the question arises what underlies this apparently universal human tendency to believe in intentional supernatural agents. One suggestion is that these beliefs emerge as by-products of normal evolved cognitive mechanisms, such as dualistic reasoning(see for a critical review, Norenzayan & Gervais, 2013). This suggestion is well established in the cognitive science of religion (i.e., the research niche investigating the foundations of supernatural beliefs, Xygalatas, 2014).

One of the key cognitive mechanisms hypothesized to underlie supernatural beliefs is the ability to mentalize or to engage in theory of mind (ToM) reasoning (Atran, 2002; Barrett, 2012; Barrett, 2000; Bering, 2002a; Bering, 2002b; Bering, 2006; Bloom, 2007; Boyer, 2003; Geertz, 2010; Gervais, 2013; Jong, 2013; McCauley, 2011; Norenzayan, Gervais, & Trzesniewski, 2012; Norenzayan & Gervais, 2013; Willard & Norenzayan, 2013). This is the ability to attribute intentions, beliefs, and desires to other minds (Baron-Cohen, Leslie, & Frith, 1985; Premack & Woodruff, 1978). The logic underlying this hypothesis is that in order for people to be able to believe in intentional supernatural agents, they should at least have the mentalizing abilities required to conceptualize the agent's intentions (e.g., Bering, 2002a; Willard & Norenzayan, 2013). Specifically, the idea is that an evolved cognitive mechanism for inferring intentionality of human agents is similarly activated when inferring the intentionality of supernatural agents. In the current study, we aimed to investigate whether mentalizing abilities are indeed important for supporting belief in supernatural agents, by investigating whether individual differences in mentalizing covary with degrees of belief. Also, we placed the relative importance of mentalizing in context by comparing it to the importance of credibility enhancing displays – the extent to which people observed credible religious acts during their upbringing (i.e., a cultural learning variable Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017).

In the existing literature, the relationship between mentalizing and belief in supernatural beliefs has been investigated in different ways. In one line of studies, researchers used the (shortened) Empathy Quotient (EQ, Baron-Cohen & Wheelwright, 2004; Wakabayashi et al., 2006), because mentalizing was argued to be important to empathy (Lindeman, Svedholm-Häkkinen, & Lipsanen, 2015; Norenzayan et al., 2012; Willard & Norenzayan, 2013). The link between the EQ and supernatural beliefs was found to be statistically significant, but modest (i.e., all *r*'s < .22). However, the EQ did not predict supernatural beliefs when variables such as analytic thinking or moral concern were taken into account (Jack, Friedman, Boyatzis, & Taylor, 2016). Moreover, the psychometric validity of the scale has been critiqued, as the scale does not correlate to mentalizing ability tasks (e.g., Muncer & Ling, 2006). As a result, the EQ cannot be considered to unequivocally assess mentalizing. In other studies, taking into account a wider variety of operationalizations of mentalizing such as the reading the mind in the eye test and the perspective-taking task, the authors reported inconsistent relationships between mentalizing and supernatural beliefs (Jack et al., 2016; Norenzayan et al., 2012). The reading the mind in the eye test was significantly related to supernatural beliefs in the study of Norenzayan et al. (Norenzayan et al., 2012) but not in the study of Jack et al. (Jack et al., 2016). In sum, at most these studies demonstrated only a modest role for mentalizing underlying supernatural beliefs.

Another line of studies linking mentalizing with supernatural beliefs comes from studies focusing on people with autism spectrum disorder (ASD) or on neurotypical people's score at measures of ASD such as the Autism Spectrum Quotient (Atran & Norenzayan, 2004; Bering, 2002a; Bloom, 2007; Deeley, 2004; Deeley, 2009; McCauley, 2011; Norenzayan et al., 2012). People with ASD are thought to be characterized by difficulties conceptualizing intentions of others (e.g., Baron-Cohen et al., 1985, but see; Broekhof et al., 2015) and ASD seems to have a strong genetic component (Miles, 2011). In two studies, researchers found people with ASD to have reduced supernatural beliefs compared to neurotypical people (Caldwell-Harris, Murphy, Velazquez, & McNamara, 2011; Norenzayan et al., 2012), but other researchers did not find such a relationship (Brezis, 2012; Gray, Jenkins, Heberlein, & Wegner, 2011; Reddish, Tok, & Kundt, 2015). Moreover, anecdotal reports show that people with ASD can believe in supernatural agents (Bering, 2002a; Swanson, 2010; Walsh, Walsh, & Gaventa, 2008; Wilschut-pennings, 2012) although they may endorse a more negative view of God (Schaap-Jonker, Sizoo, van Schothorst-van Roekel, & Corveleyn, 2013). In short, investigations into the relationship between ASD and supernatural beliefs have yielded mixed results.

In a final line of studies linking mentalizing to supernatural beliefs, researchers have linked brain areas associated with ToM (i.e., the so-called ToM-network) to supernatural beliefs and behaviors in neuroimaging studies (e.g., Ge, Gu, Ji, & Han, 2009). The ToM-network is a network of functionally related brain regions that are steadily activated in association with tasks related to mentalizing (Gallagher & Frith, 2003), such as Heider and Simmel's (1944) classical Geometrical Figures Task (GFT). In this task, geometrical figures move as if they have intentions. The ToM-network encompasses the medial prefrontal cortex, the anterior and posterior cingulate cortex, the precuneus, and the bilateral temporal parietal junction (Mahy, Moses, & Pfeifer, 2014; Schurz, Radua, Aichhorn, Richlan, & Perner, 2014; van Veluw & Chance, 2014). In a study in which religious believers silently prayed to God, the ToM-network was found to be activated, whereas this was less the case when they thought of the Lord's Prayer, made wishes to Santa Claus or thought of a nursery rhyme (Schjoedt, Stodkilde-Jorgensen, Geertz, & Roepstorff, 2009). This finding suggests that personal contact with a supernatural agent involves ToM-related processing and this finding has been replicated and extended with a control condition in which participants imaginatively spoke to a loved one (Neubauer, 2014). In a similar fashion, the ToM-network was activated when believers thought about God's mental states (Kapogiannis et al., 2009) or God's beliefs (Epley, Converse, Delbosc, Monteleone, & Cacioppo, 2009). Finally, brain regions of the ToM-network were activated more strongly in supernatural believers than skeptics when randomly moving geometrical figures were shown (Riekki, Lindeman, & Raij, 2014). Importantly, in this study the intensity of the activation in the ToM-network correlated with the intentionality ratings of the participants. Taken together, these neuroimaging studies seem to converge with the idea that naturally evolved brain mechanisms for ToM-reasoning are similarly activated when perceiving intentionality or when thinking about supernatural agents. Nevertheless, it is premature to conclude that mentalizing is an important cognitive mechanism enabling belief in supernatural agents, merely on the basis of these neuroimaging studies. Crucially, in these studies it is assumed that when the brain areas associated with the ToM-network are activated with a certain task this means that the underlying process (i.e., mentalizing) is active but this is not necessarily the case (Reddish et al., 2015).

In short, the literature so far does not provide clear-cut evidence that mentalizing abilities are indeed a driving factor behind supernatural beliefs. Thus, to shed further light on this on-going debate, we extended earlier work in four important ways. First and foremost, in studies 2, 4 and 5, we compared the relative importance of mentalizing skills (as measured in the same way as previous researchers who observed effects of mentalizing) for predicting supernatural beliefs with a specific cultural learning theory on how supernatural beliefs are acquired (i.e., credibility enhancing displays, Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017). According to some researchers, the role of culture in acquiring supernatural beliefs is secondary to primary intuitive cognitive biases (Barrett, 2012). Others acknowledge a strong reciprocal influence between cognitive biases and cultural factors (Geertz & Markússon, 2010; Geertz, 2010). However, there is a recent trend of researchers emphasizing the importance of cultural learning factors - they consider cognitive mechanisms to be secondary to cultural foundations of supernatural beliefs (Harris & Corriveau, 2014; Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017), with some even asking for a revision of the by-product framework (Gervais & Najle, 2015). Thus, to account for the current debate, we directly compared the relative importance of individual differences in mentalizing and exposure to credible religious displays during upbringing for predicting supernatural beliefs, and to our knowledge, we are the first to do so.

The theory of credibility enhancing displays (i.e., CREDs) is a cultural learning theory with a substantial explanatory potential. Henrich (Henrich, 2009) and Lanman (Lanman, 2012) have proposed that the extent to which people become supernatural believers is largely determined by the degree to which they have been exposed to credible displays of belief in the supernatural. For example, if parents or caretakers say they believe in God, pray every night before dinner and go to church every weekend, these are considered very credible displays of the existence of a supernatural realm. On the one hand, when CREDs of religiosity are observed, the likelihood is increased that observes take over supernatural beliefs expressed by actors. On the other hand, when CREDs of atheism or unreliable religious acts (e.g., highly unmoral religious actors) are observed, the likelihood is decreased that the observer acquires supernatural beliefs. Thus, CREDs provide a comprehensive explanation for both theism and atheism. Supportive data for the theory of CREDs have been presented (Gervais & Najle, 2015; Lanman & Buhrmester, 2017), but a direct comparison with cognitive biases is missing.

A second way in which our study extends previous work on the relationship between mentalizing and belief is that large sample sizes were employed (Study 1 – 4) with over 67,000 participants in total. Therefore, we have strong foundations to draw conclusions from. A third way in which our study extends earlier work is that we made use of both self-report questionnaires (i.e., the EQ, AQ and hyper-systemizing, in order to directly compare our results with previous studies on this topic) as well as an experimental test used in neuroimaging studies to localize brain areas involved with ToM processing (i.e., the Geometrical Figures Task; in Study 4 and 5). Thereby, we increased the likelihood that we tapped into the concept of mentalizing more thoroughly than in most previous studies. Finally, we investigated samples from three different countries (i.e., The Netherlands [Study 1, 2 and 5], Switzerland [Study 3] and The United States of America [Study 4]) varying in the extent to which they are religious (i.e., secularized: With secularization we refer to the societal decline in level of religiosity), thereby improving the generalizability of our findings.

Overview of the studies

As outlined above, we present five studies in which we cross-culturally investigated the relationship between mentalizing and supernatural beliefs in three countries varying in the extent to which they are secularized. We tested large samples, used different operationalizations of mentalizing and compared the relative importance of mentalizing to cultural learning (i.e., CREDs). We operationalized supernatural beliefs by several items indicative of religiosity (e.g., *'To what extent do* *you belief in God?'*, '*To what extent do you consider yourself religious?*'), hence we refer to this concept as 'religiosity'. In Study 1, we investigated the relationship between the AQ and religiosity in a large sample of participants from The Netherlands. In Study 2, we added the EQ and CREDs for a similar Dutch sample. In Study 3, we investigated the relationship between the AQ and religiosity in a less secularized country than The Netherlands (i.e., Switzerland). In Study 4, we investigated the relationship between the AQ, EQ, the geometrical figures task (as a more objective way of measuring mentalizing abilities) and compared the effects of these mechanisms in predicting religiosity to the role of CREDs in a pre-registered study (https://osf.io/6vrne/) with US participants. In Study 5 we compared adolescents from a Dutch high school specialized in ASD to adolescents from a regular high school. In all studies, we hypothesized a relationship between mentalizing abilities and religiosity, although we expected the relative influence of mentalizing abilities to be minimal compared to influences of cultural learning. Summing up, we investigated the relative contribution of mentalizing and CREDs on acquiring supernatural beliefs.

Study 1: The Netherlands 1

Materials and Methods

Participants. In total, 99,516 participants started an online survey on the website of 'Quest', a popular Dutch Science magazine. Data were collected from the 8th of April 2014 until the 14th of January 2015. We excluded all participants who were younger than 18 years old (12,688 participants) and those who did not fill out the entire survey (21,267 participants). In total, 65,561 participants were used for further analyses. Participants (54.4% female) were on average 29.5 years old (*SD* = 11.1; range 18 - 85 years). All studies were approved by the ethical committee of the University of Amsterdam, confirmed to the laws applying to the countries in which they were conducted and were conducted in accordance with the declaration of Helsinki.

Procedure. On the website of Quest, participants were offered the opportunity to participate in an online survey (i.e., http://www.quest.nl/test/hoeautistisch-ben-jij). The survey was also featured in an article on autism in the paper version of the magazine – offering participants the opportunity to get their personal score on the AQ. Before the survey started, participants were provided with some background information on autism. Participants were cautioned that the test was not an official diagnosis of autism, but rather an indication of their relative score on the autism spectrum in relation to the general population. For an official diagnosis, participants were referred to their general practitioner. The survey started with demographic questions, followed by the autism-spectrum quotient (AQ) questionnaire and subsequently participants received feedback about their scores. Participants were also given the option to fill out the shortened post-critical belief scale (Duriez, Soenens, & Hutsebaut, 2005), which was introduced by a short statement indicating that the researchers were interested in the relationship between autism and religious beliefs. The results of this questionnaire will be reported elsewhere.

Demographics. Participants were asked to report their gender, age and level of education (according to the Dutch educational system divided in 8 ordinal categories from no education to University). In addition, four questions related to religiosity were included (*'To what extent do you consider yourself religious?', 'How often do you visit a church, mosque or religious meeting?', 'How often do you pray?'* and *'To what extent do you belief in a God or a higher power?'*) and these were all measured on a 7-point Likert scale (1 = *not at all* or *never* and 7 = *very much* or *very often*). Table 1 provides an overview of the descriptive statistics for the first four studies.

Table 1. *Demographical variables for Study 1 to Study 4*

Study	*N*	% Female	% Low educated	% Atheist	Religiosity	Age	AQ	EQ
1: NL	65,561	54.4	34.5	59.8	2.04 (1.31)	29.5 (11.1)	2.13 (0.38)	-
2: NL	588	50.9	29.3	49	2.66 (1.84)	39.2 (13.1)	2.41 (0.45)	2.77 (0.55)
3: S	603	78.9	0	27.4	2.56 (1.58)	21.4 (3.8)	2.1 (0.03)	-
4: USA	797	53.3	41.8	33	3.24 (1.93)	34.6 (10.7)	2.32 (0.33)	2.94 (0.54)

Table 1 continues below

	SQ	EQ-SQ	CREDs	Geometrical Figures Video		
Study				Intentional	Random	Mechanical
1: NL	-	-	-	-	-	-
2: NL	-	-	2.27 (2.31)	-	-	-
3: S	-	-	-	-	-	-
4: USA	2.7 (0.50)	0.24 (0.68)	3.29 (1.54)	78.5 (20.8)	38.7 (24.5)	25.6 (26.0)

Note: Data are Means with standard deviations between brackets. NL = The Netherlands; S = Switzerland; AQ = Autism Quotient; EQ = Empathy Quotient; SQ = Systemizing Quotient; EQ-SQ = hyper-empathizing; CREDs = Credibility Enhancing Displays.

Autism-Spectrum Quotient. The AQ questionnaire measures participants' score on traits associated with autism (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). It consists of 50 items (e.g., *If I try to imagine something, I find it very easy to create a picture in my mind*) and all questions were scored on a 4-point Likert scale ('*definitely agree', 'slightly agree', 'slightly disagree',* and *'definitely disagree'*). This is different from the original scale, which scores questions with 0 or 1, but the reliability was comparable (i.e., Cronbah's alpha [α] = .89 for the 4-point Likert scale instead of α = .86 for the bimodal scale). For the items in which an agree-response was reflective of autistic traits the scoring was reversed. Thus, high AQ scores as well as scores on the AQ subscales (e.g., social skills) were indicative of autistic traits. We used the Dutch version of the AQ, which was translated according to the backward translation procedure (Hoekstra, Bartels, Cath, & Boomsma, 2008).

Data Analysis. To allow comparison with the data obtained in the other countries in later studies, we only examined three of the religiosity questions in the regression model (*'To what extent do you consider yourself religious?', 'How often do you visit a church, mosque or religious meeting?'* and *'How often do you pray?'),* reliability α = .84, although we did use all data in a network analysis model which will be explained below. The average religiosity score was highly positively skewed (1.78) and non-normally distributed, Kolmogorov-Smirnov (49105) = .21, $p < .001$. Therefore, religiosity was dichotomized into atheists (average score lower than 2, 59.8%) and believers (average score of 2 or higher, 40.2%). To facilitate comparisons with other countries and because the education-scores were bimodally distributed, Kolmogorov-Smirnov (49105) = .20, $p < .001$, we divided participants in two groups on the basis of a median split (34.5% low educated). To investigate the effect of traits associated with autism on participant's religiosity, we first conducted generalized linear models for all analyses in the paper. Considering the highly skewed and bimodal distribution of religiosity we first tested a mixture response with Tweedie Log Link (Ma & Jørgensen, 2007) and then divided religiosity in a categorical and subsequently a dichotomous predictor. Because these different analyses did not lead to meaningfully different results, we report the most parsimonious and comprehensible model (i.e., religiosity as a dichotomous predictor). We conducted a hierarchical logistic regression analysis in which the dichotomized religiosity dummy was predicted by the AQ, while controlling for demographic predictors. A hierarchical logistic regression analysis was preferred over a simultaneous model, as some demographical predictors have previously found to be robustly related to religiosity and had to be controlled for (e.g., Field, 2009). Therefore, in the first step, gender, age and education(Braun, 2012; Levin, Taylor, & Chatters, 1994; Meisenberg, Rindermann, Patel, & Woodley, 2012) were added as predictors of religiosity using the Enter method (for consistency with other countries, we used this same procedure for all further regression analyses). In the next step, the AQ was included as predictor. Data processing was done in R (R Development Core Team 2017, Version 3.3.3.) and analyses were conducted in R and SPSS (IBM CORP, NY, Version 22).

Results

Hierarchical Logistic Regression Analysis. Table 2 shows the outcome of the logistic regression analysis. Compared to the constant only model, the first model was statistically significant, indicating that the predictors reliably distinguished between atheists and theists, $\chi^2(3) = 889.55$, $p < .001$, although the relationship was weak (.01 = small, .09 = medium, .25 = large) (0.01 = small, 0.09 = medium, 0.25 = large, Cohen, 1992), Nagelkerke $R^2 = .02$. Gender and age both made a significant contribution whereas education did not. Females were 1.59 times more likely to be theist than males and with each unit increase in age, the odds of being theist increased with 1.01. In the second model, the AQ was added as predictor. However, the second model was not significant in comparison to the first model, $\chi^2(3) = 2.66$, $p = .103$, Nagelkerke $R^2 = .02$, indicating that religiosity could not be meaningfully predicted by the AQ.

Table 2. *Logistic Regression Analysis for Variables Predicting religiosity by Atheists (N =29,348) and Theists (N = 19,575) in Study 1, Controlling for Background Variables.*

	Model 1				Model 2			
	B	*SE B*	*eB*	[95% CI]	*B*	*SE B*	*eB*	[95% CI]
Intercept	- 1.08	<0.01			-0.99	<0.01		
Gender	0.01 *	<0.01	1.01	[1.01-1.02]	0.01 *	<0.01	1.01	[1.01-1.02]
Age	0.46 *	-0.02	1.59	[1.53-1.64]	0.46 *	0.02	1.58	[1.53-1.64]
Education	0.03	-0.02	1.03	[0.99-1.07]	0.03	0.02	1.03	[0.99-1.07]
AQ					-0.04	0.03	0.96	[0.92-1.01]

Note: Gender is coded 1 for females and 0 for males, education is coded 1 for high Educated and 0 for low educated. *eB* = exponentiated B, *B* = odds ratio. AQ = Autism Quotient. R^2 (Nagelkerke) = .02 for Model 1 and R^2 (Nagelkerke) = .02 for Model 2. * p < .001.

It could be argued that the AQ and the demographical predictors shared some variance, and that by the order in which the predictors were added to the model (i.e., demographical predictors first) there was less variance left for the AQ to explain. An additional analysis in which only the AQ was added revealed that the model reliably distinguished between atheists and theists, $\chi^2(1) = 7.18$, $p = .007$, although the explained variance of the model was very small, Nagelkerke $R^2 < .001$. To be better able to compare the relative influence of the AQ and the demographical predictors an additional analysis was conducted in which only the demographical predictors were entered. In this model, the predictors at least explained some variance, $\chi^2(3) = 889.55$, $p < .001$, Nagelkerke $R^2 = .02$.

Network Model Analysis. The general idea of the supposed relationship between mentalizing and supernatural beliefs is that our mentalizing capacities are a necessary component to be able to represent the intentions of supernatural agents. However, the religiosity questions also tapped into general religiosity and church visit. While it may be logical that mentalizing is related to representing or interacting with a supernatural agent, it may be less logical to suppose a link between mentalizing and visiting churches or religiosity in general. Therefore, in Figure1 a network analysis model was added (Borsboom & Cramer, 2013), showing a graphical representation of the inter-item correlations of all items used in the study. In this way it can be directly investigated whether specific items of the religiosity questionnaire and the AQ are interrelated. According to a clustering algorithm, nodes (i.e., circle in the figure) are placed more closely together when they are more strongly correlated. The threshold for an edge (i.e., line in the figure) to appear between two nodes was a small correlation ($r > .10$; to increase the visibility of the lines the threshold was not constant for all studies). As is evident from the model, none of the religiosity nodes is linked to any of the AQ items, suggesting that there appears to be no relationship between religiosity and the AQ, independent of the specific items used. However, gender was related to belief in God, reflected by the thin line from gender to belief in God (i.e., R1). Please not that this line is relatively thin, reflecting a small correlation ($r = .10$) and may not visible on some screens.

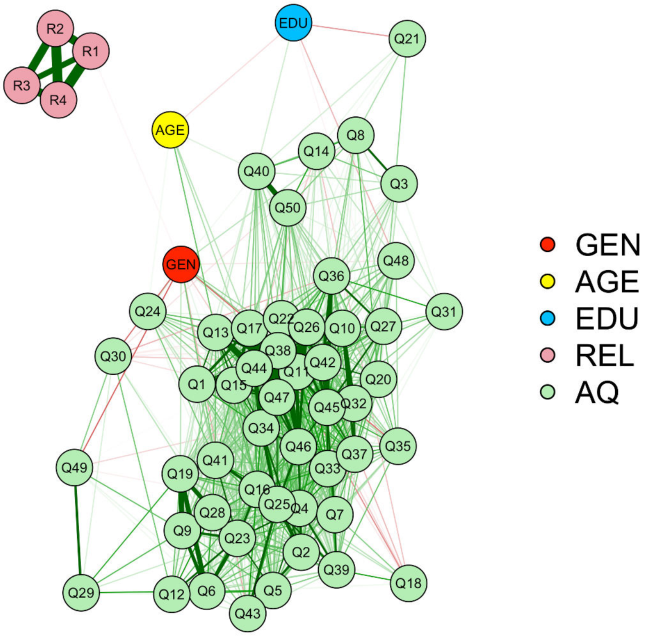

Figure 1. Network Analysis Model Showing a Graphical Representation of the Inter-item Correlations among all items used in Study 1.

Note: GEN = gender, AGE = Age, EDU = Education, REL = religiosity, AQ = Autism Spectrum Quotient, R1 = God, R2 = praying, R3 = Church, R4 = religiosity, Q1 – Q50 = item 1 – 50 of the Autism Spectrum Quotient. The lines represent the inter-item correlations. Thicker lines represent larger correlations and correlations are thresholded at $r = .10$. Green lines are indicative of positive correlations, red lines of negative correlations.

Discussion

In a large-scale survey, we could not replicate earlier findings that the AQ was a significant predictor of religiosity (Norenzayan et al., 2012). The order in which the predictors were added to the model did not have an influence on the interpretation of the results. When the AQ was entered first into the model, none of the variance in religiosity was explained by the AQ. Furthermore, a comparison of a model in which only the AQ was added as predictor and a model in which all demographical predictors were added to the model indicated that the demographical predictors at least explained some variance whereas the significant influence of the AQ was trivial due to the size of the sample. We also showed that it is unlikely that we failed to find an effect due to the way we operationalized religiosity, by adding a network analysis model that graphically visualizes the inter-item correlations between all items used in the model. Even though the threshold of the correlations to appear in the model was set at a fairly low value (a correlation of r = .10), no correlations were observed between any of the religiosity items and any of the AQ items. Overall, these results indicate that the relative importance of mentalizing (as assessed with the AQ) for predicting religiosity may be limited.

Apart from cultural differences between the Netherlands and the US that will be addressed in Studies 3 and 4, a concern may be that our sample consisted of a generally highly educated group of people interested in (popular) science (i.e., they were readers of Dutch popular science magazine). However, since previous samples also consisted of highly educated students (Norenzayan et al., 2012; Willard & Norenzayan, 2013) this characteristic of our sample seems unlikely to explain any of the differences between our and previous studies. Further, we doubt that we selectively sampled participants scoring high on the AQ due to our recruitment method (i.e., asking participants to find out how autistic they are) as we had a very large sample and the AQ was normally distributed with comparable means to an earlier study using participants from the Dutch population (Hoekstra et al., 2008).

What could be considered a limitation is that we only included the AQ as a proxy of mentalizing, while previous studies also used the EQ or the reading the mind in the eye test (Jack et al., 2016; Lindeman & Svedholm, 2012; Norenzayan et al., 2012; Willard & Norenzayan, 2013). Due to the collaboration with the popular science magazine (i.e., Quest), it was only possible for us to request readers to participate in one questionnaire. In Study 2, we addressed this problem by providing readers of the magazine a voluntary option to fill out the EQ as well. In addition, we added a questionnaire on CREDs in order to be able to compare the relative importance of mentalizing in relation to culturally learned aspects of religiosity.

Study 2: The Netherlands 2

In Study 2, we again investigated whether mentalizing was related to religiosity, this time by taking into account an additional operationalization of mentalizing (i.e., the EQ). In addition, we examined the relative importance of mentalizing in predicting religiosity as compared to CREDs, a specific instance of cultural learning focusing on the credibility of religious actions observed by children during their upbringing.

Materials and Methods

Participants. Data were collected from the 5th of January 2015 until the 26th of February 2016 from the same website as reported in Study 1. In total, 15,530 participants filled out the survey. All participants younger than 18 were removed from further analysis (leading to an exclusion of 3,626 participants). Further, we removed all participants who did not fill in all questionnaires (i.e., the additional EQ and religiosity questions; 11,316 participants excluded) and the final dataset consisted of 588 participants. Participants (50.9% female) were on average 29.5 years old (*SD* = 11.1; range 18 - 85 years), see Table 1 for all demographics.

Measures. The measures were the same as in Study 1, except for the addition of two questionnaires: The EQ and a self-constructed version of the Credibility Enhancing Displays scale (CREDs).

***Empathy Quotient*.** The EQ questionnaire is a scale devised to measure empathy in adults with normal intelligence. It was originally developed by Baron-Cohen and Wheelwright (Baron-Cohen & Wheelwright, 2004) and later abbreviated by Wakabayashi and colleagues (Wakabayashi et al., 2006) to a 22-item scale. All questions were scored on a 4-point Likert scale (‘*definitely agree’, ‘slightly agree’, ‘slightly disagree’,* and *‘definitely disagree’*). Half the items were reverse coded to prevent response bias and higher scores were indicative of higher empathy. We used the Dutch version of the EQ, which was translated according to the backward translation procedure (De Corte, Uzieblo, Buysse, & Crombez, 2006) with reliability α = .91.

Credibility Enhancing Displays Scale. At the time of this study, Lanman and Buhrmester’s CREDs scale (Lanman & Buhrmester, 2017) was not yet publically available so we constructed seven questions to tap into the concept of CREDs (e.g., ‘*How often did your parents/caretakers attend religious services?).* All other questions can be found in the supplementary material (i.e., the scale had not been validated in earlier Dutch studies, as we were the first to construct these items). All questions were scored on a 7-point Likert scale (1 = '*not at all'* to 7 = *'to a strong extent'*) with a reliability of, $\alpha = .81$.

Procedure. The participant recruitment procedure remained the same as in Study 1. After completing the AQ on the online survey and obtaining their personal AQ score, participants were welcomed to continue with the online survey by the following question: *"We would like to obtain more insight in the relationship between autism and individual differences such as religiosity. We would therefore kindly like to ask you to continue with the survey").* We do note that the way in which this question to continue the study was framed, with an emphasis on the word 'religiosity' instead of all other individual differences that could have been chosen, made it perhaps somewhat more interesting for believers to continue with the study than non-believers. This view was supported by an analysis of variance showing that the extent to which participants believed in God was somewhat higher for participants who continued ($M = 2.66$, $SD = 1.84$; 1 = does not believe at all to 7 = strongly believes) than for participants who only filled out the first part of the survey, consisting of the AQ ($M = 2.10$, $SD = 1.39$), $F(1, 9294) = 84.54$, $p < .001$. Also, the mean religiosity score of Study 2 was slightly higher than in Study 1 (see Table 1 for the demographics of both studies). However, this effect was small ($\eta 2 = .01$), and compared to the US samples used in previous studies investigating this topic, our sample was still relatively atheistic, so this effect was not likely to have influenced the results.

Data analysis. The data analysis was similar to the first study. In the first model, again the demographical predictors were taken as these have been related to religiosity in the past. In the second model the EQ or the AQ was added (correlational analyses showed a strong negative correlation between the two variables, $r = -.72$, $p < .001$, suggesting that it would not be advisable to insert them together), as we wanted to investigate whether variables associated with mentalizing are important for predicting supernatural beliefs. In the third model

CREDs were added to explore to what extent cultural learning adds to predicting religiosity in comparison to mentalizing. However, neither the EQ nor the AQ made a significant contribution to the model, so for reasons of brevity we chose to take the EQ and AQ together in the second model. As an explorative analysis, all interaction terms were added to the model but non-significant interactions were dropped for brevity.

Results

Hierarchical logistic regression analysis. Table 3 shows the outcome of the logistic regression analysis. Compared to a constant only model, the first model was statistically significant, indicating that the predictors reliably distinguished between atheists and theists, $\chi^2(3) = 11.49$, $p = .009$, although the relationship was weak, Nagelkerke $R^2 = .03$. Gender and age both made a significant contribution whereas education did not. Females were 1.55 times more likely to be theist than males and with each unit increase in age, the odds of being theist increased by 1.02.

Table 3. *Logistic Regression Analysis for Variables Predicting religiosity by Atheists (N =288) and Theists (N = 300) in Study 2, Controlling for Background Variables.*

	Model 1					Model 2					Model 3				
	B		*SE B*	*eB*	[95% CI]	*B*		*SE B*	*eB*	[95% CI]	*B*		*SE B*	*eB*	[95% CI]
Intercept	-0.79		0.29			-0.42		1.17			-1.85		1.28		
Gender	0.44	**	0.17	1.55	[1.12-2.15]	0.43	*	0.17	1.54	[1.10-2.15]	0.54	**	0.18	1.71	[1.20-2.43]
Age	0.02	*	0.01	1.02	[1.00-1.03]	0.02	*	0.01	1.02	[1.00-1.03]	0.03	**	0.01	1.03	[1.01-1.05]
Education	0.07		0.18	1.07	[0.75-1.54]	0.09		0.19	1.09	[0.76-1.57]	0.16		0.20	1.17	[0.80-1.71]
AQ						-0.14		0.27	0.87	[0.51-1.47]	-0.05		0.28	0.95	[0.55-1.65]
EQ						-0.01		0.22	0.99	[0.64-1.53]	0.03		0.23	1.03	[0.65-1.61]
CREDs											0.41	***	0.07	1.51	[1.32-1.73]
Age18*CREDs											-0.01	**	0.01	0.99	[0.99-1.00]

Note: Gender is coded 1 for females and 0 for males, education is coded 1 for high educated and 0 for low Educated. AQ = Autism Quotient; EQ = Empathizing Quotient; CREDs = Credibility Enhancing Displays scale; age18 = age centered at 18 years; *eB* = exponentiated *B*; *B* = odds ratio. R^2 (Nagelkerke) < .01 for Model 1 and Model 2, R^2 (Nagelkerke) = .14 for Model 3. *p < .05. **p < .01. ***p < .001.

In the second model, the AQ and EQ were added as predictors. However, the second model was not significant in comparison to the first model, $\chi^2(2) = 0.50$, $p = .777$, Nagelkerke $R^2 = .03$. In the third model, CREDs as well as the interaction between CREDs and age (see data analysis) were added as predictors, resulting in a significant contribution to the prediction, $\chi^2(2) = 52.65$, $p < .001$, Nagelkerke $R^2 = .14$. CREDs and the interaction between CREDs and age (centered at 18 years for ease of interpretation) were both significant predictors. For each unit increase in CREDs, the odds of being theist increased with 1.55. With regard to the interaction effect, age was centered at 18 years, so a one-unit increase in CREDs at the age of 18 decreased the odds of being a theist with 0.99. This indicates that CREDs had a stronger influence on younger participants than on older participants. The demographics did not change much: gender and age still made a significant contribution whereas Education, AQ and EQ did not.

To disentangle the relative contribution of operationalizations of mentalizing (i.e., the AQ and the EQ) from the relative contribution of the demographical predictors and CREDs, we constructed three additional models. In the first model only the AQ and the EQ were entered as predictors, resulting in a non-significant model, $\chi^2(2) = 0.88$, $p = .646$, Nagelkerke $R^2 = .002$, indicating that our operationalizations of mentalizing did not adequately distinguish atheists from theists. In the second model, only the demographical predictors were entered as predictors, resulting in a significant model, $\chi^2(3) = 11.49$, $p = .009$, Nagelkerke $R^2 = .03$. In the third model, only CREDs were entered as predictor, resulting in a significant model, $\chi^2(2) = 47.71$, $p < .001$, Nagelkerke $R^2 = .10$. Thus, a comparison of the explained variance of the models revealed that the relative contribution of both the demographical predictors and CREDs outweighed the relative contribution of mentalizing that seemed to be non-existent for this sample.

Network model analysis. Finally, similarly as in Study 1, we conducted a network model analysis to graphically represent the inter-item correlation between all items to rule out the lack of a relationship between mentalizing and religiosity is due to the way religiosity was operationalized. The outcome of the network model analysis is represented in Figure2 and shows that at least some items of the AQ and

EQ were related to religiosity, but that the correlations were weak (lines between nodes were thresholded at $r > .15$). Crucially, the model shows that an absence of a relationship is not likely to be the result of the artificial means with which we formed the construct religiosity, but that it is rather the result of the lack of correlations between the operationalizations of mentalizing and any of the religiosity items.

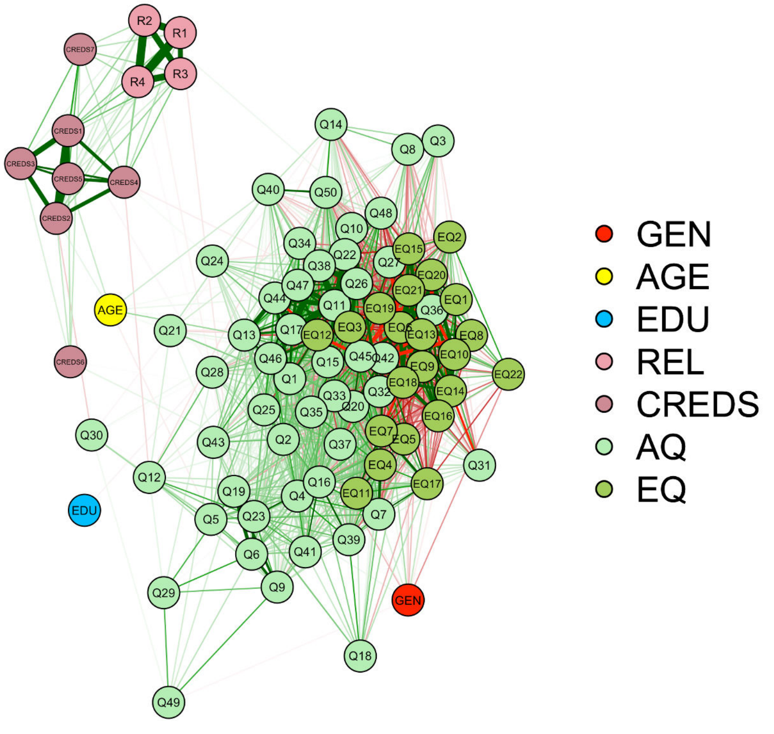

Figure 2. Network Analysis Entailing a Graphical Representation of the Inter-item Correlations among all items used in Study 2.

Note: GEN = Gender, AGE = Age, EDU = Education, REL = religiosity, CREDS = Credibility Enhancing Display Scale, AQ = Autism Spectrum Quotient, EQ = Shortened Empathy Quotient, R1 = God, R2 = praying, R3 = Church, R4 = religiosity, CREDS1 – CREDS 7 = item 1 – 7 of the own-constructed Credibility Enhancing Display Scale, Q1 – Q50 = item 1 – 50 of the Autism Spectrum Quotient. The lines represent the inter-item correlations. Thicker lines represent larger correlations and correlations were thresholded at $r = .15$. Green lines are indicative of positive correlations, red lines of negative correlations.

Discussion

Again, we did not find the hypothesized relationship between operationalizations of mentalizing (i.e., the AQ or the EQ) and belief in supernatural agents. We did find a strong effect of our self-constructed CREDs scale when predicting religiosity, thereby adding to a growing literature on this topic (Gervais, Willard, Norenzayan, & Henrich, 2011; Gervais & Najle, 2015; Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017). We acknowledge that these questions primarily tap into visible markers of religiosity of the parents and are not necessarily equivalent to the central idea of CREDs that 'actions speak louder than words' (Henrich, 2009; Lanman, 2012). Nevertheless, these findings indicate that i) whether parents' beliefs are accompanied by credibility-enhancing displays and ii) demographical predictors like age and gender, respectively, are far more important in determining whether people believe than individual differences in mentalizing capacities as assessed with the AQ. Nevertheless, cultural learning is a proximal factor (Tinbergen, 1963) that may explain why people believe and how religiosity spreads; proximal factors do not explain how belief once came into existence (one of the main topics of interest of the cognitive science of religion). For this reason, the fact that in multiple U.S. and Canadian samples in another study (Norenzayan et al., 2012), mentalizing (as assessed with people with ASD in Study 1, the AQ and EQ in Study 2, 3 and 4, and the reading the mind in the eye test in Study 4) was a significant predictor of religiosity, is theoretically highly interesting and relevant. Thus, it is important to investigate whether the absence of a role of mentalizing in our studies may be the result of cultural differences between our Dutch samples and the U.S. (and Canadian) samples investigated previously.

An important cultural difference between the U.S. and the Netherlands is that the Netherlands is far more secularized than the U.S. In The Netherlands, only 10% of the believers frequently attend church and The Netherlands have one of the highest percentages of atheists in the Western World (Schmeets, 2014). In contrast: in the U.S., 37% of the population frequently attends church (Gallup International,) and the U.S. has the lowest percentage of atheists of all countries in the Western World (P. Zuckerman, 2007). Even the president engages in religious CREDs (e.g., ending each speech by saying *"May God bless you and may God bless the United States of America"*). A possibility is that in highly religious countries fluctuations in mentalizing capabilities (i.e., decreases) can lead to observable effects on religiosity, whereas in highly secular countries fluctuations do not help to explain already prevalent atheism (i.e., a floor effect). Before investigating a religious sample from the U.S. in Study 4, in Study 3, we tried to address this issue by looking at dataset that was available from a study in Switzerland in which all necessary variables were included. Switzerland is a country less secularized than the Netherlands (Schmeets, 2014; Schweizerische Steuerkonferenz, Swiss Federal Tax Administration,), but more than the U.S (P. Zuckerman, 2007).

Study 3: Switzerland

Switzerland has a moderate to strong interwoven relationship between society and Christianity (Schweizerische Steuerkonferenz, Swiss Federal Tax Administration,). The percentage of the population that self-reports to be atheist is almost twice as large in The Netherlands as in Switzerland (P. Zuckerman, 2007). Whereas 39-44% of the people reported to be atheist in the Netherlands, this was only true for 17-27% in Switzerland. In this study we investigated the relationship between the AQ and religiosity in a similar fashion as in the first two Dutch studies, although in this dataset the EQ was not taken into account.

Materials and Methods

Data were collected from first year psychology students from the 10^{th} of October 2014 until the 18^{th} of December 2014 at the University of Lausanne. The investigation was part of a larger study validating questionnaires on trait schizotypy and autistic traits (Sierro, Rossier, Mason, & Mohr, 2016; Sierro, Rossier, & Mohr, 2016). In total, 627 participants filled out the survey, but AQ data from one participant was missing. Participants (78.9% female) were on average 21.4 years old (*SD* = 3.8; range 15 to 50 years), see Table 1 for all demographics. The religiosity measure was different from the two studies, with minor changes in terms of the assessed demographics. In the Swiss sample, 15 questions were measured that related to religiosity, however not all participants filled out all these questions.

Participants were first asked to answer the question whether they were believer, atheist or agnostic. Second, participants were asked how they defined themselves religiously (i.e., *Christian, Jew, Muslim, Buddhist, Hindu, Atheist/ not believer, agnostic/ we cannot know, other*). To be as much consistent with the first studies as possible, we used religiosity (believer vs. atheist) as a dichotomous predictor and left the agnostic people out because agnostics can be either believers or non-believers (leading to an exclusion of 23 participants). The other 13 religiosity items were only filled in by believing and agnostic participants. In the first question, people were asked how often they visited churches and in the third question participants were asked how often they prayed (*rarely or never, 1 -2 times a month, more than 2 times a month*). Items 4 -13 were measured on a 7 point Likert scale, (1 = *not at all/ not important at all,* to 7 = *strongly/ very important*; e.g., translated from French: '*is it easy to represent yourself God or/and his will?'*). Further data analyses were similar to Study 1, apart from the predictor 'education' that was dropped because all participants were university students.

Results

Hierarchical logistic regression analysis. Table 4 shows the outcome of the logistic regression. The first model was not statistically significant different from a constant only model, indicating that the predictors did not reliably distinguish between atheists and theists, $\chi^2(2) = 0.16$, $p = .923$, Nagelkerke $R^2 < .01$. In the second model, the AQ was added as predictor. However, the second model was also not significant in comparison to the first model, $\chi^2(1) = 2.15$, $p = .143$, Nagelkerke $R^2 = .01$.

Table 4. Logistic Regression Analysis for Variables Predicting religiosity by Atheists (*N* =240) and Theists (*N* = 168) in Study 3, Controlling for Background Variables.

	Model 1				Model 2			
	B	*SE B*	*eB*	[95% CI]	*B*	*SE B*	*eB*	[95% CI]
Intercept	1.13	0.52			-0.04	0.95		
Gender	0.01	0.22	1.01	[0.65-1.57]	0.05	0.23	1.06	[0.68-1.64]
Age	-0.01	0.02	0.69	[0.95-1.04]	-0.01	0.02	0.99	[0.95-1.04]
AQ					0.53	0.37	1.71	[0.83-3.50]

Note: Gender is coded 1 for females and 0 for males. *eB* = exponentiated *B*; *B* = odds ratio; AQ = Autism Quotient. None of the models was significant. R^2 (Nagelkerke) < .01 for Model 1 and R^2 (Nagelkerke) = .01 for Model 2.

Network model analysis

Similarly as in the first studies, we conducted a network model analysis to graphically represent the inter-item correlation between all items to rule out that the lack of a relationship between mentalizing and religiosity is due to the way religiosity was operationalized. The outcome of the network model analysis represented in Figure3 shows that at least some items of the AQ were related to religiosity, but that the correlations were weak (lines between nodes emerged only for $r > .15$). There are more green lines than red lines between the AQ and religiosity items, indicating that the correlations between AQ and religiosity items are more often positive than negative. Crucially, the model shows that an absence of a relationship is not likely to be the result of the means by which we formed the construct religiosity (believing yes/no), but that it is rather the result of the lack of the strength of the correlations between the AQ and any of the religiosity items.

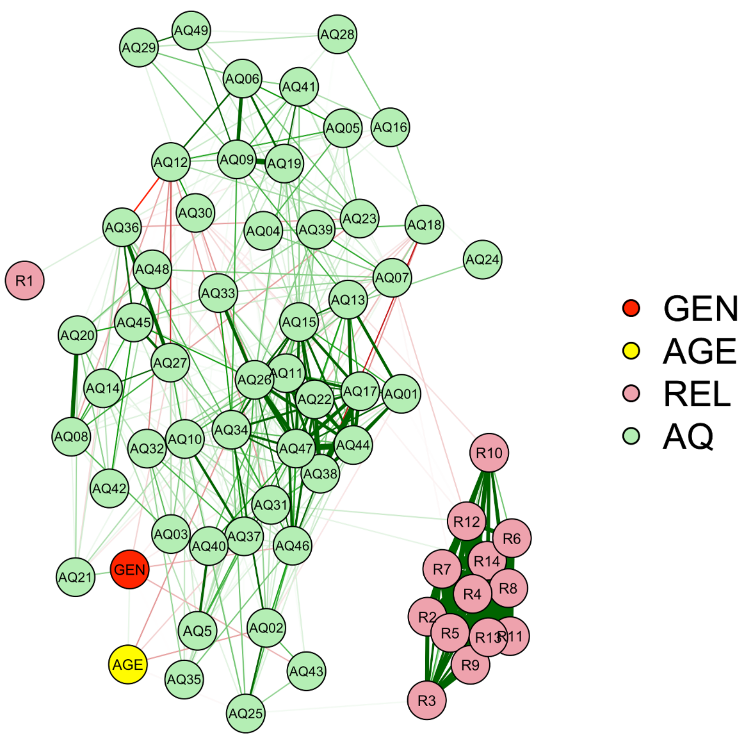

Figure 3. Network Analysis Entailing a Graphical Representation of the Inter-Item Correlations among all items used in Study 3.

Note: GEN = gender (1 = female, 2 = male); AGE = age, REL = religiosity; AQ = Autism Spectrum Quotient; R1 - R14 = religiosity items (see supplementary material online); Q1 – Q50 = item 1 – 50 of the Autism Spectrum Quotient (see supplementary material online). The lines represent the inter-item correlations, thicker lines represent larger correlations and correlation lines start from r = .15. Green lines are indicative of positive correlations, red lines of negative correlations.

Discussion

In Study 3, we investigated the possibility that in highly religious countries fluctuations in mentalizing capabilities (i.e., decreases) can lead to observable effects on religiosity, whereas in highly secular countries they do not add to explain the already prevalent atheism. However, we did not find the presumed relationship between the AQ and religiosity in a sample from a less secularized country than the Netherlands. The percentage of atheists was lower in the Swiss sample than both Dutch samples. Thus, it is unlikely that we failed to observe an inverse relationship between religiosity and the AQ in The Netherlands due to the high secularity in this country. Moreover, in the network analysis model all measured religiosity items were taken into account and the AQ items were more often positively related with religiosity rather than negatively.

Two differences between the Dutch and the Swiss sample are important to note. First, the Swiss sample was more highly educated than both of the Dutch samples as all Swiss participants were university students. On the one hand, it may seem remarkable that the percentage of theists was higher although analytic thinking (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012) as well as intelligence (M. Zuckerman, Silberman, & Hall, 2013) have repeatedly been related to disbelief. On the other hand, the effects of analytic thinking and intelligence were weak and the previous studies from the current paper as well as other studies (Norenzayan et al., 2012; Pennycook et al., 2012) have shown that education may not be a robust predictor when it comes to explaining religiosity when factors as gender and age are being controlled for.

Second, the percentage of females was considerably higher in the Swiss sample than in the Dutch samples, a factor that could also explain the higher percentage of theists in the Swiss sample since the experiments above and previous studies have shown that females more strongly believe than males (Braun, 2012; Norenzayan et al., 2012; Pennycook et al., 2012). Further, females score lower on the AQ than males (Baron-Cohen et al., 2001), possibly diminishing the potential influence of individual differences in the AQ on predicting religiosity. Speaking against this, however, is the finding that the AQ score was somewhat higher in the Swiss sample than in the Dutch samples, probably due to the fact that the Swiss sample consisted of only high-educated participants and highly educated people score higher on the AQ than lower educated participants (Baron-Cohen et al., 2001). Nevertheless, while Switzerland may be less secularized than The Netherlands, there are still large differences between Europe and the United States, as the United States is one of the most religious countries of the Western World (P. Zuckerman, 2007). Thus, there may be cultural differences between the United States and Europe that may explain why a relationship between mentalizing and religiosity is more present in the USA than in Europe. To address this issue we conducted a direct replication of the study of Norenzayan et al. (Norenzayan et al., 2012) by recruiting a group of participants from the US. We pre-registered this study on the Open Science Framework (https://osf.io/6vrne/).

Study 4: United States of America

In Study 4, we conducted a replication of the study of (Norenzayan et al., 2012) by using a sample from the U.S. as well as using the exact materials as provided by of one of the co-authors of that study (i.e., Will Gervais). This means that we used the same material as in Study 2 and added the systemizing quotient (SQ) and several religiosity items. The SQ measures the drive to analyze or construct systems. This scale was not related to religiosity in the study of Norenzayan et al. (Norenzayan et al., 2012). It has been suggested, however, that not mentalizing, but hyper-empathizing is predictive of religiosity (Lindeman et al., 2015). The underlying idea is that humans have two parallel cognitive systems, one for mentalizing (i.e., interaction with the psychological environment) and one for systemizing (interaction with the physical environment)(Baron-Cohen, 2002; Baron-Cohen, Knickmeyer, & Belmonte, 2005). Specifically the combination of high empathizing (good mentalizing capacities) and low systemizing (poor understanding of how the physical world works) may encourage supernatural beliefs. Thus, adding the SQ allowed us to more directly replicate the study of Norenzayan et al. (16) as well as to test the hypothesis that hyper-empathizing predicts religiosity as has been suggested and found in earlier studies (Lindeman & Svedholm, 2012).

Furthermore, we wanted to tap into the concept of mentalizing ability differently by using an experimental measure of mentalizing ability (i.e., not relying on self-report questions with validity problems that have been outlined in the introduction). Therefore, we added the geometrical figures task (GFT). In this task, participants watch geometrical figures move as if they have goal directed intentions (i.e., the figures chase each other). In line with the proposed theory that mentalizing deficiencies decrease religiosity, we predicted that decreased intentionality ratings on the videos would be associated with decreased religiosity.

Materials and Methods

Participants. Data were collected from the 4th of November 2015 until the 16th of January 2016 on Amazon's Mechanical Turk in which we aimed to test approximately 250 atheists, 250 spiritual and 250 Christian believers to obtain sufficient variability in religiosity for another study. In total, 1.235 participants started the survey, and of which 797 participants (53.3% female) completed it (64.5% completion rate; *M* age = 34.6, *SD* = 10.7, range 18 to 70). Participants received $2.50 for participation.

Measures and Procedure. On the website of Amazon Mechanical Turk, participants were offered the opportunity to conduct an online survey. The first question required participants to indicate the kind of belief system they endorsed ("*non-believer/atheist, Christian, Muslim, Hindu, Spiritual believer,* or *another belief system")*. If participants reported not to consider themself an atheist, Christian or spiritual believer, they were directed to the end of the survey. To prevent people from participating twice, people could not participate with the same IP-address more than one time. The following questionnaires were obtained in respective order: demographics (age, gender, social economical status, years of education), religiosity (although we used the exact same questions as used in Norenzayan et al. [16] we only analyzed the questions that were also obtained in Study 1 and 2 to ease comparison between countries), α = .89, CREDs (as measured with Lanman and Burhmester, [22] scale), α = .92, AQ, α = .86, EQ, α = .83, the systemizing quotient (SQ), α = .88 and the Geometrical Figures Task.

Systemizing Quotient. The SQ measures the drive to analyze or construct systems. It was first developed by Baron-Cohen (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003), later abbreviated by Wakabayashi et al. (Wakabayashi et al., 2006) and consists of 25 items on which participants could either agree or disagree (e.g., *"I am fascinated by how machines work"* and *"I find it difficult to read and understand maps"*), some of which were reverse-scored. Higher scores were indicative of higher self-reported systemizing skills, α = .83.

Credibility Enhancing Displays. As explained above, CREDs are signals (i.e., displays) of actions that increase or decrease the likelihood of believing in the existence of the supernatural (Lanman, 2012). We here used Lanman and Buhmester's validated CREDs scale [22]; e.g., *Overall, to what extent did your caregiver(s) act as good religious role models?*"). All questions were scored on a 7-point Likert scale (1 = '*not at all'* to 7 = *'to a strong extent'*) with reliability α = .92.

Geometrical Figures Task. We used an adapted version of the Geometrical Figures Task developed by Riekki, Lindeman and Raij (Riekki et al., 2014) in which animations displayed moving geometrical figures. Participants had to rate to what extent movements performed by the geometrical figures were intentional by adjusting a scale from 1 (*no intentionality present*) to 100 (*strong intentionality present*). Participants were first shown three practice videos, one of each category (i.e., intentionality, mechanically and random). Each practice video was accompanied by an instruction explaining why the video was intentional or non-intentional (mechanic or random). For the intentional movements video it was explained that the figures moved as if they had an intention, for example as if one figure chased the other. For the mechanical video, it was explained that the figures moved as if following the laws of physics. So, if one figure touched another the other figure would also start moving or if the figure touched the wall it would bounce back. The random movements were semi-random as the animations were programmed in such a way that figures would not touch each other, otherwise figures would appear to run through each other. Participants were instructed that these figures moved randomly and that there was no logical mechanical or intentional pattern observable in the movements of the figures.

The stimuli of Riekki et al. (Riekki et al., 2014) were developed for a functional magnetic resonance imaging study and therefore quite easy to rate in terms of intentionality and randomness. In order to increase the difficulty (and ambiguity) we cut the original videos of 30 seconds in 3 parts of 10 seconds. In addition, we increased the speed of the videos by changing the length to 6 seconds per video. In total, we used 24 clips, 8 of each video type (i.e., intentional, random and mechanical motion). Each participant rated only a pseudo-randomized subset of 9 videos (3 from each video type).

Data analysis. The logistic analyses were similar to the previous studies: religiosity was non-normally distributed, Kolmogorov-Smirnov (787) = .09, p < .001. Therefore, religiosity was dichotomized into atheists (average score lower than 2, 33%) and theists (average score of 2 or higher, 67%). In the first model the demographical variables were taken as predictors. In the second model all operationalizations of mentalizing were added: the AQ, EQ-SQ and the GFT. In the final model, CREDs were added. As an explorative analysis, all interaction terms were added to the model but non-significant interactions were dropped for conciseness.

Results

Hierarchical Logistic Regression. Compared to a constant only model, the first model was statistically significant, indicating that the predictors reliably distinguished between atheists and theists, $\chi^2(3) = 35.17$, $p < .001$, Nagelkerke R^2 = .06 (see Table 5 for the outcomes of the logistic regression analysis). Gender and age both made a significant contribution whereas education did not. For females, the odds were 1.78 times more likely to be theist than for males and with each unit increase in age, the odds of being theist increased with 1.03. In the second model, all operationalizations relating to mentalizing (i.e., the AQ, EQ-SQ and the GFT) were added as predictors to the model and they significantly contributed to the model, $\chi^2(5) = 33.40$, $p < .001$, Nagelkerke $R^2 = .12$. Seeing intentionality in random videos as well as mechanistic videos made a significant contribution to the model, whereas the AQ, hyper-systemizing, and seeing intentionality on intentional videos did not. With each unit increase on the random video as well as on the mechanistic video (scale = 1 – 100), the odds were 1.01 times more likely to be theist than atheist. The other predictors did not change much in comparison to the first two models: gender and age still made a significant contribution.

Table 5. *Logistic Regression Analysis for Variables Predicting religiosity by Atheists (N = 263) and Theists (N = 524) in Study 4, Controlling for Background Variables.*

	Model 1					Model 2				
	B		*SE B*	*eB*	[95% CI]	*B*		*SE B*	*eB*	[95% CI]
Intercept	-0.67		0.29			-1.24		0.52		
Gender	0.58	***	0.17	1.78	[1.31-2.43]	0.50	**	0.17	1.64	[1.17-2.30]
Age	0.03	***	0.01	1.03	[1.02-1.05]	0.04	***	0.01	1.04	[1.02-1.06]
Education	0.10		0.18	1.11	[0.81-1.51]	0.02		0.16	1.02	[0.74-1.40]
AQ						-0.21		0.29	0.81	[0.46-1.43]
EQ-SQ						0.26	*	0.15	1.30	[0.97-1.75]
Intentional						0.00		0.01	1.00	[0.99-1.01]
Random						0.01	*	0.00	1.01	[1.00-1.01]
Mechanistic						0.01	**	0.00	1.01	[1.00-1.02]
CREDs										

Table continues

	Model 3				
	B		*SE B*	*eB*	[95% CI]
Intercept	-2.19		0.56		
Gender	0.52	**	0.18	1.68	[1.19-2.37]
Age	0.03	***	0.01	1.03	[1.02-1.05]
Education	0.06		0.17	1.07	[0.77-1.48]
AQ	-0.06		0.36	0.95	[0.53-1.70]
EQ-SQ	0.29		0.18	1.33	[0.98-1.81]
Intentional	0		0.01	1	[0.99-1.01]
Random	0.01	*	0	1.01	[1.00-1.02]
Mechanistic	0.01	**	0	1.01	[1.00-1.02]
CREDs	0.38	***	0.06	1.46	[1.30-1.63]

Note: Gender is coded 1 for Females and 0 for Males, education is coded 1 for High Educated and 0 for Low Educated. AQ = Autism Quotient; EQ = Empathizing Quotient; EQ-SQ = hyper-systemizing; intentional, random, and mechanistic are the different intentionality ratings for the geometrical figures videos; CREDs = Credibility Enhancing Displays scale; *eB* = exponentiated *B*; *B* = odds ratio. R^2 (Nagelkerke) = .06 for Model 1, R^2 (Nagelkerke) = .07 for Model 2, R^2 (Nagelkerke) = .12 for Model 3 and R^2 (Nagelkerke) = .19 for Model 4. *$p < .05$. **$p < .01$. ***$p < .001$.

In the third model, CREDs were added resulting in a significant contribution, $\chi^2(1) = 47.91$, $p < .001$, Nagelkerke $R^2 = .19$. With each unit increase on the CREDs scale (1 to 7) the odds of being theist increased with 1.46. The other predictors did not change much in comparison to the first models: gender, age and the random and mechanical videos still made a significant contribution whereas education, the AQ and hyper-systemizing did not.

To disentangle the relative contribution of operationalizations of mentalizing (i.e., the AQ, SQ-EQ and the GFT) from the relative contribution of the demographical predictors and CREDs, we constructed three additional models. In the first model the AQ, EQ and GFT were entered as predictors, resulting in a significant model, $\chi^2(3) = 14.08$, $p = .001$, Nagelkerke $R^2 = .03$, indicating that our operationalizations of mentalizing did distinguish atheists from theists. In the second model, only the demographical predictors were added, resulting in a significant model, $\chi^2(3) = 35.17$, $p < .001$, Nagelkerke $R^2 = .06$. In the third model, only CREDs were entered as predictor, resulting in a significant model, $\chi^2(1) = 60.60$, $p < .001$, Nagelkerke $R^2 = .10$. Thus, a comparison of the explained variance of the models revealed that the relative contribution of both the demographical predictors and CREDs outweighed the relative contribution of our operationalizations of mentalizing.

Finally, similar to the previous studies we conducted a network model analysis to graphically represent the inter-item correlation between all items. The outcome of the network model analysis is represented in Figure4 and shows that several items of the AQ and EQ were related to the religiosity items (lines between nodes were thresholded at $r > .15$). Essentially, the model shows that there are multiple correlations between the AQ, EQ and SQ items on the one hand and religiosity items on the other hand. Importantly, most of these relationships are negative and thus in line with the notion that reduced ToM capacities are linked to reduced belief in supernatural agents.

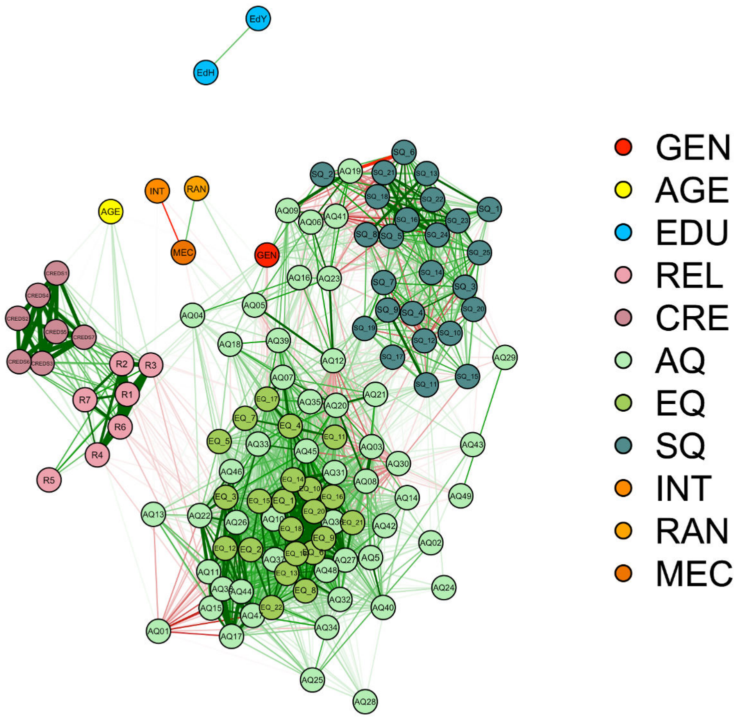

Figure 4. Network Analysis Entailing a Graphical Representation of the Inter-Item Correlations among all items used in Study 4.

Note: GEN = gender (1 = female, 2 = male); AGE = age; EDU = education; REL = religiosity; CRE = CREDs (i.e., Credibility Enhancing Displays scale); AQ = Autism Spectrum Quotient; EQ = Empathy Quotient; SQ = Systemizing Quotient; INT = intentionality rating for the intentionally moving geometrical figures; RAN = intentionality rating for the random moving geometrical figures; MEC = intentionality rating for the mechanically moving geometrical figures; R1 - R14 = religiosity items (see supplementary material online); Q1 – Q50 = item 1 – 50 of the Autism Spectrum Quotient (see supplementary material online). The lines represent the inter-item correlations, thicker lines represent larger correlations and correlation lines start from r = .15. Green lines are indicative of positive correlations, red lines of negative correlations.

Explorative analysis: Curvilinear Relation between AQ and Religiosity. A still open-standing possibility is that the relationship between the AQ and belief in supernatural agents might better be captured by a curvilinear relationship than by a linear relationship, perhaps explaining the lack of the fit of the AQ in the previous models. The underlying idea is that for people with high scores on the AQ it may be problematic to represent supernatural agents or read the intentions of supernatural agents, whereas for people scoring low to moderate on the AQ, no relationship would be expected (resulting in a random distribution). To investigate this possibility a logistic regression model was conducted similar to the first model of Study 4, except for the fact that the quadratic term was added to account for a possible curvilinear effect (e.g., McDonald, 2009). In order to do so, the AQ was centered (i.e., AQ-centered) and added to the model and the quadratic term of the centered predictor (i.e., AQ^2-centered) was also added to the model.

The outcomes of the first model are identical to the first model of Study 4. In the second model all operationalizations relating to mentalizing (i.e., the AQ-centered, AQ^2-centered, EQ-SQ and the GFT) were added as predictors to the model and they significantly contributed to the model, $\chi^2(6) = 50.87$, $p < .001$, Nagelkerke $R^2 = .14$ (see Table 6). The quadratic term of the AQ as well as attributing intentionality to both the random and mechanistic videos all significantly added to the model. For each unit increase on the quadratic term of the centered AQ, the odds were 6.99 (i.e., 1/0.143) more likely to be theist than atheist. For each unit increase on the random and mechanical video, the odds of being theist increased with 1.01. The other predictors did not change much in comparison to the first model: gender and age still made a significant contribution.

Table 6. *Explorative Logistic Regression Analysis for Variables Predicting religiosity by Atheists (N =263) and Theists (N = 524) in Study 4, Controlling fc Background Variables.*

	Model 1					Model 2					Model 3				
	B		*SE B*	*eB*	[95% CI]	*B*		*SE B*	*eB*	[95% CI]	*B*		*SE B*	*eB*	
Intercept	-0.67		0.29			-1.14		0.53			-2.06		0.56		
Gender	0.58	***	0.17	1.78	[1.31-2.43]	0.58	***	0.18	1.78	[1.26-2.51]	0.60	***	0.18	1.82	[1
Age	0.03	***	0.01	1.03	[1.02-1.05]	0.04	***	0.01	1.04	[1.03-1.06]	0.04	***	0.01	1.04	[1
Education	0.10		0.18	1.11	[0.81-1.51]	-0.03		0.16	0.98	[0.71-1.35]	0.03		0.17	1.03	[0
AQ-centered						-0.16		0.29	0.85	[0.48-1.51]	-0.02		0.30	0.99	[0
AQ^2-centered						-1.95	***	0.49	0.14	[0.06-0.37]	-1.88	***	0.51	0.15	[0
EQ-SQ						0.24		0.15	1.27	[0.94-1.71]	0.26		0.16	1.30	[0
Intentional						0.00		0.01	1.00	[0.99-1.01]	0.00		0.01	1.00	[0
Random						0.01	*	0.00	1.01	[1.00-1.01]	0.01	*	0.00	1.01	[1
Mechanistic						0.01	**	0.00	1.01	[1.00-1.02]	0.01	**	0.00	1.01	[1
CREDs											0.37	***	0.06	1.45	[1

Note: Gender is coded 1 for females and 0 for males, education is coded 1 for high educated and 0 for low educated. AQ-centered = centered Autism Quotient; AQ2-centered = quadratic term of the centered Autism Quotient; EQ-SQ = hyper-systemizing; intentional, random, and mechanistic are the different intentionality ratings for the geometrical figures videos; CREDs = Credibility Enhancing Displays scale; *eB* = exponentiated *B*; *B* = odds ratio. R^2 (Nagelkerke) = .06 for Model 1, R^2 (Nagelkerke) = .07 for Model 2, R^2 (Nagelkerke) = .12 for Model 3 and R^2 (Nagelkerke) = .19 for Model 4. *p < .05. **p < .01. ***p < .001.

In the third model, CREDs were added to the model resulting in a significant contribution, $\chi^2(1) = 45.69$, $p < .001$, Nagelkerke $R^2 = .22$. With each unit increase on the CREDs scale (1 to 7) the odds of being theist increased with 1.45. The other predictors did not change much in comparison to the first models: gender, age, the quadratic term of the centered AQ and the random and mechanical videos still made a significant contribution whereas education, the centered AQ and hyper-systemizing did not.

To be able to disentangle the relative contribution of all operationalizations of mentalizing (i.e., the AQ-centered, AQ^2-centered, SQ-EQ and the GFT) from the relative contribution of the demographical predictors and CREDs, we constructed two additional models. In the first model only the operationalizations of mentalizing were entered as predictors, resulting in a significant model, $\chi^2(6) = 44.04$, $p < .001$, Nagelkerke $R^2 = .08$, indicating that our operationalizations of mentalizing distinguished atheists from theists. In the second model only the quadratic term of the centered AQ was entered as predictor, resulting in a significant model, $\chi^2(1) = 14.59$, $p < .001$, Nagelkerke $R^2 = .03$, again indicating that the quadratic term of the centered AQ distinguished atheists from theists. Above, we already showed that the explained variance of the demographical predictors was Nagelkerke $R^2 = .06$, whereas the explained variance of the CREDs was Nagelkerke $R^2 = .10$. This indicates that in the US sample the operationalizations of mentalizing were somewhat less important than CREDs, but comparable to the demographical predictors gender and age.

Discussion

In the fourth study, we could explain 19-22 % of the variance in religiosity by means of just two demographical variables (i.e., gender and age) and two constructs (i.e., all mentalizing operationalizations and CREDs). The findings of the studies above were partially replicated: CREDs, age and gender significantly predicted religiosity, whereas the AQ and hyper-systemizing did not. Extending the studies above, we observed that attributing intentionality to mechanical or random videos did account for some of the variance in religiosity.

Explorative analyses revealed that it may be the case that specifically high scores on the AQ are linked to decreased belief in supernatural agents, whereas no such relationship was present for lower scores (i.e., an inverted hockey stick shape). We ruled out that this was the result of adding a quadratic term in general: for none of the other predictors we found a significant contribution when the centered quadratic term was added, even not for the CREDs. Following these outcomes, we also fitted curvilinear models on all other studies (i.e., Study 1 – 3), but this did not result in similar findings; the quadratic term was not related to religiosity in the Dutch or Swiss sample. Thus, this relation may be considered a false positive, or there is a cultural difference explaining why we observed a curvilinear relationship between the AQ and religiosity in the U.S. but not in the other countries (e.g., due to a floor-effect of religiosity in some countries, the association between mentalizing and religiosity does not become apparent).

Attributing intentionality to random and mechanistic videos significantly contributed to predicting religiosity. Thus, when participants reported to perceive more intentionality in moving geometrical figures in which intentionality was absent, they also more strongly endorsed religious beliefs. Similar findings were obtained by van Elk (van Elk, 2013) and Riekki et al. (Riekki et al., 2014), who observed that paranormal believers attributed more intentionality to random moving geometrical figures than skeptics. The findings that over-attribution of intentionality is predictive of supernatural beliefs is in line with the idea of a hyperactive agency detection (Barrett, 2000) or intentionality 'device' (Lisdorf, 2007). According to these ideas, over-attribution of agency (i.e., seeing intentionality where it is objectively not present) encourages people to belief in supernatural intentionality. Considering that the data are correlational, it could also be the case that people who have been raised religiously and learned to perceive intentionality (e.g., God's will) in coincidental events are more sensitive to perceive intentionality in ambiguous situations.

The videos were added to be able to tap more directly into mentalizing abilities than the self-report measures (EQ, SQ and AQ) used in earlier studies (Lindeman et al., 2015; Norenzayan et al., 2012; Willard & Norenzayan, 2013), but perceiving intentionality in the videos was not related to the questionnaires. For scales that are used for their indirect association with the ability to mentalize, the absence of a relationship with a task that is used to localize mentalizing in the brain seems at least undesirable. On the one hand, these findings may add to comments of other researchers who have questioned the validity of using the EQ as operationalization of mentalizing capacities (Lindeman, Riekki, & Svedholm-Häkkinen, 2015; Muncer & Ling, 2006; Willard & Norenzayan, 2013). On the other hand, these findings may just suggest that operationalizations of somewhat different constructs were used. Whereas the AQ and EQ may tap into the self-reflected mentalizing ability of people, the outcomes on the GFT may be rather a reflection of implicit mentalizing abilities, or the result of deliberate systemizing skills (see the introduction and discussion of Study 4).

With regards to hyper-empathizing, our findings deviate from earlier suggestions of Baron-Cohen et al. (Baron-Cohen et al., 2005) and observations of Lindeman et al. (Lindeman et al., 2015) who suggested that rather than high systemizing or low mentalizing alone, the specific combination of high mentalizing and weak systemizing skills may encourage religiosity. Our findings add to this literature by showing that if anything, the relative contribution of this cognitive bias in the way we operationalized is small when compared to the relative importance of demographical variables like gender and age or cultural learning factors such as CREDs. However, other researchers (Badcock, 2004a; Badcock, 2004b; Crespi & Badcock, 2008) have pointed out that the empathizing/systemizing dichotomy insufficiently captures the two parallel modes of cognition that humans have evolved (i.e., mentalistic cognition and mechanistic cognition). Especially systemizing is criticized for being a too narrow construct, as it is restricted to understanding the behavior of systems, whereas mechanistic cognition incorporates this as well as it basically extends to the entire physical world. Thus, future research should try to better capture these modes of cognition, to investigate its relationship to supernatural beliefs.

Further, the network analysis showed that for the US sample far more items of the AQ were related to religious beliefs than for the first three studies. This indicates that in general, the correlations between religiosity and the AQ items were somewhat higher than in the Netherlands and Switzerland. This suggests that the differences may be the result of cultural differences. One problem of the previous studies in the current paper is that all the operationalizations of mentalizing used have limitations, making it unclear to what extent the construct mentalizing was captured. Therefore, in the final study a group of people with ASD (i.e., a group with mentalizing deficiencies) was compared to a group of people without ASD (see the introduction for a discussion of previous studies on this topic).

Study 5: The Netherlands 3

Similar to Study 1 of Norenzayan et al. (Norenzayan et al., 2012), we investigated whether people with mentalizing problems (i.e., people with an ASD diagnosis) are less inclined to endorse supernatural beliefs. To investigate this, we compared adolescents with an ASD diagnosis to adolescents without such a diagnosis in terms of their religiosity, religious behaviors and CREDs. Religious behaviors (e.g., praying, ritualized behaviors) were also taken into account because we speculated that the way in which people with ASD engage in religiosity might still be high but rather different (i.e., with a focus on ritualized behavior instead of beliefs). For example, Swanson (Swanson, 2010) proposed that children may be able to come to know God via ritual (i.e., behavioural) practices in religion. CREDs were taken into account to rule out that any between group differences in religiosity were the result of stronger religious upbringing. On the basis of the curvilinear relationship observed in the U.S. sample (i.e., Study 4) we predicted that a group of people with ASD would have significantly lower supernatural beliefs than people without an ASD diagnosis. Further, we speculated that if people with ASD would engage in religiosity, then this would be rather reflected primarily in religious behaviors rather than religious beliefs. Finally, we predicted that autistic people would overall attribute less intentionality to videos of the GFT, but that this would be especially evident in the videos in which intentionality was present.

Materials and Methods

Participants. Data were collected from two nearby high schools (2 kilometers in distance) in the center of Rotterdam. One high school (Heer Bokel College) was specialized in educating adolescents with ASD, the other was a regular high school (Wolfert van Borselen) but we recruited adolescents from the same educational level (i.e., HAVO: The Dutch equivalent of the senior general secondary education). We recruited 34 participants at the high school for adolescents with ASD but one did not have an official ASD diagnosis and was dropped from further analyses (for the descriptive statistics of both groups, see Table 1). Specifically, 8 adolescents were diagnosed with classical ASD, 13 with Asperger's syndrome, 15 with pervasive developmental disorder - not otherwise specified, 1 with multiple-complex developmental disorder, 2 with a social communication disorder and of 4 we could not obtain the specific diagnosis. In addition, these disorders were sometimes accompanied by attention deficit hyperactivity disorder (16.2%) or attention deficit disorder (13.2%). We recruited 30 control participants but one participant had an ASD diagnosis and was dropped from further analyses (we did not add this participant to the ASD group as we reasoned that the severeness of ASD may have been weaker considering that the participant went to a general high school). Significantly more males were recruited in the group with ASD (28) than in the control group (17), $\chi^2(1) = 5.34$, $p = .021$, Cramer's $V = 0.29$, which is in accordance with previous literature (Baron-Cohen, 1997; Baron-Cohen et al., 2001), but the groups did not differ in age (range 13 – 18 years, ASD group $M = 14.6$, $SD = 1.4$; NO ASD group = 14.5, $SD = 1.3$), Welch's t (59.8) = 0.27, $p = .787$, $d = 0.07$. Participants received confectionery and fruit for participating in the survey. The adolescents as well as the parents signed informed consent and the Ethical Committee of the University of Amsterdam approved the study. With regard to the 'capacity' of people with ASD to provide consent, it is important to note that all participants were high-functioning individuals on a high educational level.

Measures. We used the same materials as in the earlier studies: the AQ (α = .84), GFT (intentional, random and mechanic videos; reliabilities are not available as not all videos were seen by all participants), religiosity (α = .84) and CREDs (α = .74).

In addition, a self-constructed and unvalidated religious behavior scale was added consisting of 4 items (i.e., *How often do you engage in the following religious activities: praying, meditation, religious ceremonies, ritualized behaviors*) on a 7-point Likert scale (1 = never, 7 = very often). The reliability was accurate, α = .86.

Procedure. Participants had to report their demographical variables and filled in the religiosity questionnaires and the CREDs scale. Subsequently, participants were instructed about the GFT (see Study 4 for a detailed description of this task). They were shown three practice videos; one of each category (i.e., intentional, random and mechanical). In total, we used 24 clips, 8 of each video type (i.e., intentional, random and mechanical motion). Each participant rated only a pseudo-randomized subset of 15 videos (5 from each video type). Finally, participants filled in the AQ.

Data analysis. To investigate whether adolescents with ASD differed from adolescents without ASD on the AQ, religiosity, religious behaviors, CREDs and the GFT videos (i.e., intentional, mechanical and random) we conducted a series of independent samples Welch's *t*-tests and all significance levels were set at .05 (i.e., two-tailed).

Results

As expected, adolescents with ASD diagnoses scored higher on the AQ than adolescents without such a diagnosis, Welch's *t* (60) = 2.89, *p* = .005, *d* = .73 (see Table 7 for *M*'s and *SD*'s). With regards to the religiosity measures, in contrast to our expectations the groups did not differ on religiosity, *t*(59.8) = 0.23, *p* = .819, *d* = 0.06, religious behaviors, *t*(57.2) = 0.21, *p* = .836, *d* = 0.05, or CREDs, *t*(59.5) = 0.96, *p* = .340, *d* = 0.24. With regards to the GFT videos, we found that adolescents with ASD ascribed less intentionality towards random, *t*(59.1) = 2.14, *p* = .036, *d* = 0.55 and mechanical videos, *t*(51.0) = 2.79, *p* = .007, *d* = 0.72, than adolescents without ADS, but no difference was observed for the intentional videos, *t*(56.8) = 1.12, *p* = .266, *d*

= 0.29, while we specifically expected a reduction for people with ASD for this latter category.

Table 7. *Descriptive characteristics of the variables used in Study 5.*

	Group	*N*	*M*	*SD*	*SE*
AQ**	ASD	33	2.24	0.35	0.06
	No ASD	29	2.00	0.31	0.06
Religiosity	ASD	33	2.31	1.75	0.31
	No ASD	29	2.22	1.45	0.27
Religious	ASD	33	1.94	1.25	0.22
Behaviours	No ASD	29	2.01	1.37	0.25
CREDs	ASD	33	2.42	1.42	0.25
	No ASD	29	2.10	1.13	0.21
Intentional	ASD	33	78.53	16.24	2.83
	No ASD	29	73.59	18.10	3.36
Random*	ASD	33	27.40	22.94	3.99
	No ASD	29	39.86	22.77	4.23
Mechanical*	ASD	33	15.53	18.23	3.17
	No ASD	29	31.09	24.71	4.59

Note: ASD = Autism Spectrum Disorder; No ASD = adolescents without Autism Spectrum Disorder; AQ = Autism Quotient; CREDs = Credibility Enhancing Displays Scale; Intentional, Random and Mechanical refer to the Geometrical Figures Task videos.* $p < .05$, ** $p < .005$.

Discussion

In Study 5, we observed that adolescents with ASD did not differ from adolescents without ASD on religiosity, religious behaviors, CREDs or intentional videos, but did differ on random and mechanical videos in the sense that they attributed less intentionality towards these latter videos. Following suggestions of Swanson (2010) we hypothesized that religiosity in autistic people may perhaps be somewhat more oriented towards religious behavior (i.e., in the form of ritualized behaviors), but we found no support for this idea. With regards to the absence of a difference on the religiosity measures, our study deviates from the findings of Caldwell-Harris et al. (2011) and Norenzayan et al. (2012) who did observe differences between people with and without ASD. Our findings were comparable to those of Reddish et al. (2015) who observed only very few differences between the people with and without ASD on seven measures of religious beliefs and behaviors. These findings indicate that at least in the Netherlands, mentalizing deficiencies were not associated with disbelief. Further, we observed that adolescents with ASD attributed less intentionality to mechanical and random videos. This is in line with the idea that people with autism are better in systemizing (Baron-Cohen et al., 2001; Wakabayashi et al., 2006). Interestingly, adolescents with ASD did not seem to have difficulties with attributing intentionality to intentional movements. However, as pointed out in the discussion of Study 4 as well, it is possible that participants with ASD conducted the task using a systematic strategy (i.e., maximizing the contrast in ratings between videos from different categories) . Thus, for future studies, it may be practical to establish what type of intentionality people with ASD perceive in the videos in a more qualitative approach, instead of working with a scale from 1 to 100.

General Discussion

In four large sample studies from three countries and a small sample study involving people with ASD we found mixed evidence for a relationship between mentalizing and religiosity. Importantly, we could not replicate the finding that the AQ was predictive of religiosity in any of the studies. Only when fitting a curvilinear model we observed that high scores on the AQ were related to decreased levels of religious belief, but only in the US sample. In addition, correlations between religiosity and all other variables were higher in the US than in the other samples. Further, we directly compared different measures of mentalizing (i.e., the AQ, EQ, EQ-SQ and GFT) with demographical characteristics (i.e., gender, age and education) and cultural learning variables (i.e., CREDs). We found that mentalizing and hyper-systemizing only made a small contribution to predicting religious beliefs in the US, whereas gender, age and CREDs made robust contributions in the Netherlands and the US. Furthermore, in a Dutch sample we found no differences in terms of the strength of religious beliefs between people with and without strong mentalizing deficiencies. In short, the current studies highlight the importance of culture for determining religious beliefs in two respects. First, when explaining supernatural beliefs, the influence of cultural learning seems more important than individual characteristics such as gender, age and mentalizing. Second, even if mentalizing explains anything about supernatural beliefs, it could be that this is only the case in countries where believing is normative.

Overall, the current findings add to recent work in which authors questioned whether mentalizing was related to religious beliefs (Coleman III, 2016; Jack et al., 2016; Lindeman et al., 2015; Reddish et al., 2015). Although we did find a curvilinear effect, we only observed this for the AQ, not for any other of the operationalizations of mentalizing (i.e., the EQ, GFT or EQ-SQ). One intriguing possibility would be to analyze previously published data (i.e., Caldwell-Harris et al., 2011; Jack et al., 2016; Lindeman et al., 2015; Norenzayan et al., 2012; Reddish et al., 2015) using curvilinear models on the AQ, to see whether it this theoretical suggestion can be replicated in other samples as well. However, the findings that people with ASD did not differ from people without ASD (Reddish et al., 2015) in a US sample makes a strong case against the idea that only strong mentalizing deficiencies are inversely related to supernatural beliefs in countries where religiosity is normative.

In Study 5, we conducted a similar study and we observed that when comparing adolescents with and without ASD, we did not find any difference in terms of the level of religiosity. These findings coincide with anecdotal reports that showed that people with ASD are in fact capable of believing in supernatural agents (Bering, 2002a; Brezis, 2012; Swanson, 2010; Walsh et al., 2008; Wilschut-pennings,

2012) and our findings are in accordance with the findings of other researchers investigating the level of religiosity in people with ASD (Brezis, 2012; Gray et al., 2011; Reddish et al., 2015). Our observations contrast to the findings of two previous investigations involving the religiosity of people with ASD. However, it is important to note that these findings were based on a small sample (*N* = 12 vs. *N* = 13; [16]) or were obtained by comparing forums of websites (Caldwell-Harris et al., 2011), which may not have resulted in representative samples.

Interestingly, our findings on the GFT in Study 4 showed that people with ASD were as capable as people without ASD in attributing intentionality to geometrical figures, but did attribute less intentionality to random and mechanical videos. This is somewhat in line with the findings of Gray et al., (2011) who observed that people with ASD were better able to interact with nonhuman animals and robots than humans. According to the authors reading the intentions of these agents does not require deconstruction of complex social behaviors. A similar suggestion could be made regarding the reading the intentions of supernatural agents; in some cases, these might even be easier to understand (e.g., the 10 commands Mozes received from God), than the intentions of human agents (Gray et al., 2011). Nevertheless, ASD is a very heterogeneous disorder so that generalizations should be made with caution (Deeley, 2009).

Further, we observed in Study 4 that people without ASD who attributed more intentionality towards random and mechanical moving geometrical figures endorsed stronger religious beliefs. We hypothesized that attributing intentionality towards random and mechanical moving figures would require the activation of the ToM-network. If this is the case, these findings are in support of the idea that over-attribution of mentalizing capacities may underlie supernatural beliefs (e.g., 16). Alternatively, the data are in line with the theoretical idea that ontological confusions may underlie supernatural beliefs (Lindeman & Svedholm, 2012; Lindeman et al., 2015). That is to say, people seem to have confused the distinctive attributes of mental, physical, living and animate phenomena (i.e., applying mental states to non-animate phenomena).

At least four limitations of the present studies are worth mentioning. First, our study may exaggerate the distinction between mentalizing skills and CREDs. Specifically, children likely need mentalizing skills in order to understand and represent the beliefs of their parents. Thus, there may be a strong interaction between mentalizing skills and CREDs that we could not capture by means of our regression analyses. Children that reason in a more mechanistic fashion may have a more difficult time to present their beliefs (Badcock, 2009). It is hard to disentangle mentalizing and mechanistic cognition from CREDs as they are an inherent part of the process whereby CREDs are acquired. A possible way of disentangling these concepts better is by means of a longitudinal study in which researchers follow children with more dominant mentalistic or mechanistic cognition and investigate how CREDs interact with these types of cognition. Relatedly, it would be interesting to study children or twins to investigate the heritability component of CREDs. There may be a common genetic factor that underlies both sensitivity to learning and practicing CREDs, which could partly explain the heritability component of religiosity and the observed effect of CREDs on religiosity.

Second, a shortcoming of the studies is that it is unclear to what extent we truly captured the construct mentalizing or other related processes (e.g., empathy, social skills etc.). Future research should focus on better tools to capture individual differences in mentalizing capacities. The effects of mentalizing on religiosity seem minor in the way we operationalized it, but it may still be worthwhile to further explore the effects of mentalizing in future research. For example, schizophrenic hallucinations and delusions are often characterized by magical and religious phenomena. It has been argued that this may be the result of too dominant mentalistic cognition and hyper-mentalizing (Badcock, 2009).

Third, we used different religiosity questions for all of the countries. To keep the questions as consistent as possible we operationalized religiosity by means of the questions that were comparable over the three countries (i.e., the questions related to belief in God, praying and church visit). However, these three questions may not have necessarily been the best ways to address the question of interest: Does an evolved cognitive mechanism for inferring intentionality (i.e., mentalizing) underlie the capacity of inferring the intentionality of supernatural agents? It could be argued that our measures of religiosity encompassed both intrinsic and extrinsic indicators of religiosity, whereas primarily intrinsic measures of religiosity may be related to mentalizing. To address this potential problem, we added network analysis models in all of the studies (except for Study 5 considering the small sample) and incorporated all questions that were related to religious beliefs, so that we could investigate whether some religiosity questions were stronger related to mentalizing than others. Also, we could investigate which AQ items specifically would underlie this relationship. However, only in the US sample some weak correlations were observed between the religiosity items and the AQ and EQ. This again supports the idea that there were cultural differences between the US and the European countries and future studies may address why exactly the relationship between operationalizations of mentalizing and religiosity seems stronger in one country than the other.

Fourth, in this study we compared CREDs with demographical factors and cognitive biases and it could be argued that this comparison between proximal and ultimate factors (e.g., Tinbergen, 1963) in determining religious beliefs actually answers different questions. Proximal factors such as CREDs answer the question why people believe in supernatural agents nowadays. It is obvious that how your parents raised you is a strong determinant of one's personal worldview and religious beliefs (e.g., Geertz & Markússon, 2010; Geertz, 2010). Distal factors (e.g., cognitive biases as often discussed in the cognitive science of religion literature) could explain how supernatural beliefs once came into existence. How is it that at so many places on earth people independently started to believe in supernatural agents (e.g., Bulbulia, 2004)? CREDs can help answer how, once one member of a tribe had supernatural beliefs, these beliefs were able to go ‘viral’ (i.e., quickly spread from one member of a tribe to another). However, CREDs cannot answer how this specific member started believing in supernatural agents for the first time. In that sense, it may be an unfair comparison to compare factors that are important to belief nowadays with factors that are nowadays no longer important but may have originated thousands of years ago. Nevertheless, as outlined in the introduction, the influence of mentalizing is often discussed in the literature (the current paper included) as if it distinguishes believers from non-believers nowadays (Caldwell-Harris et al., 2011; Norenzayan et al., 2012; Willard & Norenzayan, 2013). So ultimately, the current studies show that nowadays there is a strong importance of cultural learning in the form of CREDs, and that variations in mentalizing are unlikely to discriminate believers from non-believers.

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Supplementary material

S1: Explorative analysis 2: Direct replication of (Norenzayan et al., 2012)**.**

To investigate whether our differences with the study of Norenzayan et al. (2012) could be attributed to differences in the analyses, we conducted a similar analysis as reported in the original study (Experiment 3a and 3b). Therefore, a logistic regression was conducted instead of a hierarchical logistic regression. Belief in a personal God was predicted by the AQ and gender, while controlling for age, education, income, EQ and SQ. Similarly as in the study of Norenzayan et al. (2012), visual inspection of the data showed that religiosity was bimodally distributed, Kolmogorov-Smirnov(787) = .09, p < .001. Therefore, religiosity was dichotomized with a median split into low believers (average score lower than 3.71, 61.6%) and high believers (average score of 3.71 or higher, 38.4%). Compared to a constant only model, the first model was statistically significant, indicating that the predictors reliably distinguished between atheists and theists, $\chi^2(7) = 38.31$, p < .001, Nagelkerke R^2 = .08. Gender (Wald = 9.43, B = 0.02, p = .002), age (Wald = 9.69, B = 0.02, p = .002) and income (Wald = 5.01, B < 0.01, p = .025) all made a significant contribution whereas AQ (Wald = 0.65, B = -0.29, p = .422), education (Wald = 0.95, B

= 0.01, p = .329), EQ (Wald = 0.02, B = 0.03, p = .881) and SQ (Wald = 1.03, B = -0.18, p = .311) did not. These results show that neither the type of analysis (i.e., hierarchical logistic regression instead of logistic regression) nor the specific variables included in the model can account for the lack of a relationship between AQ and religiosity.

S2: Items of all questionnaires used in the Network analyses models

The Autistic-Spectrum Quotient (Baron-Cohen et al., 2001)**, French validation** (Sierro et al., 2016)**, Dutch validation** (Hoekstra et al., 2008)

Used in Study 1 – 4

1. I prefer to do things with others rather than on my own.
2. I prefer to do things the same way over and over again.
3. If I try to imagine something, I find it very easy to create a picture in my mind.
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.
5. I often notice small sounds when others do not.
6. I usually notice car number plates or similar strings of information.
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.
8. When I'm reading a story, I can easily imagine what the characters might look like.
9. I am fascinated by dates.
10. In a social group, I can easily keep track of several different people's conversations.
11. I find social situations easy.
12. I tend to notice details that others do not.
13. I would rather go to a library than a party.
14. I find making up stories easy.
15. I find myself drawn more strongly to people than to things.
16. I tend to have very strong interests, which I get upset about if I can't pursue.

17. I enjoy social chit-chat.
18. When I talk, it isn’t always easy for others to get a word in edgeways.
19. I am fascinated by numbers.
20. When I’m reading a story, I find it difficult to work out the characters’ intentions.
21. I don’ t particularly enjoy reading fiction.
22. I find it hard to make new friends.
23. I notice patterns in things all the time.
24. I would rather go to the theatre than a museum.
25. It does not upset me if my daily routine is distubed.
26. I frequently find that I don’t know how to keep a conversation going.
27. I find it easy to “read between the lines” when someone is talking to me.
28. I usually concentrate more on the whole picture, rather than the small details.
29. I am not very good at remembering phone numbers.
30. I don’t usually notice small changes in a situation, or a person’s appearance.

31. I know how to tell if someone listening to me is getting bored.
32. I find it easy to do more than one thing at once.
33. When I talk on the phone, I’m not sure when it’s my turn to speak.
34. I enjoy doing things spontaneously.
35. I am often the last to understand the point of a joke.
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, I can switch back to what I was doing very quickly.
38. I am good at social chit-chat.
39. People often tell me that I keep going on and on about the same thing.
40. When I was young, I used to enjoy playing games involving pretending with other children.
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).

42. I find it difficult to imagine what it would be like to be someone else.
43. I like to plan any activities I participate in carefully.
44. I enjoy social occasions.
45. I find it difficult to work out people's intentions.
46. New situations make me anxious.
47. I enjoy meeting new people.
48. I am a good diplomat.
49. I am not very good at remembering people's date of birth.
50. I find it very easy to play games with children that involve pretending.

Religiosity items derived from Norenzayan et al., 2016

1. I believe in God
2. When I am in troubleI find myself wanting to ask God for help
3. When people pray they are only talking to themselves (Reversed-coded)
4. I don't really spend much time thinking about my religious beliefs (Reversed-coded)
5. I consider myself a spiritual believer (not a religious believer)
6. I often pray
7. I often visit a religious/spiritual institution (e.g. church)

Self-constructed credibility enhancing displays items

Used in the Dutch sample, translated from Dutch (Study 2)

1. To what extent did your parents/caretakers have a religious lifestyle during you upbringing?
2. To what extent did your parents/caretakers visit the church/musk or other religious institution?
3. To what extent was religiosity an affair of the family?
4. To what extent did your parents pray during dinner?
5. To what extent was Sunday seen as a sacred day of rest?
6. To what extent where religious ornaments/decorations part of the interior?
7. To what extent did your parents/caretakers wear religious clothing?

Religiosity items used in the French sample (translated from French)

Used in the Swiss sample (Study 3)

1. How do you define yourself religiously?

   Please choose from: Christian, Jew, Muslim, Buddhist, Hindu, Atheist (not believer), Agnostic (we cannot know), Other

   More than 2 times a month

   1-2 times a month

   Rarely or never

2. How often do you go to practice your religion in your cult place?
3. How often do you address your divinity or pray?

1 = not (important) at all, 7 = very important/ much

4. How important is religion in your daily life?
5. How important is it for you to belong to a religious community?
6. Is it easy to represent yourself God or/and his Will?
7. How much do you feel protected by God?
8. How much do you feel in relation with God?
9. Is religion a moral guide for you?
10. Do you believe in a form of spiritual existence after death?
11. How much does religion help you to know yourself better?
12. To what extent do you think your actions can be judged by a superior entity and there can be consequences for your life or afterlife?
13. To what extent is it important to you to generally practice your religiosity.

Credibility enhancing displays scale (Lanman & Buhrmester, 2017)

Used in the US sample (Study 4)

1. To what extent did your caregiver(s) attend religious services or meetings?
2. To what extent did your caregiver(s) engage in religious volunteer or charity work?

3. Overall, to what extent did your caregiver(s) act as good religious role models?
4. To what extent did your caregiver(s) make personal sacrificies to religion?
5. To what extent did your caregiver(s) act fairly to others because their religion taught them so?
6. To what extent did your caregiver(s) live a religiously ‘pure’ life?
7. To what extent did your caregiver(s) avoid harming others because their religion taught them so?

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Chapter 7

DISCUSSION & CONCLUSION

Cultures from all around the globe seem to have started believing in the supernatural independently from each other (Sterelny, 2017). According to many scholars from the Cognitive Science of Religion (CSR) this indicates that either supernatural beliefs are adaptive, or that humans possess certain cognitive factors that make them predisposed to become supernatural believers (Pyysiäinen & Hauser, 2010; Sosis, 2009). In this thesis we focused on the cognitive by-product account and zoomed in on two cognitive factors (i.e., the hyperactive agency detection device or HADD and mentalizing; Chapters 2, 3, 4 and 6) and one socializing factor (i.e., credibility enhancing displays, or CREDs; Chapter 6) that have frequently been marked as being important facilitators of supernatural beliefs. We further validated a tool to manipulate supernatural beliefs in a laboratory setting (i.e., placebo brain stimulation; Chapters 4 and 5). When discussing the outcomes of these studies, we make a distinction between distal factors (i.e., why did people ever start to believe in the supernatural?) and proximate factors (i.e., why do people believe in the supernatural nowadays?; Tinbergen, 1963). In the literature on supernatural beliefs, this distinction is often absent (Andersen, 2017a; Willard & Cingl, 2017). The distinction is important, however, because supernatural beliefs in the distant past and nowadays might be caused by different processes. Specifically, processes such as cognitive biases could help explain why people started to believe in the first place, why supernatural beliefs are so widespread and what type of supernatural beliefs arose; in contrast, processes such as CREDs can help explain how beliefs are transferred from one generation to the other in current cultures.

Throughout most of our experiments, we did not observe a relation between cognitive biases and supernatural beliefs. There are two exceptions. In one experiment agency detection was related to supernatural beliefs (i.e., Chapter 4, Pilot Study), and in another mentalizing abilities were related to supernatural beliefs (i.e., Chapter 6, Study 4). This suggests that cognitive biases do not seem useful in distinguishing supernatural believers from people who do not believe in the supernatural nowadays (i.e., in a proximate setting). On the other hand, a proximate social learning factor (i.e., CREDs) was a strong and robust predictor of supernatural beliefs (Chapter 6), in line with recent work of others (Gervais & Najle, 2015; Lanman

& Buhrmester, 2017). Thus, in contrast to distal cognitive factors, a proximate social learning factor was predictive of supernatural beliefs.

Ultimately, the question that now needs to be addressed is whether the investigated cognitive biases are no longer important for acquiring supernatural beliefs, or whether they have never played a causal role in inducing religious beliefs in the first place. To address this question, we will first globally discuss the findings on distal factors (i.e., agency detection, mentalizing), then we will discuss the findings on proximate factors (i.e., CREDs, placebo brain stimulation) and we will try to bring these together by using the more over-arching theoretical framework of predictive processing (see Chapters 3, 5 and A1).

Agency detection as distal factor

In Geertz' and Markússons' (2010) biocultural theory of supernatural beliefs, cognitive biases such as the HADD and mentalizing are probabilistic encouragers of supernatural beliefs: they make it more likely that people become supernatural believers. According to them, when a group of young children strands on a deserted island, it is more likely that they become supernatural believers than that they do not: "The island's untouched, natural environment is filled with opaque causal processes, animal life, and such that are likely to stimulate various cognitive mechanisms, such as the ones that overextend animacy and agency." (Geertz & Markússon, p. 156). Thus, they take for granted that cognitive biases could still encourage supernatural beliefs in proximate settings, if people encountered an untouched natural environment. In today's societies, however, the urgency to detect agency may be greatly reduced, because the environment is almost entirely man-made (Barrett, 2004). In addition, due to the high degree of education, naturalistic explanatory frameworks are readily available (Barrett, 2004). The underlying assumption is that cognitive biases would still be encouragers of supernatural beliefs in the right settings. Thus, following the logic of these scholars, if we wanted to investigate the importance of cognitive biases for supernatural beliefs, it would be necessary to investigate people in settings that have been relatively unaffected by modern society. Considering that we have focused on 'WEIRD' participants (i.e., people who were Western, Educated, Industrialized, Rich and Democratic, Henrich, Heine, & Norenzayan, 2010;

Norenzayan, 2016), a fair criticism might be to say that we might have been unable to directly test their predictions.

However, efforts have been made by others to focus on people that have been relatively uninfluenced by modern society. For example, researchers have tried investigating the relationship between intuitive thoughts about death and supernatural beliefs of tribes in rural Madagascar (Astuti & Harris, 2008; Harris, 2011b). They observed repeatedly that young children (under seven) intuitively thought that people's minds and bodies cease after death, whereas this was not the case for older children. Older children started using a supernatural narrative: people's minds can start a new beginning after death. Thus, these findings are much more in favour of the idea of a social learning account of supernatural beliefs, like how we observed that spirituality predicted extraordinary experiences in Chapter 5 and CREDs predicted supernatural beliefs in Chapter 6, than to the idea of intuitive cognitive biases. This poses another problem though, if you go back long enough in the past, somebody should have acquired supernatural beliefs without social learning (Guthrie, 2017, we will address this issue below). Nevertheless, similar experimental-anthropological studies should be conducted to investigate the claims that agency detection and mentalizing abilities encourage supernatural beliefs. As long as such claims are not empirically tested, the influence of cognitive biases on supernatural beliefs remains a 'just-so' story: an unverified narrative explanation.

What Barrett (e.g., 2011), Geertz (e.g., Geertz, 2010) and many others in the field (e.g., Atran, 2004; Boyer, 2003; Norenzayan, 2016) do not seem to dispute is whether we have cognitive biases such as agency detection and mentalizing in the first place. The findings in this dissertation revealed that CSR scholars ought to be more critical of these assumptions and future research efforts should be invested in testing the ideas that other frequently mentioned supposed biases such as teleological reasoning and dualism[31] come natural (i.e., without much cultural scaffolding). In Chapters 2 and 4, we could not find compelling evidence for the existence of a general agency detection bias (i.e., overall people did not make more

[31] Paul Harris and colleagues have observed repeatedly that dualistic reasoning as well as afterlife beliefs are also likely to be the result of social learning (Harris & Giménez, 2005, Harris, 2011a, Harris, 2011b, Harris & Corriveau, 2014).

false alarm responses in a variety of agency detection tasks). Of course, we note that the manipulations to affect agency detection in these Chapters may have been inadequate. In Chapter 2, threat levels were moderate and threat was manipulated too independently from the agency detection paradigm, while in real-life situations, the stimuli are inherently interpreted as being threatening themselves. For example, hearing a breaking branch in a dark forest is inherently threatening and therefore it may be interpreted as an agent. In Chapter 4, the extraordinary experiences did not affect the agency detection paradigm, because placebo brain stimulation elicited extraordinary experiences that inherently rely on internal processes, whereas the agency detection paradigm requires people to focus on external processes. Thus, those studies might have been inadequate to provide information on the relationship between threat and supernatural experiences on the one hand, and agency detection on the other hand.

Nevertheless, participants did not show an overall bias for perceiving agency. If anything, participants seemed hypoactive of perceiving agency: they more often reported absence than presence of agency. It could be argued that all agency detection paradigms we used reflected inadequate operationalizations of agency detection as they all involved deliberate forced decisions about computerized stimuli (we made a similar argument in Chapter A1). Still, it is difficult to see how a 'hyperactive' cognitive bias specifically evolved for quickly inferring the presence of agency in biological motion (Atran, 2004) and noises (Barrett, 2012) would not be activated by such paradigms. Although the human brain evolved relatively quickly (Gilbert, Dobyns, & Lahn, 2005), our brains are unlikely to be substantially different from the brains a few thousand years ago. So, if the agency detection bias exists at all, it does not seem 'hyperactive' or 'hypersensitive'. This relates to recent suggestions of Guthrie (2017), who proposed that agency detection is not 'hyperactive', but 'just about right'. Thus, as already proposed in Chapter 2, we should stop naming it a HADD. The term 'agency detection capacities' seems more appropriate.

In Chapter 3, we tried to move away from the deliberate forced decision agency detection paradigms to a relatively more ecologically valid virtual reality forest environment. In this case, participants could make subjective decisions about ambiguous audio-visual or auditory stimuli. Under those circumstances, people frequently reported the presence of agents, although it was especially ambiguity that triggered agency detection, not so much threat. It is nevertheless questionable to what extent this series of experiments truly reflects an agency detection 'bias'. First, a subsequent task (i.e., the White Christmas Task) revealed that participants' agency reports were influenced by demand characteristics. Relatedly, participants were likely to be primed by the instructions, which explicitly told them to press the button when they perceived a 'person, animal or creature' and to follow their gut feeling. So, while some agency experiences were probably somewhat comparable to real-life agency experiences, others may have been caused by participants doing what they thought was the purpose of the study (i.e., response-expectancy effects). Also taking into account that participants did not press the button after each stimulus, it is too preliminary to conclude from this line of experiments that people have an agency detection 'bias'. Overall, our findings are inconsistent with the view that people have an evolved hyperactive agency detection bias.

Predictive processing as proximate factor

We also discussed an alternative theoretical framework to explain agency detection occurrences – namely the theory of predictive processing (Andersen, 2017a; Andersen, Pfeiffer, Müller, & Schjoedt, 2017; Van Leeuwen & van Elk, 2017, Chapters 4 and A1). The general idea of predictive processing is that the way we perceive and make judgements about the environment results from a combination of top-down prior predictions, bottom-up sensory processing and model-updating prediction errors (Friston, 2005; Friston & Kiebel, 2009, see for more extensive explanations Chapters 4, 6 and A1). Predictive processing cannot only explain why we interpret a falling branch as a bird, but also why we can sometimes mistake a bird for a branch (Andersen, 2017a), so it has more explanatory power than HADD theorizing. In case of the virtual reality studies in Chapter 4, participants were instructed to report when they felt the presence of persons, animals or creatures. In combination with the forest environment, participants likely had high priors for interpreting the auditory and audio-visual stimuli as being caused by 'threatening agents in forests' in the threatening environment, and by 'agents in forests' in the non-threatening environment. Furthermore, due to the ambiguity of the stimuli and the environments, participants had to rely more on top-down predictions than on bottom-up processing. In accordance with this framework, participants reported predominantly forest agents such as birds and foxes, and more threatening forest agents such as wolves in the threatening forest.

Whereas the predictive processing framework provides explanations for several of our observations, these same observations pose difficulties for HADD-like theorizing. First, we observed that the frequency of agency reports was stronger linked to ambiguity than to threat (Chapter 3). In line with predictive processing, ambiguous situations require people to rely more on their priors and since these were strong, this resulted in more frequent agency detection. HADD theorizing predicts also more frequent instances under threatening conditions as it increases the sensitivity of the agency detection module, while predictive processing predicts that a threatening condition would mostly affect the type of agents that people report. We observed the latter; participants reported more threatening types of agents such as wolves in threatening conditions. Second, we observed that over time, the number of agency reports declined (follow-up from Chapter 3). Predictive processing can account for this observation by means of the feedback provided by prediction errors over the course of the experiment. Likely, participants started noticing that there were in fact no agents present in the forests, which made them less liberal in reporting agents as the experiment unfolded. HADD theorizing cannot explain well why an evolved module for agency detection would become less hyperactive over time in a constant environment. Third, we observed no agency detection bias in the agency detection paradigms of Chapters 2 and 4 (i.e., the Biological Motion Task and the Auditory Agency Detection Task). In contrast to predictive processing, HADD theorizing cannot explain this absence of an overall bias. In terms of predictive processing, participants simply had no strong prior predictions favouring agents, as we showed participants different types of stimuli in the instruction phase. This means that participants had to rely on bottom-up processing to determine whether an agent was present or not. As both tasks were difficult and ambiguous, this resulted in more instances where participants did not perceive agents.

Using the predictive processing framework not only provides a more parsimonious explanation for our findings, it can also be used to explain research findings that have previously been used to support the HADD framework. For example, 'pareidolia', the psychological phenomenon that a face can be detected in random stimuli (Rieth, Lee, Lui, Tian, & Huber, 2011), has been interpreted in terms of an agency detection bias (e.g., van Elk, 2013, Chapter 2). However, it has also been shown that perceiving a face depends on people's prior expectations (Liu et al., 2014). When people were led to believe that faces were embedded in 50% of random noise trials, while in fact faces were never present, people report faces in 34% of the trials. Another article used to support HADD theorizing is a retrospective correlational study, in which researchers found that extraordinary supernatural experiences such as ghost appearances often occurred in ambiguous and threatening situations (Barnes & Gibson, 2013). This was explained in terms of the hypersensitivity of agency detection, but the forest examples show how such instances can be more parsimoniously explained by means of predictive processing.

Some criticism of our adaption of the predictive coding framework to explain agency detection instances is in place. First, we did not purposefully design experiments to disentangle HADD theorizing from predictive coding. In future studies, it would be interesting to investigate whether the forest stimuli are also interpreted as agents if people are given a non-agentic narrative. For example, participant may be told that a snowstorm recently hit the forest and that the snow is now slowly melting. With a predictive coding framework, we would expect people to interpret the stimuli as melting snow, whereas the agency detection bias narrative would still predict agentic interpretations of the stimuli. Second, predictive processing has a large number of degrees of freedom (top-down predictions, bottom-up sensory processing and error monitoring), making it possible to provide post-hoc explanations for a wide range of observations. This makes it all the more important that the specific expectations are pre-registered (like in Andersen et al., 2017, Chapters 3 and 5). As Chapter 5 showed (i.e., the study on the influence of alcohol on placebo brain stimulation), it is then still possible that certain predictions made on basis of the predictive processing fail. Third, the predictive processing framework is mostly supported by relatively low-level decision-making research

(Clark, 2013; Friston & Kiebel, 2009) and scholars that apply the model to higher order cognition such as supernatural beliefs, do that mostly at a high theoretical level (e.g., Andersen, 2017a; Schjoedt & Andersen, 2017; Taves & Asprem, 2017; van Elk & Aleman, 2016; van Elk & Wagenmakers, 2017; Van Leeuwen & van Elk, 2017). Thus, it still needs to be established whether predictive processing can be applied to higher order cognitions such as the interpretation of agents - studies that combine low level and higher order features do show the possible integration between low-level visual processing and higher-level expectations (e.g., Pajani, Kok, Kouider, & de Lange, 2015; van Pelt et al., 2016). Finally, as HADD theorizing is much coarser than predictive processing, it could be argued that HADD theorizing can be integrated within the predictive processing framework (Chapter A1). For example, priors could have evolved for interpreting phenomena as agents (Asprem, 2017; Granqvist & Nkara, 2017; Guthrie, 2017, and Chapter A1). What speaks for this idea is the observation that young children are more afraid of evolutionary relevant wild animals than of urban threats such as passing cars (Maurer, 1965). However, in a response to our commentary (i.e., Chapter A1), Andersen (2017b) rightfully observed that there may well be specific evolved priors (in line with predictive processing), but that there is currently no evidence that supports a general agency detection bias. Our studies are in line with that conclusion.

To sum up, we could not firmly establish that people have an agency detection bias, agency detection is not generally increased by threat and most importantly, agency detection was consistently unrelated to supernatural beliefs. In line with these observations, there has been a gradual shift towards a more critical view of the supposed relationship between agency detection on supernatural beliefs (Andersen, 2017b; McKay, 2017; Sterelny, 2017; Van Leeuwen & van Elk, 2017; Willard, 2017) and articles from our research team (Chapters 2-4, van Elk, Rutjens, van der Pligt, & van Harreveld, 2014) have significantly contributed to this shift. Finally, we (Chapter 3) and others (Andersen, 2017a; Andersen et al., 2017; Van Leeuwen & van Elk, 2017) proposed that agency detection occurrences can be more parsimoniously explained by means of predictive coding.

Mentalizing as distal factor

We concluded for agency detection that there is no relationship with supernatural beliefs and that it is even unwarranted to speak of an agency detection 'bias'. For mentalizing, however, it may be more reasonable to speak of a bias. In both Chapter 2 and 6 we observed that people more often than not attributed intentions and beliefs towards non-mental geometrical figures. They attributed intentionality when the figures moved as if they had intentions, but also when they moved randomly and even sometimes when they moved mechanically. Thereby, we replicated and extended a robust finding that dates back to the fifties of the previous century (Heider & Simmel, 1944) and has been observed frequently ever since (e.g., Bartneck, Kulić, Croft, & Zoghbi, 2009; Blakemore et al., 2003; Gobbini, Koralek, Bryan, Montgomery, & Haxby, 2007). These findings are in line with suggestions of Lisdorf (2007), who was early to note that we more likely have a hyperactive *intentionality* detection device than a HADD[32]. Similarly, Nieuwboer and colleagues (2014) pointed out that previous CSR literature had erroneously focused on agency detection instead of intentionality detection.

Now the question is, do our findings provide support for the idea that a mentalizing bias encourages supernatural beliefs? The findings regarding the relationship between mentalizing and supernatural beliefs were inconsistent. In Chapter 2, we did not observe a relationship between intentionality ratings on the Geometrical Figures Task and supernatural beliefs, but relatively few supernatural believers were included in that study. In Chapter 6, we did observe a relationship with the same procedure ((thereby replicating Riekki, Lindeman, & Raij, 2014). Further in Chapter 6, we did not find a relationship between mentalizing abilities as operationalized with the Empathy Quotient and supernatural beliefs in the Netherlands and Switzerland, but we did observe a weak relationship in the United States, which has also been observed by others (Abeyta & Routledge, 2018; Lindeman, Svedholm-Häkkinen, & Lipsanen, 2015; Norenzayan, Gervais, & Trzesniewski, 2012; Willard & Norenzayan, 2013; Willard & Cingl, 2017).

[32] He wrote this in a theoretical article with the clever-found title: "What's HIDD'n in the HADD?'.

Importantly, the weak relationships between empathizing and supernatural beliefs that have been frequently observed are by no means proof that mentalizing abilities encourage (proximate) supernatural beliefs, in contrast to what CSR researchers have suggested (e.g., Norenzayan et al., 2012; Willard & Norenzayan, 2013). It still remains unclear to what extent this self-report questionnaire truly reflects mentalizing abilities (Muncer & Ling, 2006). In addition, researchers observed that the relationship between the Empathy Quotient and supernatural beliefs disappeared when they controlled for moral concern (Jack, Friedman, Boyatzis, & Taylor, 2016). Furthermore, they found other mentalizing measures to be unrelated to supernatural beliefs. Other researchers noticed in a large sample study (*N* = 2984) that believers as well as non-believers can be categorized by diverse cognitive profiles (Lindeman & Lipsanen, 2016). There was even more variation found within, than between believers. For example, people who believed in the supernatural scored somewhat higher on empathizing, but there were subgroups of non-believers scoring high on empathizing and subgroups of believers scoring low on empathizing. Also, if mentalizing abilities are indeed important for encouraging supernatural beliefs, it remains a conundrum that we (Chapter 6) and others (Reddish, Tok, & Kundt, 2015) did not observe an inverse relationship between people with reduced mentalizing abilities and supernatural beliefs. In short, to say that mentalizing encourages, predisposes or makes people vulnerable to supernatural beliefs seems to diverge from a variety of observations.

An alternative explanation for the weak relationship between mentalizing and supernatural beliefs may be in conflict with what some CSR scholars previously suggested (e.g., Norenzayan et al., 2012; Willard & Norenzayan, 2013). It could be that when people have socially learned to interpret non-mental phenomena as being caused by supernatural agents (e.g., by CREDs), this ‘broadens’ people’s mentalizing abilities (Andersen, 2017a; Andersen et al., 2017; Ma-Kellams, 2015; Van Leeuwen & van Elk, 2017 and Chapter 6). That would explain why supernatural believers sometimes interpret more intentionality to non-mental phenomena such as geometrical figures (Chapter 6). The reversed causation can also be applied to the weak relationship between scores on the empathy quotient and supernatural beliefs we observed in the United States (Chapter 6). People in the United States generally score higher on supernatural beliefs (e.g., Chapter 6). If they want to come across as devoted believers, it would be in their interest to self-report as being more empathic. Finally, scholars have argued (Norenzayan et al., 2012) that the frequently observed gender difference on supernatural beliefs (i.e., women typically believe more strongly in religion, e.g., Chapter 6) could be explained by the fact that women have stronger mentalizing abilities (e.g., Lindeman & Lipsanen, 2016). However, it has also been observed that mothers generally talk more to their daughters than to their sons (Johnson, Caskey, Tucker, & Voher, 2014) and that parents in general talk more to their daughters in emotional terms (Fivush, 2014), both likely facilitating mentalizing abilities. Importantly, however, the reversed causal relationship is still partially in line with some other CSR scholars, who proposed that mentalizing and supernatural beliefs are mutually reinforcing (e.g., Barrett & Lanman, 2008).

So, while we are skeptical of the view that a mentalizing bias encourages supernatural beliefs in a proximate setting, we do agree that a mentalizing bias provides an elegant explanation for the observation that supernatural intentional agents and forces are so widespread among cultures (Willard, 2017). Somewhat comparable, Guthrie (1980) proposed with his anthropomorphisation account of religion, that people's tendency to anthropomorphise (i.e., ascribing humanness to non-human phenomena) could explain why people started to believe in supernatural agents. On the one hand, we think the observed mentalizing bias could explain why people so easily anthropomorphise. Similar as Guthrie, we think that because humans are of such central importance in our lives, it makes sense that a default model to explain a range of phenomena is to do this from a human perspective. In terms of a predictive processing framework, the priors to explain phenomena with human-like intentions are generally high. This is why intentional interpretations are generally wide-spread, also outside the supernatural domain. We all find ourselves ascribing human-like intentions to our animals and to non-mental phenomena (e.g., 'Stupid computer'!). On the other hand, there is a big gap between attributing mental states to non-mental phenomena (e.g., the thundercloud is angry), and believing that it is a supernatural being (i.e., Wodan/Thor/Indra). This is known as the 'Mickey Mouse' or 'Zeus' problem (Gervais & Henrich, 2010). We ascribe intentions towards Mickey Mouse, but we do not believe it truly exists or impacts our lives. People also no longer believe in Zeus, but they do believe in other gods. In sum, we agree with CSR scholars that a mentalizing bias is part of the explanation of the wide presence of supernatural agents (Willard, 2017) and that this bias may have encouraged which type of elements (i.e., intentional agents and forces) became dominant in supernatural beliefs in a distal setting. This is substantially different from the suggestion that mentalizing abilities are antecedents or encouragers of supernatural beliefs in contemporary societies. Likely, mentalizing, social learning (see below) and a whole bunch of other factors work together in a complex interplay to create supernatural beliefs, but mentalizing is not strictly necessary nor sufficient for supernatural beliefs.

Credibility enhancing displays and placebo brain stimulation as proximate factors

Credibility enhancing displays. Whereas the distal cognitive biases were not predictive of supernatural beliefs in contemporary societies, a proximate social learning factor in the form of CREDs was strongly and robustly related to supernatural beliefs (Chapter 6). This relationship has now been observed in several studies (Gervais & Najle, 2015; Lanman & Buhrmester, 2017; Willard & Cingl, 2017). A fair point of criticism to our studies is that the evidence is based on retrospective correlational questionnaire research, but at least the retrospective part does not apply to the study of Gervais & Najle (2015). Furthermore, in essence, CREDs can be seen as a specific instance of Bandura's Social Learning Theory (Bandura & Walters, 1963; Bandura, 1971) applied to supernatural beliefs and his theory has been supported in a wide range of experimental settings (for reviews see Pratt et al., 2010; Reed et al., 2010). In short, we are confident that CREDs and other forms of social learning such as peer religiosity and type of education (e.g., Gunnoe & Moore, 2002; Myers, 1996) are important for acquiring supernatural beliefs in a proximate setting. Nevertheless, for the specific importance of CREDs relative to other social learning factors, a longitudinal study would be helpful. Lastly, CREDs also fit within in the predictive processing framework. CREDs are simply one way of acquiring models through interaction with the social environment.

Placebo brain stimulation. The placebo brain stimulation studies aimed at eliciting extraordinary experiences in the lab can be considered as an example of how prior expectations shape supernatural beliefs and experiences (Chapters 4 and 5). As discussed in these chapters and elsewhere (Andersen, Schjoedt, Nielbo, & Sørensen, 2014), we are confident that this type of manipulation is capable of eliciting authentic extraordinary experiences that are not substantially different from extraordinary experiences outside the lab (e.g., people experiencing the holy spirit) and that hinge on similar processes (e.g., boosting expectations, decreasing sensory input). However, only a minority of the participants is vulnerable to the expectancy manipulation and report these experiences. We think it could be worthwhile to investigate whether the manipulation could be made more effective for a broader sample. We tried this with alcohol to reduce cognitive control and failed (Chapter 5), but we note that the testing conditions were suboptimal. It would still be interesting to see whether the manipulation could be made more effective in a more controlled lab environment. Other conscious altering substances might also be helpful to induce extraordinary experiences. Especially nitrous oxide might be a relatively non-invasive short-lasting substance, which could be combined well with the framing of the God helmet manipulation.

Interestingly, also in the real world only a minority of people seem to be 'vulnerable' to having extraordinary experiences. In that sense, it might be more fruitful to deepen our understanding of the type of individual differences or personality traits that are predictive of such experiences. We already observed that both the tendency to get absorbed (Chapter 4) and considering oneself to be spiritual (Chapter 5) were predictive of extraordinary experiences. However, it is important to further establish whether such individual difference measures are truly causal antecedents of extraordinary experiences. A problem that we frequently encountered in studies aimed at investigating the causal antecedents, is that there was conceptual overlap between the scales to measure cognitive biases on the one hand, and supernatural and paranormal beliefs and experiences on the other hand. For example, schizotypic personality traits are frequently mentioned as being 'predictive' of supernatural beliefs (e.g., Lindeman & Lipsanen, 2016; van der Tempel & Alcock, 2015), as if they are causal antecedents of supernatural beliefs. Inspection of the questionnaires that are used often learns that the schizotypic items (e.g., 'Have you ever had the sense that some person or force is around you, even though you cannot see anyone?') could also be used to measure paranormal beliefs and experiences (e.g., van der Tempel & Alcock, 2015). Similarly, spiritual beliefs and extraordinary experiences likely relate to each other. Therefore, much more than spiritual beliefs, we do think that absorption has the potential to be causally related to extraordinary experiences. The explanatory potential of the personality trait of absorption lies not only in the fact that it has been repeatedly related to extraordinary experiences (Granqvist et al., 2005; Van Elk, 2014, Chapter 4), but because it makes theoretical sense. People scoring high on absorption get more immersed into the suggestions, their bodily sensations, their internal mental imagery or a combination thereof. It could well be that people scoring high on absorption generally overweigh their priors. Researchers could test this outside the domain of extraordinary experiences and supernatural beliefs. To further solve the problem of conceptual overlap between the different constructs, researchers could adopt a network analysis approach, as we did in Chapter 6. By doing so, it can become evident that items from different questionnaires relate to the same construct and causality could be inferred by looking specifically at the partial correlation network.

Apart from investigating which type of people are prone to having extraordinary experiences, it would also be interesting to investigate what type of individual difference measures are related to being resistant to these types of manipulations. This information might be helpful to help people build a resistance to such manipulations. Building resistance can have important implications for today's societies. People spend billions on extraordinary claims and placebos that have been proven to be ineffective (e.g., alternative medicine, spiritual healing etc.). By means of the predictive processing framework, people could be trained to focus on whether a context seems to be designed to increase prior expectations or reduce error monitoring. Why does this ritual need to occur in a dark setting? Are they trying to boost my expectations of the situation? Does this person make logical sense or am I distracted by charismatic characteristics?

To sum up, we showed that authentic extraordinary experiences can be elicited in a lab setting. We discussed that these experiences can be explained by means of the predictive coding framework. We further briefly pointed out that the placebo brain stimulation experiences are not markedly different from extraordinary experiences elicited in the real world (will elaborate on this further below). Taken these things together, our studies have contributed to validating a tool for investigating extraordinary experiences. Finally, we discussed interesting lines for future research. Specifically, investigating how the manipulation could be made more effective, what personal variables are antecedents of extraordinary experiences and how people can be made resistant to the manipulation.

Implications

Now, let’s turn to some implications of our studies. A widely supported view in the CSR on supernatural beliefs before the beginning of this thesis, portrayed by Barrett & Lanman, 2008, is graphically represented in Figure 1. Consider the case that there was a to be explained phenomenon, such as a breaking branch. It was thought that this triggered an evolved agency detection module, so that people instantly inferred that an agent caused the sound (i.e., system 1), especially in ambiguous and threatening situations, which increased the hypersensitivity of the module. Subsequently, people attributed intentions to the agent through their mentalizing abilities, e.g., that the agent is a dangerous bear (i.e., system 2). How people interpreted the agent was also dependent on social discourse. Together with social discourse, the mechanisms made people predisposed to infer that agency detection instances were caused by supernatural agents, such as deceased ancestors. Such interpretations influenced social discourse on its turn. Above, we elaborated on how some of our findings were inconsistent with the model.

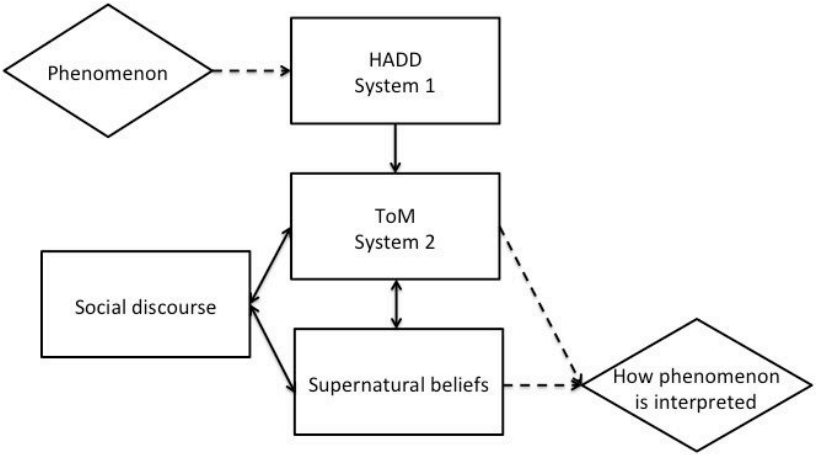

Figure 1. Graphical representation of the view portrayed by Barrett & Lanman, 2008
It was thought that certain phenomena (e.g., a breaking branch) triggered the HADD (there is an agent), after which the theory of mind (ToM) system attributed intentions to the phenomena (e.g., the agent is dangerous). This mechanism was thought to predispose supernatural beliefs. Social discourse was thought to have a reciprocal relationship with the theory of mind system and supernatural beliefs.

In Figure 2, a graphical situation is depicted of how we can look at a similar example as above, but based on the predictive processing framework. This model more precisely specifies how different factors determine how the sound of the breaking branch is interpreted. A first factor is the observer, who acquired models of how the world works due to a combination of genes and interaction with the social environment. As we learned from the CREDs theory, supernatural beliefs can be more or less successfully transmitted from the social environment to the observer. A second factor is the context, as this will influence whether the observer relies mostly on top-down predictions or on bottom-up processing. Is the context well-known or new, is it ambiguous or clear? If the context is a well-known and clear forest to an observer, it is possible that the observer interprets the noise of a breaking branch as a bear but unlikely that it results in the interpretation of a deceased ancestor, even if this person is a strong supernatural believer. If, however, the context is new and very dark, or if the person just walked away from a ritualistic setting, it could well be that the same sound results in the interpretation of a supernatural agent. As should become evident is that the predictive processing explanation has more explanatory power than the HADD explanation. It can not only explain how a noise can be interpreted as a bear but also how a bear could potentially be interpreted as a breaking branch, for example, if the observer is in a territory where bears are uncommon.

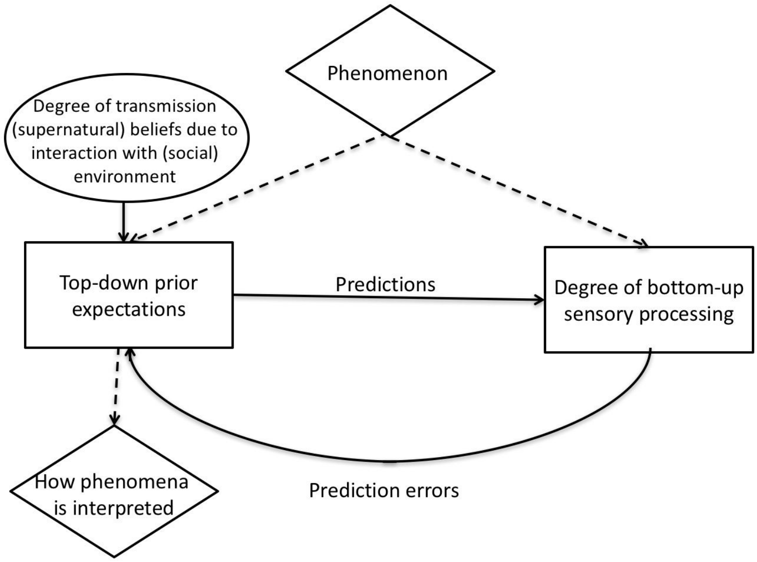

Figure 2. Graphical representation of the interpretation of phenomena following the predictive processing framework and outcomes of the present dissertation.
How a certain phenomenon is interpreted depends on predictions of top-down prior expectations, which were on its turn acquired through the observer's life-long interaction with the (social) environment. These predictions are compared to sensory input and the resulting difference, the prediction error, is used to update the model (i.e., the top-down expectations) of the observer. In ambiguous sitations, the degree of bottom-up sensory processing is lower, so that prediction errors have diminished influence on the interpretation of the phenomenon.

This framework can also be applied to more contemporary examples of extraordinary interpretations. Recently in India, a statue of Jesus was found that appeared to be crying as there was water dripping from the statue[33]. The local people were devoted Christians, so they had strong supernatural priors. This likely resulted in top-down expectations relating to the supernatural to explain the bottom-up sensory input. Additionally, people's mentalizing bias likely also contributed to an intentional interpretation. As priors for intentions might be generally high, and the statue was a human-being, it makes sense that water was interpreted as coming from a 'crying' Jesus. Later, a skeptic of supernaturalism came by to see what was going on. He inspected the statue and the surrounding more thoroughly. Thus, he was more focused on bottom up sensory information for his interpretation of the situation. He noticed that the tears were a result of bad plumbing and that kissing the hands of the statue actually posed a health threat to the citizens. Unfortunately for him, the leaders were blinded by their beliefs and accused the man of blasphemy.

Interestingly, many supernaturally oriented contexts almost appear designed to decrease bottom-up sensory input (Andersen et al., 2017). Over the course of thousands of years, cultures shaped these contexts to become successful for generating extraordinary experiences. Such culturally shaped ideas or concepts are called 'memes' – the cultural version of genes (Blackmore, 1999; Dawkins, 2016). For example, it is probably not a coincidence that religious institutions such as churches, mosques and synagogues have special resonance are all relatively dark. Similarly, environments aimed at eliciting ghost appearances (e.g., haunted houses), and séances where deceased people are called upon are dark. Likewise, ritualistic sessions often occur at night and for prayer and meditation, people have to close their eyes (Andersen et al., 2014). Apart from decreasing bottom-up sensory input, supernaturalistic contexts frequently have characteristics that decrease prediction errors. For example, it has been shown that listening to charismatic leaders (Schjoedt, Stodkilde-Jorgensen, Geertz, Lund, & Roepstorff, 2011) or participating in extreme rituals (Fischer et al., 2014; Xygalatas et al., 2013) can decrease executive cognitive functioning and predictions errors (Schjoedt et al., 2013). Combining these factors explains why the God Helmet can be so effective. The manipulation fosters

[33] https://www.theguardian.com/world/2012/nov/23/india-blasphemy-jesus-tears

increasing one's priors and decreasing prediction errors by means of people with an authority in science (i.e., neuroscientists), while participants are also sensory deprived, both visually (i.e., blindfolded) and auditory (i.e., listening to white noise). Summing up, predictive processing can more parsimoniously explain than by-product theories how people can have agency and extraordinary experiences.

Unsolved pieces & future directions

We discussed the predictive processing framework, according to which priors can be acquired through interaction with a social environment. Due to the importance of our social environment, we think it is plausible that priors are generally high for interpreting phenomena in an intentional fashion. On basis of this framework we could explain the outcomes in our studies, how beliefs can be transferred from one generation to another and how a range of supposed extraordinary experiences in real-life can be understood. We also argued that proximate social learning explanations cannot account well for the distal emergence of supernatural beliefs in the past. So, if supernatural beliefs are due to social learning, then why did the first person ever start to believe and how did beliefs arise independently at different parts of the world (Guthrie, 2017)? The elegance of the by-product theory was that cognitive biases could potentially pose an answer to this central yet unresolved question.

When asking this question, it is important to think back about the introduction, where we zoomed in on the role of cognitive biases in supernatural beliefs. We acknowledge that there are many other theories that may provide more plausible explanations for the emergence of supernatural beliefs than the cognitive biases account, but they fell outside the scope of this dissertation. With regard to the cognitive biases, we zoomed in on only three of them (i.e., agency detection, mentalizing and to a much lesser extent anthropomorphisation), although we did investigate the ones that were marked as being most important (e.g., Norenzayan & Gervais, 2013). Although speculative, we think that for other frequently mentioned biases such as teleological reasoning (i.e., reasoning as if things have a purpose) and dualism (i.e., thinking that mental states are not caused by physical states), similar problems may emerge as for the biases we investigated. They may be able to account for the wide-spread elements in supernatural beliefs such as believing in a purpose or afterlife beliefs, but they will not be useful for explaining why people believe nowadays. For future research, it is important to acknowledge that this problem is not solved by using questionnaires and relating these to supernatural beliefs, considering that there is often conceptual overlap between the different scales that are used to. Recently, for example, a questionnaire study was conducted where researchers concluded that dualism is important for supernatural beliefs (Willard & Cingl, 2017), while on the other hand several researchers have shown that supernatural beliefs have a strong influence on dualistic thinking (Harris & Giménez, 2005; Harris, 2011a; Harris, 2011b; Harris & Corriveau, 2014). Thus, it remains a challenge to disambiguate the bidirectional relation between supernatural beliefs and cognitive biases that has been established to some extent in the existing literature. Apart from the network approach we suggested above, another possibility would be to use longitudinal or cross-sectional approaches to see how certain biases relate to supernatural beliefs over time. It would also be interesting to look into the interactions between social learning and cognitive biases. Are stories that rely on certain biases more readily transmitted for instance?

Lastly, we will address some future directions we believe could be fruitful for furthering our understanding of the emergence of distal supernatural beliefs. First, we learned that credibility enhancing displays, a form of rituals, increase the chance that beliefs are adopted. Further, we know that apart from believing in supernatural agents, ritualistic behaviours are a recurring element in most supernatural beliefs. It has even been argued that rituals gave rise to supernatural beliefs (Sterelny, 2017). Interestingly in that sense is a study in which it was found that people used rituals as a means of coping mechanism (Lang, Krátký, Shaver, Jerotijević, & Xygalatas, 2015). The possibility could be explored that people started with rituals, for example as a means of compensatory control against terror management (e.g., Greenberg, Solomon, & Pyszczynski, 1997), and that the rituals were later interpreted in agentic terms when they seemed effective. Rituals are also often used to make beliefs more credible, think for example about the actions of magicians. This would bring together cognitive biases approaches, motivational theories of religion and the study of rituals, and the answer likely lies in the dynamic interplay between these multiple factors. Second, we need to better understand how we move from an interpretation to a belief. As soon as the belief is there, cultural transmission can explain how the belief can quickly spread. Placebo brain stimulation can be a very useful tool to induce specific beliefs, and the narrative with which participants are provided can be used to study the down-stream consequences of beliefs on brain functioning and behaviour. For example, does belief in neuro-enchancement (i.e., people's widespread trust in the power of brain stimulation devices) make them more likely to attribute positive outcomes to the brain stimulation – akin to the processes involved in magical thinking and spirit possession?). Third, it has often been noted that considering the complexity and variety of supernatural beliefs, it would be good to investigate specific elements and try to explain these rather than focusing on religion as a unified construct (e.g., Boyer, 1994). Adding to that idea, it might be good to focus on elements that are restricted to the supernatural domain. Much investigated elements, such as reading intentions, detecting agents and rituals, occur as frequently outside as inside the domain of supernatural beliefs, so causal antecedents of these elements are less likely to have strong explanatory power when it comes to religion. Finally, we should also look at how supernatural beliefs are formed that are relatively new, such as scientology and sects. What factors can explain how those arose? Frequently, strong narratives and charismatic leaders are involved, potentially suggesting a central role for reduced error monitoring contributing to belief formation – in line with the predictive processing framework (Schjoedt et al., 2011).

Conclusion

The findings in this empirical quest on the socio-cognitive roots of supernatural beliefs do not support the view that has been dominant over the last two decades in the CSR. This dominant view holds that people become supernatural believers due to cognitive biases such as agency detection and mentalizing abilities. Our research revealed that important assumptions about the universality of agency detection biases did not hold in empirical tests and that predictive processing provides a more parsimonious explanation for agency detection occurrences. Thereby, we highlighted the necessity of investigating other supposed cognitive biases and their relationship with supernatural beliefs. We further helped understanding that at least nowadays, socially acquired priors make the supernatural realm credible. On its turn, this could make people more likely to explain ambiguous phenomena in an intentional fashion. Other researchers have reached similar conclusions (Andersen, 2017b; Sterelny, 2017), and some even asked for revisions of the popular by-product framework (Gervais & Najle, 2015). We partially agree. Cognitive biases should no longer be considered the main factor predisposing supernatural beliefs, but the by-product framework might still be useful to explain why certain aspects of supernatural beliefs are so widespread. Belief in supernatural intentional agents and forces is a key element in many supernatural beliefs (Pyysiainen, 2009) and mentalizing abilities likely enable us to conceive of these agents in the first place. If anything, the studies in this dissertation showed that supernatural beliefs are a complex phenomenon that are not easily explained away. Only the spaghetti monster knows the definite answer to these questions.

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POSTFACE

Exciting times in science

Past years have been turbulent for science, and psychological science in particular. The fraud case of Diederik Stapel (Tilburg University, 2011), who was able to publish dozens of confabulated research articles, asked for some serious introspection of the academic field. On the one hand, it opened up a can of worms. Studies could not be replicated (i.e., better known as the 'replication crises'), because researchers engaged in so-called 'questionable research practices'. Often unbeknown to most researchers themselves, they used statistical analysis techniques or methodologies that increased the chances of finding a statistically significant effect. In addition, there was a strong incentive to publish articles as this strengthens your career chances. As a result, the scientific literature is full of meaningless 'significant' effects that could not be reproduced, while 'non-significant' effects ended up in the file-drawer. On the other hand, the increased awareness of the state of science was the starting point of a new era. Open science (making research articles and data publically available) thrived, pre-registration websites and journals saw the light and large scale many lab replication projects were initiated. In these exciting times, I started my PhD-project on investigating the foundations of supernatural beliefs.

Idealistic as I can be, I wanted to be part of a new generation of scientists. No more *p*-hacking (i.e., torturing data until they gave a statistically significant result), but open and transparent research practices only! As I often experience when I have simple idealistic ideas, reality turns out to be a bit more complex. So, the least I can do, is to be as transparent about it. I will start with opening my own file drawer. Two entire studies that were conducted during the PhD project have not been written up and I have some more failed experiments of Chapter 2 (i.e., we thought six null-results was enough to make our point). One file drawer study consisted of a series of experiments conducted at both the psychic fair and the Christmas fair. Our goal was to investigate whether supernatural believers would see more agency and intentionality in threatening pictures than in non-threatening pictures of animals and natural scenes (e.g., a rainbow). In three different experiments, the effects were inconsistent and it was impossible to find a 'red thread' throughout these experiments. In addition, I doubted whether the psychic fair visitors had actually understood the task properly. The lesson that we learned: pilot thoroughly, then pre-register. The other study, which we did pre-register, consisted of two online surveys in which we asked supernatural believers to pray (an explicit prime of supernatural beliefs) or say a nursery rhyme (in the control condition). Following this manipulation we gave people the option to donate some of the money they got for filling out the survey. It has often been suggested that supernatural believers are more 'generous' and that especially priming them with religiosity should reveal this (see for a meta-analysis, Shariff, Willard, Andersen, & Norenzayan, 2016). Yet, we did not find this in over 200 participants (although that is still considered to be a relatively small sample for a between-subjects design chasing a small effect size). We did not try to publish this (yet) for time reasons and because other researchers were doing something similar and better (e.g., Michael McCollough has tested over 800 participants and did not find an effect of religious priming on prosocial behavior).

Now that my file-drawer is out in the open, I will turn to the more grey area. But before that, I note that doing good ethical research is extremely difficult. It is unbelievable how much things you have to be an expert in to do it the right way. You have to be extremely conscientious, you have to be a master in statistics, you have to be a programmer, you have to be a good reader and writer in another language than your mother tongue, you have to be able to design and operationalize research questions and you have to be very patient. Especially this last skill is lacking from my research repertoire, so imagine how much fun it was for me to publish my master thesis which took me six(!) years (Now you also know you why I placed it in the appendix). Thus, so much time and effort was put in that master thesis that it became like a financial institution. It became 'too big too fail'. The data was collected in 2010 – well before the start of the replication crisis. We looked at the data a couple of times before stopping with testing, we checked the outliers and tried different statistical analyses. Also during my PhD project there were instances in which I would act differently in hindsight. In the first data-set that we collected (i.e., described in Chapter 4), we included a wide variety of questionnaires without having a sound theory. Also, the introduction of this chapter was written only after the results were known. I also regret that I have not yet placed my data on the Open Science Framework (working on it though!).

There are also parts to be proud of. I pre-registered three out of five studies, I was so eager to do the statistics right that the Stats Store became a second home and I acquired decent programming skills. In addition, as a PhD representative I promoted open science to my fellow PhD candidates (i.e., at the PSAIKO), in the dissertation committee of the Association for Social Psychological Research (i.e., ASPO) as well as in the Scientific Advisory Board (i.e., WAR). Given my four-years of experience with trying to increase my research skills, I think I am now in the position to provide some tips. First, we should reduce 'HARKing' (i.e., hypothesizing after the results are known) and increase providing constructive feedback before the study has started. Giving critique after the data has collected can be helpful (e.g., the whole peer-review system builds on this assumption), but it is even more helpful when there is constructive feedback before the data is collected (e.g., through the use of preregistered publication reports) – there is no substitute for good data. Thus, lab groups, colloquia and maybe even conferences should shift their focus from talking about research outcomes to talking about research ideas. In pursuing this ideal, some journals have brought forward the review process to the stage of the design of the study (e.g., Comprehensive Results in Social Psychology). Second, when the critique on the design of a study by your peers has been as adequately handled as possible, do a pilot and thoroughly analyze the data. Do all the analyses you think are worthwhile and discuss these with statisticians (e.g., go to the Stats Store, discuss with statistician colleagues or place them on Stackoverflow). Third, pre-register the hypothesis and analysis plan on the OSF. The first objection I often hear is that 'it takes so much time'. I will tell you what actually takes a lot of time; making dozens of data analytical choices after you collected the data and trying to come up with a red thread (case in point, Chapter 4). The second concern I often hear is that 'it reduces researcher creativity'. There is no reason to be afraid for this, as you can still do all analyses you forgot to pre-register, as long as you just place them in a separate section, called exploratory results. I believe that these three small steps can move science a giant leap forward.

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Appendix 1

EVOLVED PRIORS FOR AGENT DETECTION

Commentary to Marc Andersen's 'Predictive coding in agency detection'

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We compliment Andersen on an outstanding theoretical article integrating agency detection experiences within the framework of predictive coding. We pursued a similar pathway in our work as we believe the idea is generally spot on and adequately outlines the trajectory the cognitive science of religion should follow (van Leeuwen & van Elk, submitted; van Elk & Aleman, 2016; van Elk & Wagenmakers, 2017; van Elk & Zwaan, 2017; Maij & van Elk, in preparation; Maij, van Schie, & van Elk, submitted). Nevertheless, Andersen's theoretical idea can be further elaborated in at least two respects.

First, the predictive coding framework proposed by Andersen places a strong emphasis on prior expectations formed by interaction with the environment (e.g., instruction, cultural transmission, learning and reliance on source credibility). At the same time, we should acknowledge the possibility of 'evolved priors' that were selected for through a process of natural selection (Friston, Thornton, & Clark, 2012). The literature on preparedness for learning shows that organisms are prepared to learn readily about phenomena that were relevant in an evolutionary past (for reviews, see Mallan, Lipp, & Cochrane, 2013; Öhman, 2009; Öhman & Mineka, 2001; Seligman, 1971). For example, it is easier to condition people to fear of animals, thunder, heights and social events than to condition fear responses to modern threats such as cars or handguns (Öhman, 2009). Such biases are hard to explain without assuming evolved priors that predispose humans for learning specific associations. In addition, without assuming evolved priors, the 'dark room problem' lures - a philosophical argument proposed against the predictive coding framework. This argument entails that an energy- and prediction error-minimizing biological agent situated in a dark room, would be unmotivated to move, as moving out of the room would increase surprise (Friston et al., 2012; Klein, 2016). Evolved priors solve this problem, by defining what states are considered 'surprising'. When a prior model expects a light environment, the agent will immediately try to leave the room (Friston et al., 2012).

Applying the idea of evolved prior models to agency detection means that as a result of evolutionary pressures, specific innate models have evolved that are dedicated towards detecting predator and prey. For example, babies quickly associate snakes with fear (DeLoache & LoBue, 2009) and look longer to pictures of spiders than to reconfigured and distorted images of these spiders (Rakison & Derringer, 2008). Five and six year old children in cities are afraid of monsters with claws, while they are initially unafraid of urban threats (Maurer, 1965; Boyer & Bergstrom, 2011). Adults in general have a bias towards detecting threatening animal agents, as evidenced for instance by an attentional bias to prioritize emotionally threatening stimuli (Brosch & Sharma, 2005; Flykt, 2004; Lipp, 2006; Lipp, Lipp, Derakshan, Waters & Logies, 2004). In short, these findings are what we should expect if there were to be an evolved bias (Barret, H. C., 2005), or 'prior model' as we now like to call it, for detecting agents that were behaviorally relevant in an evolutionary past. Importantly, the notion of an evolved prior model for detecting agents is in line with the HADD proposal that many other scholars have proposed (Barrett, J., 2000; Barrett, H.C., 2005; Boyer & Bergstrom, 2011; Öhman, & Mineka, 2001;), although they did not frame the notion of an evolved cognitive module in terms of predictive coding. Hence, the evolutionary psychological theories that Andersen refutes, may be more compatible with predictive coding than currently assumed. In sum, we propose that Andersen's proposal should be extended by acknowledging the possibility that evolved constraints (especially in the domain of fear and agency) exist on the potential space that priors could take.

Of course, Andersen rightly points out that several experimental paradigms have not yielded convincing evidence for a universal bias towards detecting agents, as evidenced for instance by studies on binocular rivalry (Denison, Piazza & Silver, 2011) and the face / house categorization task (van Elk, Rutjens, Pligt, & Harreveld, 2016). However, we would like to point out that the dependent measures in these studies may have been ill-suited to capture an eventual bias for agent detection, as they primarily involved the deliberate decision of whether an agent stimulus was consciously perceived. Evolved biases for agent detection might well exert behavioral effects without producing any direct accompanying reflective beliefs (McKay, & Efferson, 2010) - akin to the output of the intuitions generated by System 1 (Risen, 2016). The examples discussed above also illustrate that agent-like stimuli readily trigger adaptive behavioral responses (e.g., fear conditioning) and in many cases, we respond to potentially threatening stimuli instantaneously without deliberate perceptual decision making.

To further establish the presence (or absence) of evolved agent detection biases, we need good behavioral proxies that are more ecologically valid than the computer-based tasks. Therefore, we commend Andersen's proposal to use virtual reality techniques to test their model, and we propose to infuse such studies with relevant physiological or behavioral measures indicative of (implicit) agent detection (e.g., skin conductance, approach / avoidance measures etc.). When adopting this method in a series of virtual reality experiments that we are currently conducting, we already observed that participants often detect agents when they are objectively not present (Maij & van Elk, in preparation). This was especially the case in threatening environments, when the detection of agents is evolutionary seen highly advantageous.

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Appendix 2

COGNITIVE CONTROL IN YOUNG ADULTS WITH CANNABIS USE DISORDER:

An event related brain potential study

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Abstract

Contemporary models of substance use disorders emphasize the role of cognitive control, which has been linked to difficulties resisting the use of substances. In the present study, we measured two aspects of cognitive control, response inhibition (operationalized by a Go/NoGo Task) and performance monitoring (operationalized by an Eriksen Flanker Task), in a group of young cannabis-use disorder (CUD) patients and compared these functions with two control groups (i.e., a group of cigarette smokers and a group of non-smokers). We employed both behavioral and electrophysiological measures. The results indicate that CUD patients displayed reduced NoGo-P3 event related potentials compared to non-smoking controls, but not compared to smoking controls. In addition, CUD patients were slower on Go trials than both control groups. No other between-group electrophysiological or behavioral differences were observed. These results seem to suggest that CUD patients have problems related to response inhibition but performance monitoring seems relatively unaffected.

Cannabis (i.e., 9delta-tetrahydrocannabinol, a partial agonist at the cannabinoid receptor) is the most frequently used illicit drug among young adults in the Western world (Vicente, Olszewski, & Matias, 2008). This is problematic since adolescence is an important period for the continued development of cognitive functions like cognitive control (e.g., Luna, Marek, Larsen, Tervo-Clemmens, & Chahal; Gogtay et al., 2004; Sowell, Trauner, Gamst, & Jernigan, 2002; Tapert et al., 2007). The term 'cognitive control' refers to the higher order mental abilities by which people the flexible use of limited cognitive resources for goal directed behavior is optimized (Mansouri, Tanaka, & Buckley, 2009). Although cognitive control is a broad concept, we presently focus on two aspects of cognitive control in cannabis use disorder (CUD) patients that have repeatedly been emphasized in models explaining substance use disorders (SUDs; DSM-IV: “A maladaptive pattern of substance use with clinically significant impairment or distress.”), namely response inhibition and performance monitoring (e.g., Luna et al., 2015; Garavan & Weierstall, 2012; Luijten, Machielsen, Veltman, Hester, de Haan and Franken, 2014).

Response inhibition has been defined as the ability to withhold a prepared response upon the appearance of new information (Nigg et al., 2006). The significance of impaired response inhibition is stressed in a number of contemporary models of SUDs; e.g., Feil, Sheppard, Fitzgerald, Yücel, Lubman, & Bradshaw, 2010; Goldstein & Volkow, 2002; Ivanov, Schulz, London, & Newcorn, 2008; Verdejo-Garcia, Lawrence & Clark, 2008). These models suggest that impaired response inhibition is associated with difficulties resisting the use of a substance. For example, CUD patients may find it more difficult to decline a joint (i.e., a marijuana cigarette) when offered. This assumed relation between impaired response inhibition and substance abuse in humans has been well documented in imaging studies (see for a review Dom, Sabbe, Hulstijn, & Van den Brink, 2005). Furthermore, other studies investigated the direct and long-term effects of substance abuse on response inhibition (see for a review Verdejo-Garcia et al., 2008). Response inhibition in substance users is usually assessed using behavioral inhibition tasks such as the Go/NoGo Task (see for a review, Luijten et al., 2014), during which participants have to inhibit well-rehearsed prepotent responses (i.e., always responding at Go trials but inhibiting response at NoGo trials). Impaired behavioral response inhibition has been found in nicotine (e.g., Luijten, Littel, & Franken, 2011a), alcohol (e.g., Rubio et al., 2008), cocaine (e.g., Fillmore & Rush, 2002), heroin (e.g., Fu et al., 2008), and ecstasy (Roberts & Garavan, 2010) patients. Although cannabis use has been associated with several cognitive problems (Solowij et al., 2002), response inhibition of cannabis users has been studied before in only one study. In that study, response inhibition of chronic cannabis users was investigated during a Go/NoGo Task, while their blood-oxygen-level-dependent (BOLD) response was measured (Hester, Nestor, & Garavan, 2009). No behavioral response inhibition deficits were observed, however an increased activity was evident in the right inferior parietal lobe, putamen and middle cingulate gyrus (Hester et al., 2009). this increase in activation was explained as a compensatory processes.

With regard to the electrophysiological correlates of response inhibition in general, most studies using the Go/NoGo Task focus on two components of event-related potentials (ERPs; Falkenstein, Hoormann, & Hohnsbein, 1999). The first component is the NoGo-N2, which is a negative wave seen approximately 200-400 ms after the NoGo stimulus with a maximum peak at frontal (Fz) and frontocentral cites (FCz; Bekker, Kenemans, & Verbaten, 2005). A source analysis of the NoGo-N2 indicated that the neural generator is situated in medial frontal regions, presumably the anterior cingulate cortex (ACC; Bekker et al., 2005). It was originally thought that the N2 reflects a modality specific non-motor inhibition process (Falkenstein et al., 1999), but the evidence is accumulating that the N2 represents a more general process, such as conflict monitoring (Bekker, 2004; Burle et al., 2004; Enriquez-Geppert, Konrad, Pantev, & Huster, 2010; Nieuwenhuis, Yeung, Van den Wildenberg, & Ridderinkhof, 2003). The second component is the NoGo-P3, which is a positive wave following the NoGo-N2. It is seen approximately 300-500 ms after stimulus onset and has a maximum peak at frontocentral sites (FCz; e.g., Simson, Vaughan & Ritter, 1977; Schupp, Lutzenberger, Rau & Birmbaumer, 1994). The NoGo-P3 has been suggested to reflect inhibition (e.g., Bekker, Kenemans, & Verbaten, 2004; Enriquez-Geppert et al., 2010; Fallgatter and Strik, 1999; Tekok-Kilic et al., 2001), although it has also been argued to be the result of conflict between different responses (e.g., Bekker et al., 2005; Smith, Smith, Provost, & Heathcote, 2010). With regard to the inhibition interpretation of the P3, this component is thought to represent a later stage of the inhibition process that is closely related to the actual inhibition of the motor system in the premotor cortex (Garavan, Ross, & Stein, 1999; Enriquez-Geppert et al., 2010). Deficits in the NoGo-N2 and NoGo-P3 have been found in other substance abuse groups such as smokers (Luijten et al., 2011a), alcoholics (Kamarajan et al., 2003) and ecstasy users (Gamma, Brandeis, Brandeis, & Vollenweider, 2005), but no studies among cannabis users are known.

Performance (or error-) monitoring is another aspect of the cognitive control system that is hypothesized to be affected in substance use populations. Performance monitoring is the process that allows humans to regulate their behavior by means of self-evaluation of errors (Ullsperger & Von Cramon, 2001). Performance monitoring can be operationalized by a variety of tasks in which participants are likely to make errors. Contemporary models of addictive behaviors suggest that SUD patients are often insensitive to future negative consequences (e.g., Garavan & Stout, 2005; Lubman, Yücel, & Pantelis, 2004). For example, CUD adolescents may be insensitive to the aversive consequences their high may have on homework. This insensitivity is reflected in the poorer performance monitoring of SUD patients compared to controls (e.g., Franken, Van Strien, Franzek, & Van de Wetering, 2006; Hester et al., 2009; Schoenbaum & Setlow, 2005). Therefore, it has been hypothesized that reduced performance monitoring underlies prolonged substance abuse in face of its adverse consequences (Forman et al., 2004; Hester, Simoes-Franklin, & Garavan, 2007).

With regard to the electrophysiological correlates of performance monitoring in general, most studies have focused on error related negativity (ERN; Falkenstein, Hohnsbein, Hoormann, & Blanke, 1990). The ERN is a negative ERP component measured approximately 0-150 ms after an error in performance. There is increasing evidence that the ACC plays an important role in performance monitoring (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004) and may be the neural generator of the ERN (Dehaene et al., 1994; Van Veen & Carter, 2002). This ERN is usually followed by a positive ERP (Pe) component, although there is some debate about the meaning of this component (Overbeek, Nieuwenhuis, & Ridderinkhof, 2005). The Pe component has been found to be reduced on unconscious errors compared to consciously perceived errors (Endrass, Franke, & Kathmann, 2005). Therefore, it has been related to error awareness, conscious error processing and the updating of the error context (Ventouras, Asvestas, Karanasiou, & Matsopoulos, 2011). Overall, SUDs have been associated with reductions in performance monitoring (Ruchsow et al. 2005). Reduced ERN's were found in people with SUDs compared to healthy controls in studies assessing nicotine (Luijten & Franken, 2010; Franken, Van Strien, & Kuijpers, 2010), cocaine (Franken, Van Strien, Franzek, & Van de Wetering, 2007), opioids (Forman et al., 2004) and cannabis (Hester et al., 2009), see Luijten et al. (2014) for a systematic review. However, two studies show an increased ERN in people with alcohol use disorder (Padilla et al., 2011; Schellekens et al., 2010). Schellekens et al. (2010) suggested that an increased ERN observed in SUDs might be associated with internalizing psychopathology, which is typically associated with an increased ERN (Hajcak et al. 2010). The only study in which performance monitoring was investigated in cannabis users (not CUD patients), showed no aberrations of the ERN (Fridberg, et al. 2013). Thus, more research is needed to investigate how performance monitoring is affected in CUD patients. Since it is known that almost all CUD patients either smoke tobacco or mix tobacco with the cannabis in their cigarettes (joints), and it is known that cigarette smokers have problems with cognitive control (Luijten et al., 2010), we adequately controlled for the use of tobacco by including a group of smokers as well as a group of non-smokers as control group.

In the present study, several hypotheses regarding response inhibition and performance monitoring in CUD patients were investigated by means of a Go/NoGo Task and an Eriksen flanker Task respectively, to ease comparison with previous studies. With regard to response inhibition, we expected to find an increased percentage of errors and longer RTs for CUD patients compared to cigarette smoking as well as non-smoking controls on infrequent Go trials, which would reflect inhibition problems. On an electrophysiological level, we expected to find reduced response inhibition in CUD patients compared to controls as reflected by reduced NoGo-N2 and -P3 components. With regard to performance monitoring, we expected that CUD patients would show reduced performance monitoring compared to controls as reflected by 1) an increased percentage of errors, 2) deviant post-error accuracy and/or reaction time (RT) response patterns as have been found in cocaine use disorder patients (Franken et al., 2007), and 3) reduced ERN and Pe ERP components on the Eriksen Flanker Task. To the best of our knowledge, this is the first study that investigated response inhibition and performance monitoring simultaneously in CUD patients while adequately controlling for the use of cigarette smoking.

Methods and Materials

Participants

We included 37 CUD patients at two locations of a large urban addiction treatment service in Rotterdam, the Netherlands (Antes). Inclusion criteria were 1) age between 18 and 25 years, 2) presence of the DSM-IV diagnosis for CUD, clinically assessed by a physician of the treatment service, and 3) the ability to speak, read, and write in Dutch at an eighth-grade literacy level. The amount of time that the CUD patients had been abstinent varied from two to six weeks. The treatment service screened their patients routinely on drug use and patients were excluded from the study if they were positive on these tests. We acknowledge that we cannot completely rule out any influence of the direct effects of cannabis on cognitive control, but the chance that we included intoxicated patients is low.

As indicated above, the CUD patient group was compared to two control groups. The first was a non-smoking control group (*N* = 41); a healthy non-smoking and non-substance using group. The second was a smoking control group (*N* = 38), since it has been shown that impaired cognitive control is associated with the use of tobacco (e.g., Luijten, et al., 2011a; Luijten, Van Meel, & Franken, 2011b; Luijten et al., 2014). Cigarette smokers smoked on average 11.1 (*SD* = 5.5) cigarettes per day. Both control groups were recruited via an advertisement on social media and snowballing method. Table 1 shows the demographic and substance use variables of all groups.

Participants with a substance-related DSM-IV use disorder other than nicotine or cannabis were excluded. Participants with a history of head trauma or severe current psychiatric symptoms were excluded from participation. We did not exclude participants with ADHD/ADD or depression as this would lead to a non-representative sample. In both the CUD and the cigarette smoking control group there were four participants with ADHD/ADD. No other comorbidities were observed. In Figure 1 a participant flow chart is provided to make clear how many participants from each group were included in each step of the analyses. Participants were excluded if they scored below chance level (i.e., fewer than 50% trials correct) on either of the tasks. Further, participants were removed if they had too noisy data. On the Go/NoGo Task, participants with fewer than 20 trials were excluded. On the Eriksen Flanker Task, participants with fewer than 5 trials were excluded. One-hundred-and-sixteen participants met the inclusion criteria. The questionnaires of two participants were missing and the behavioral data on both the Go/NoGo Task as well as the Eriksen Flanker Task were missing for one participant. On the Go/NoGo Task, two participants scored below chance level (fewer than 50% correct trials), data of these participants were not analyzed. With regard to the EEG data, on the Go/NoGo Task four participants had too noisy data (fewer than 20 trials) and the data of one participant could not be retrieved due to hardware failure. On the Eriksen Flanker Task, one participant performed below chance level (less than 50% correct trials), data of these participants were not analyzed. With regard to the EEG data, on the Eriksen Flanker Task two participants had too noisy data (fewer than 5 trials) and the data of one participant could not be retrieved due to hardware failure. Participants were paid 15 euros for participating in the experiment. Testing took place according to a standardized protocol in the Erasmus Behavioral Lab of the Erasmus University Rotterdam. The Ethics Committee of the Erasmus University Medical Centre approved the study and all procedures were conducted in accordance with the understanding and written informed consent of the participants.

	Cannabis Dependent Patients N = 37	Cigarette Smoking Controls N = 38	Non-Smoking Controls N = 41	Total Participants N = 116
Questionnaire Data	37	38	39	114
Behavioural GoNoGo#	36	37	40	113
Behavioural Flanker#	36	37	41	114
EEG Data GoNoGo Task*N2/P3	35	35	39	109
EEG Data Flanker Task*ERN/Pe	35	38	39	112

Figure 1. Valid Number of Participants for each Part of the Study.

Note: # Indicates missing scores or more than 50% errors. *Indicates missing, too noisy or too few trials.

Questionnaires

Barratt Impulsivity Scale 11 (BIS-11). The BIS-11 is a 30-item self-report measure of impulsivity developed by Barratt (1959) and last revised by Patton, Stanford and Barratt (1995), the general reliability was adequate, Cronbach's alpha (α) = .73. The test yields three second-order factors with weak to moderate reliabilities: attentional (8 items), α = .62, motor (11 items), α = .57, and non-planning impulsiveness (11 items), α = .57.

DSM-IV Substance Use Disorder Checklist. Cannabis patients were screened for CUDs according to the DSM-IV criteria, based on clinical interviews of clinicians of Antes Rotterdam.

The Alcohol Use Disorders Identification Test (AUDIT). The AUDIT (34 items) is a valid and reliable alcohol screening tool (Allen et al., 1997) and was used to screen for alcohol consumption and related risks in both patients and controls, the reliability was adequate, α= .83.

The Fragerström Test of Nicotine Dependence (FTND). The FTND (Heatherton, Kozlowski, Frecker, & Fagerström, 1991) is a six item screening tool for tobacco use disorders and was used to screen tobacco use disorders in both patients and controls, the reliability was adequate = .73.

Task Paradigm

Go/NoGo Task. A Go/NoGo blocked design (i.e., blocks of trials intermitted by pauses) Task was developed to measure response inhibition. Each of the four blocks consisted of 150 trials (i.e., 600 trials in total) and in between blocks a one-minute pause was presented. Participants were required to suppress a well-rehearsed, prepotent motor response (i.e., Go) in favor of an alternative less frequent response (i.e., NoGo). Stimuli (i.e., vowel letters) were presented fast (700 ms; (e.g., Littel, Berg, Luijten, Rooij, Keemink, & Franken, 2012) and NoGo trials infrequent (25%). Participants were instructed to press on the rightmost button of a response box with their index finger *each* time any vowel letter (i.e., *A, I, E, O, U*) was shown, but to withhold their response when the exact same letter was shown two times in a row (e.g., A, A or E, E). Letters were presented semi-randomly because a pilot-study indicated that it confused participants if the same letter was shown three times in a row (e.g., E, E, E), but each letter was presented approximately the same number of times per participant. Before each stimulus, a fixation cross (+) was shown for 300 ms. Participants were stressed to respond as quickly and accurately as possible. The task was programmed with E-Prime 2.0 (Psychology Software Tools).

Eriksen Flanker Task. A modified Eriksen Flanker Task (Eriksen & Eriksen, 1974) from the study by Franken et al. (2007) was used to measure performance monitoring. Participants were randomly shown four different letter strings (*SSHSS, SSSSS, HHSHH, HHHHH*), which were all presented 100 times and divided into five different blocks. They were instructed to press the rightmost button of the response box with their right index finger if the central letter was an *H* and the leftmost button of the response box with their left index finger if the central letter was an *S*; the buttons had an *H* or *S* written next to them. Before each stimulus was presented, a fixation cross appeared for 150 ms. Then the letter string was presented for 50 ms. After a response had been made within a black screen response window with a maximum time of 1000 ms, a feedback display showed the correctness of the response (+ or -) for 500 ms. If no response was detected within the response time window, a feedback display informed the participant that the answer was not fast enough ("*Too Late!* [in Dutch]"). Response times from stimulus onset to button press on congruent (*SSSSS, HHHHH; n* = 200) and incongruent trials (*SSHSS, HHSHH; n* =

200) were recorded. Participants were stressed to respond as quickly and accurately as possible. The task was programmed with E-Prime 2.0 (Psychology Software Tools).

Electroencephalographic Recording and Signal Processing

The EEG was recorded with a Biosemi Active-Two amplifier system from 32 scalp sites (10–20 system) and two additional sites (FCz and CPz) with Ag/AgCl electrodes (active electrodes) mounted on an elastic cap. Furthermore, six additional electrodes were attached to left and right mastoids, two outer canthi of both eyes (horizontal electrooculogram [HEOG]), and infraorbital and supraorbital regions of the eye (vertical electrooculogram [VEOG]). All signals were digitized with a sampling rate of 512 Hz and 24- bit A/D conversion with a bandpass of 0–134 Hz. Data were further processed off-line with Brain Vision Analyzer (Brainproducts, Munich). Data were referenced off-line to computer-linked recordings from the mastoids. Off-line, EEG and EOG activity was filtered with a bandpass of 0.10-30 Hz for the Go/NoGo Task and 0.15–30 Hz for the Eriksen Flanker Task (both with phase shift-free Butterworth filters; 24 dB/octave slope). Data were segmented into epochs of 1 s (-200 ms to +800 ms with respect to response in the Go/NoGo Task). After ocular correction (Gratton et al., 1983), epochs including an EEG signal exceeding ± 75 µV were excluded from the average. The mean of the period -200 ms to 0 ms with respect to the response served as a baseline for both tasks. All ERPs were studied at a cluster of frontocentral electrodes; Fz, FCz and Cz.

Concerning the Go/NoGo Task, after baseline correction, average ERP waves were calculated for artifact-free trials at each scalp site for correct and incorrect responses separately. Segments with incorrect responses (miss for GO trials or false alarm for NoGo trials) were excluded from the EEG analyzes. The N2 was defined as the mean value of the 200–300 ms time interval after stimulus onset. The P3 was defined as the mean value of the 300–500 ms time interval after stimulus onset. Participants had to have at least 20 analyzable trials. The mean number of analyzable Go segments was 355 and the mean number of analyzable NoGo segments was 56. With regard to the Eriksen Flanker Task, after baseline correction, average ERP waves were calculated for artifact-free trials at each scalp site for correct and incorrect responses separately. The ERN was defined as the mean value in the 25–75 ms time segment after response. The Pe was defined as the mean value in the 150-250 ms time segment after response. Participants had to have at least 5 analyzable trials. The mean number of analyzable correct segments was 327 and the mean number of analyzable incorrect segments was 29.

Procedure

All participants were asked to abstain from alcohol and cannabis for at least 24 hours before entering the lab and to abstain from nicotine for at least two hours before entering. They were told that this would be checked with a breath analyzer, although breath analyzers in our lab were actually not able to check whether participants had stopped smoking for such a short amount of time. On the one hand, this smoking deprivation was necessary to reduce the acute effects of nicotine on ERP amplitudes (Houlihan, Pritchard, & Robinson, 2001), and on the other hand, it was short because we did not want to induce withdrawal effects (Luijten et al., 2011a). After signing the informed consent, the participants filled in their demographics, the AUDIT, the FTND, drugs consumption and the BIS-11, so we were able to characterize the participants. Subsequently, the participants were seated in a comfortable EEG-chair in a light and sound-attenuated room, and electrodes were attached. For both tasks, the participants watched instructions on a screen in order to learn how the tasks worked and that they had to sit still, to make as few errors as possible, and to respond as quickly as possible. The Go/NoGo Task started with 15 practice trials. After the Go/NoGo Task had been finished, participants had a three-minute break before the instructions of the Eriksen Flanker Task appeared on the screen. The Eriksen Flanker Task started with 15 practice trials, too. After the Eriksen Flanker Task, all electrodes were removed and participants had the opportunity to be informed about the aims of the study. The total duration of the experiment was 1.5 hours per participant.

Data Analysis

Repeated measurement analyzes of variance (RM-ANOVA; with Greenhouse-Geisser adjusted *p*-values in case the sphericity assumption was violated) were conducted to analyze the behavioral outcomes of performance as well as the ERPs for both the Go/NoGo Task and the Eriksen Flanker Task. In all RM-ANOVAs, Group (CUD patients vs. cigarette smoking controls vs. non-smoking controls) was added as between-subject factor. Post-hoc tests for interactions with Bonferroni corrections for multiple comparisons were performed only for interactions including the between-subject factor Group. All tests were two-tailed with a significance level of .05. Statistical information is presented in the following format: *F*(degrees of freedom), *p*, and the effect sizes are presented in eta-squared (η^2), and Pearson's *r* (following recommendations of Fritz et al., 2009).

With regard to the behavioral data of the Go/NoGo Task, a Group X Inhibition (Go vs. NoGo) RM-ANOVA was used to analyze both the accuracy rates and the RT data. Concerning the behavioral data of the Eriksen Flanker Task, we included the two-level within-subject factor Congruency (congruent vs incongruent trials). A Group X Congurency RM-ANOVA was used to analyze the accuracy rates. Further, ANOVAs with Group as independent variable were conducted to analyze the percentages of overall errors, of errors following an error trial and of missing responses. For the RT data, we used ANOVAs in order to analyze overall RT differences. In addition, three RM-ANOVAs were conducted with different two-level within subject factors: Group X Correctness RT (correct vs. incorrect trials), Group X Post-error RT (post-error vs. post-correct trials), and Group X Congruency. Behavioral data were analyzed in R (R Development Core Team 2008).

For all ERP analyses, the three-level within-subject factor Electrode (Fz, FCz and Cz) was included. To analyze the ERPs of the Go/NoGo Task, a Group X Inhibition X Electrode RM-ANOVA was conducted. To analyze the ERPs of the Eriksen Flanker Task, we included the two-level within-subject factor Response Type (incorrect vs. correct trials). Finally, a Group X Electrode X Response Type RM-ANOVA was conducted. ERP-data were analyzed in SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Macintosh, Version 22.0. Armonk, NY: IBM Corp.).

Results

Background Variables

Table 1 shows all demographic and substance-use variables for the final samples included in the analyses. In comparison to the smoking control group, the

CUD patient group reported lower GHB and cocaine use. In comparison to the non-smoking control group, the CUD patient group reported more alcohol use and obtained higher scores on the motor and non-planning subscales of the BIS-II

Table 1. *Demographics, Substance Use and Behavioral Inhibition Variables of Cannabis- Dependent Patients, Cigarette Smoking Controls and Non-Smoking Controls.*

	Cannabis Dependent (*N* = 37)	**Cigarette Smoking Controls (*N* = 38)**	**Non-Smoking Controls (*N* = 39)**	**Test value**	***p*-value**	**Effect size**	
Demographic Variables				X^2		Cramer's *V*	
Male (%)	83.8	65.8	69.2	3.45	.178	.18	
Low Education (%)	51.4	36.8	27.5	4.68	.096	.20	
				F		η^2	*r*
Age	21.7 (2.10)	21.4 (2.5)	22.1 (2.1)	0.87	.460	.01	.12
Substance Use Variables							
AUDIT	8.7 (4.8)	11.0 (6.7)	6.5 (4.9)	5.53	.005	.11	.33
FTND	5.1 (1.9)	4.2 (1.8)	-	3.76	.057	.06	.24
Daily cigarette consumption	11.4 (6.3)	11.1 (5.5)	-	0.04	.846	.01	.05
Lifetime cannabis use#	186.0 (48.4)	48.4 (77.7)	-	87.14	<.001	.56	.76
Lifetime XCT use	40.5 (54.5)	51.2 (56.1)	-	0.58	.448	.01	.09
Lifetime GHB use	6.7(12.2)	42.4 (53.4)	-	6.82	.013	.17	.40
Lifetime amphetamine use	34.2 (52.3)	43.3 (50.7)	-	0.53	.528	.01	.08
Lifetime cocaine use	23.6 (31.3)	52.3 (57.8)	-	4.27	.034	.08	.29
Lifetime magic mushroom use	6.9 (14.0)	4.8 (8.9)	-	0.22	0.639	<.01	.07
BIS-11							
Motor	2.0 (0.2)	2.1 (0.3)	1.8 (0.3)	8.35	<.001	.13	.35
Nonplanning	1.9 (0.4)	1.9 (0.3)	1.7 (0.2)	7.52	.008	.08	.36
Attentional	2.0 (0.5)	2.0 (0.4)	1.9 (0.3)	0.26	.693	.01	.07

Note: Values represent means, standard deviations between brackets. -Indicates that non-smokers were not taken into account for this particular analysis because too few of them had ever used this substance causing heterogeneous variances. # Indicates that for all lifetime questionnaires the scale range was 1 to 200, so for some participants this may not represent an accurate estimation of the number of times the substance was used. BIS-11: the Barratt Impulsiveness Scale-II (Patton et al., 1995). FTND: the Fragerström Test for Nicotine Dependence (Heatherton et al., 1991). AUDIT: The Alcohol Use Disorders Identification Test (Allen et al., 1997).

Behavioral Data.

Go/NoGo Task. Table 2 shows the accuracy rates in percentages of the CUD patients and both controls on the Go/NoGo Task. In line with our expectations, participants were less accurate on NoGo trials than on Go trials, $F(1,110) = 549.41$, $p < .001$, $\eta^2 = .83$, $r = .91$. This indicates that the experiment provoked the intended result: Participants had difficulties inhibiting their response on infrequent NoGo trials. Further, we found no overall differences in accuracy between CUD patients and the control groups, $F(2,110) = 1.12$, $p = .330$, $\eta^2 = .02$, $r = .14$. Most importantly, we also did not observe a Group X Inhibition interaction, $F(2,110) = 0.72$, $p = .488$, $\eta^2 < .01$, $r = .04$. Thus, the groups did not differ with respect to the size of the inhibition effect. Notably however, we did observe a between-group difference on the reaction times of the Go trials, $F(2,110) = 4.92$, $p = .009$, $\eta^2 = .08$, $r = .29$. Post-hoc tests were in line with expectations; CUD patients were slower on Go trials ($M = 357.3$; $SD = 39.9$) than cigarette smoking controls ($M = 334.6$; $SD = 37.7$), mean difference = 22.75 ($SE = 9.06$), $p = .036$, and non-smoking controls ($M = 331.4$; $SD = 38.5$), mean difference = 25.88 ($SE = 8.90$), $p = .012$.

Table 2. *Accuracy Rates in Percentages and Reaction Times in Milliseconds on the Go-NoGo Task.*

	% Correct Go		**% Correct NoGo**		**RT Go**	
CDP (*N* = 36)	94.7	(4.7)	61.1	(16.3)	357.3	(39.9)
C-S controls (*N* = 37)	96.4	(2.2)	60.7	(15.4)	334.6	(37.7)
N-S controls (*N* = 40)	96.4	(3.4)	64.5	(15.2)	331.4	(38.5)

Note: Group means, standard deviations between brackets. CPD = Cannabis Dependent Patients; C-S = Cigarette smoking controls; N-S = Non-smoking controls.

Eriksen Flanker Task. Table 3 displays the error rates in percentages for CUD patients as well as both control groups. The groups did not differ on overall accuracy, $F(2,111) = 0.92$, $p = .402$, $\eta^2 = .02$, $r = .13$. Furthermore, we did not find differences on trials following an error, $F(2,111) = 0.34$, $p = .712$, $\eta^2 = .01$, $r = .08$. Also, we did not find between-group differences on missed responses (i.e. too quick, too late or no responses), $F(2,76) = 1.16$, $p = .318$, $\eta^2 = .03$, $r = .18$. With regard to the congruency effect, more errors were made on incongruent than on congruent trials, $F(1,111) = 229.51$, $p < .001$, $\eta^2 = .67$, $r = .82$, which shows that the task provoked the intended result. However, in contrast to our expectations, no overall group differences were observed, $F(2,111) = 0.91$, $p = .406$, $\eta^2 = .02$, $r = .13$. We did not find a Group X Congruency interaction effect, which indicates that the groups did not differ with respect to the size of the congruency effect, $F(2,111) = 1.32$, $p = .271$, $\eta^2 = .01$, $r = .09$.

Table 3. *Error rates on the Eriksen Flanker Task.*

	Overall		**Post-Incorrect**		**Missing***	
CPD (*N* = 36)	11.1	(9.8)	13.5	(14.5)	3.4	(7.5)
C-S Controls (*N* = 37)	11.5	(9.3)	13.5	(12.7)	1.8	(3.0)
N-S Controls (*N* = 41)	8.9	(7.4)	11.5	(10.5)	1.5	(1.7)

Table 3 continues below

	Congruent		**Incongruent**	
CPD (*N* = 36)	7.1	(8.6)	15.0	(11.6)
C-S Controls (*N* = 37)	6.5	(8.6)	16.5	(10.7)
N-S Controls (*N* = 41)	3.8	(4.1)	14.1	(11.3)

Note: Group means (SD), error rates in percentages. CPD = Cannabis Dependent Patients; C-S = Cigarette smoking controls; N-S = Non-smoking controls. *Missing responses were no response, too quick (<150 ms) or too slow (>1000 ms). Not all participants had missing responses, *N*'s were 32, 25, 22 for cannabis use disorder patients, cigarette smoking controls and non-smoking controls respectively.

Table 4 shows the mean values of the RT data for CUD patients as well as both control groups. We did not observe differences in overall RTs, $F(2,111) = 0.95$, $p = .389$, $\eta^2 = .02$, $r = .13$. With regard to the correctness of the trials, RTs were slower for correct trials than for incorrect trials, $F(2,111) = 245.82$, $p < .001$, $\eta^2 = .68$, $r = .84$. However, no overall group differences were observed, $F(2,111) = 0.70$, $p = .501$, $\eta^2 = .01$, $r = .09$. Importantly, no Group X Correctness interaction was found, indicating that the difference between correct and incorrect reaction times did not differ between the groups, $F(2,111) = 1.22$, $p = .299$, $\eta^2 = .01$, $r = .10$. With respect to post-error trials, RTs were slower for post-error trials than for post-correct trials, $F(1,111) = 12.43$, $p < .001$, $\eta^2 = .10$, $r = .32$[34]. Neither overall differences between the groups, $F(2,111) = 0.79$, $p = .457$, $\eta^2 = .01$, $r = .11$, nor a Group X Post-error RT interaction effect, $F(2,111) = 0.40$, $p = .743$, $\eta^2 = .01$, $r = .07$, was observed. So, the difference between post-error and post-correct trials did not differ between the groups. Regarding the congruency effect, RTs were slower on incongruent than on congruent trials, $F(1,111) = 718.59$, $p < .001$, $\eta^2 = .86$, $r = .93$. However, no overall group differences were observed, $F(2,103) = 1.25$, $p = .291$, $\eta^2 = .02$, $r = .15$ and no differences were found between groups on either congruent or incongruent trials, $F(2,111) = 0.95$, $p = .390$, $\eta^2 < .02$, $r = .07$.

Table 4. *Reaction Time Measures on the Eriksen Flanker Task.*

	Overall		**Correct**		**Incorrect**	
CPD (*N* = 36)	477	(53)	483	(50)	422	(69)
C-S Controls (*N* = 37)	460	(58)	466	(56)	412	(67)
N-S Controls (*N* = 41)	471	(45)	475	(46)	427	(52)

table continues below

	Congruent		**Incongruent**		**Post-Correct**		**Post-Incorrect**	
CPD	453	(52)	500	(58)	477	-50	490	-81
C-S	438	(55)	483	(63)	460	-58	476	-68
N-S	444	(42)	498	(48)	471	-44	479	-44

[34] Levene's test for the Equality of Variances indicated that the assumption of homogeneity was not met for the post-incorrect reaction time trials, $F(1,111) = 6.81$, $p = .002$. However, since the variation observed was larger for the group with the smaller sample size, the estimated F-value is conservative rather than liberal (Field, 2009).

Note: Group means, standard deviations between brackets, reaction times (RT) in milliseconds. CPD = Cannabis Dependent Patients; C-S = Cigarette smoking controls; N-S = Non-smoking controls.

Event-Related Potentials

Go/NoGo Task. ***N2 amplitudes.*** Figure 2 shows the N2 and P3 amplitude for both CUD patients and the control groups at the frontocentral electrode cluster. Figure 3 shows the mean amplitude of the N2 for each of the frontocentral electrodes for each group. We did not find that N2 amplitudes differed between Go and NoGo trials at the frontocentral electrode cluster, $F(1,106) = 2.92$, $p = .090$, $\eta^2 = .03$, $r = .17$. This suggests that for the N2 amplitude the Go/NoGo Task may not have provoked the intended result as it was expected that N2 amplitudes would generally be larger for NoGo than for Go trials. In addition, we did not find overall differences between the N2 amplitudes of CUD patients and either of the controls at the frontocentral electrode cluster, $F(2,106) = 0.88$, $p = .417$, $\eta^2 = .02$, $r = .14$. We did observe a Group X Inhibition interaction effect, $F(2,106) = 3.10$, $p = .049$, although the effect was small, $\eta^2 = .06$, $r = .23$. Post-hoc tests did not reveal that N2 amplitudes were significantly reduced for CUD patients on the NoGo trials compared to either of the control groups, all p's > .177. Post-hoc tests did reveal that for the non-smoking control group, the N2 amplitudes for the NoGo Trials were significantly reduced compared to the Go trials, mean difference = 0.90 ($SE = 0.38$), $p = .021$. This was not the case for the other groups, all p's > .101. Further, we observed a significant Electrode X Group interaction effect, $F(4,212) = 2.88$, $p = .024$, although the effect was small, $\eta^2 = .05$, $r = .22$. Post-hoc tests did not reveal that the N2 amplitudes differed between the groups on one or more of the electrodes, all p's > .187. Post-hoc tests did reveal that for the cigarette smoking control group the N2 amplitude was somewhat larger for the Cz electrode than for the FCz electrode, mean difference = 0.65 ($SE = 0.25$), $p = .036$. This was not the case for the other groups, all p's > .451, or for a combination of electrodes within the cigarette smoking control group, p's > .070.

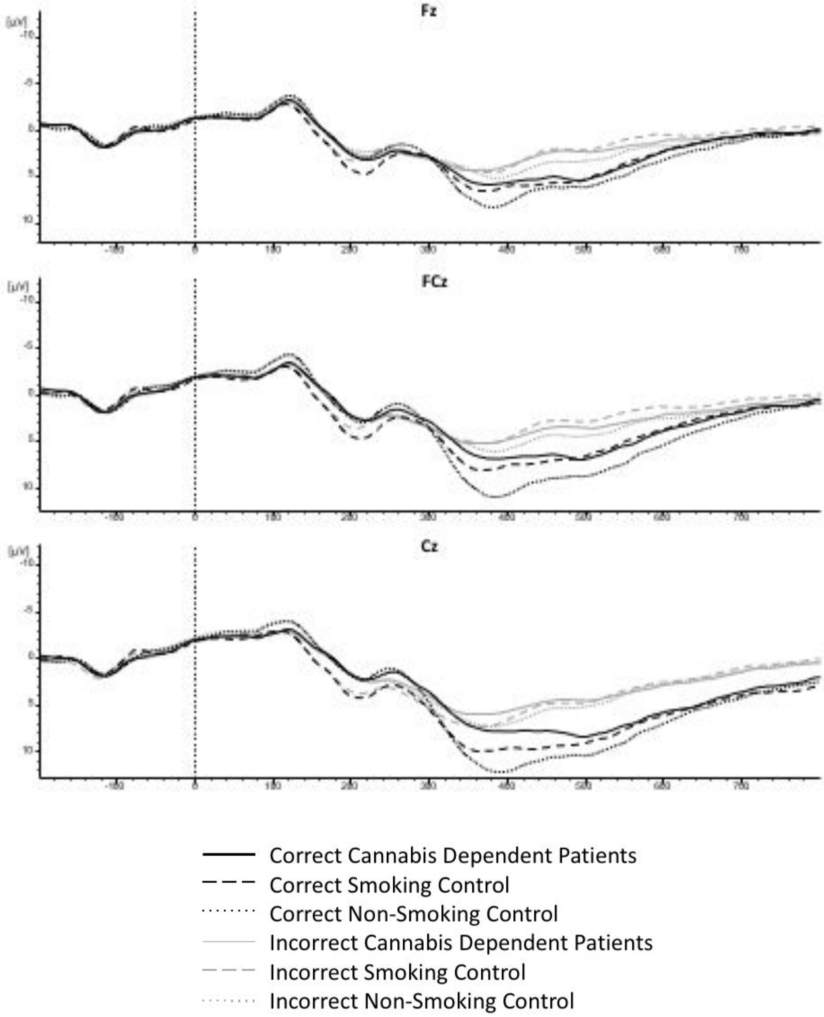


Figure 2. Grand-average stimulus-locked waveforms at Fz, FCz and Cz for correct Go and NoGo trials on the Go/NoGo Task for cannabis use disorder patients, tobacco smoking controls and healthy controls.

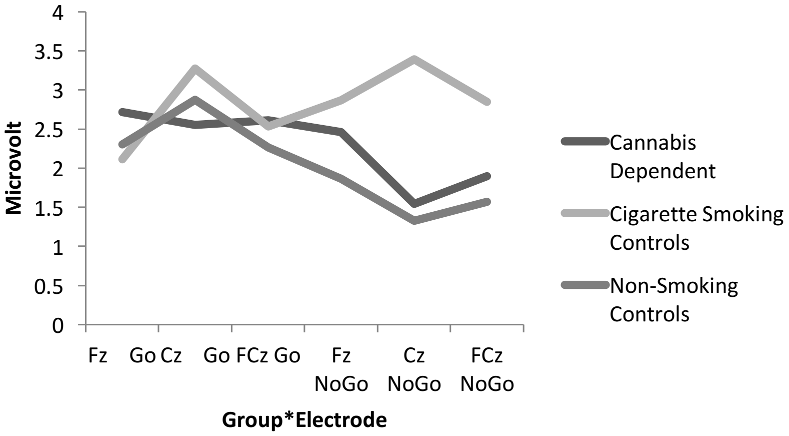


Figure 3. Mean amplitude of the N2 for each of the frontocentral electrodes for each group on the Go/NoGo Task.

P3 amplitudes. Figure 4 shows the mean amplitude of the P3 for each of the frontocentral electrodes for each group. We found that P3 amplitudes at the frontocentral electrode cluster were generally larger for NoGo trials than for Go trials, $F(1, 106) = 110.18$, $p < .001$, $\eta^2 = .51$, $r = .71$. This suggests that for the P3 amplitude the Go/NoGo Task provoked the expected result. Again, we did not find overall differences between the P3 amplitudes of CUD patients and either of the controls at the frontocentral electrode cluster, $F(2,106) = 2.18$, $p = .118$, $\eta^2 = .04$, $r = .20$. Most importantly, we observed a Group X Inhibition interaction effect, $F(2,106) = 3.25$, $p = .043$, $\eta^2 = .06$, $r = .25$. Post-hoc tests revealed that this was due to the CUD patients having lower NoGo P3 amplitudes than non-smokers, mean difference = 2.44 (*SE* = 0.98), $p = .044$. No difference was observed between CUD patients and smokers, mean difference = 1.16 (*SE* = 0.97), $p = .744$.

We did not observe a significant Electrode X Group interaction effect, $F(4,212) = 2.40$, $p = .051$, $\eta^2 = .04$, $r = .21$, indicating that the difference in P3 amplitudes between the electrodes did not generally differ between the groups, although the effect was close to significance. Further, we observed an Electrode X Inhibition X Group interaction effect, $F(3.48, 212) = 3.66$, $p = .010$, $\eta^2 = .07$, $r = .26$. Post-hoc tests revealed that this effect was driven by CUD patients who had lower

P3 amplitudes on the Cz Electrode than non-smokers in the NoGo condition, (M difference = 3.04, SE = 1.08), *p* = .018, while there was no significant difference between CUD patients and smokers, (*M* difference = 1.98, SE = 1.10), *p* = .220. In addition, the three-way interaction was caused by CUD patients who had lower P3 amplitudes on the FCz Electrode than non-smokers in the NoGo condition, (*M* difference = 2.75, SE = 1.08), *p* = .037, while there was no significant difference between CUD patients and smokers, (*M* difference = 0.91, SE = 1.10), *p* = .266.

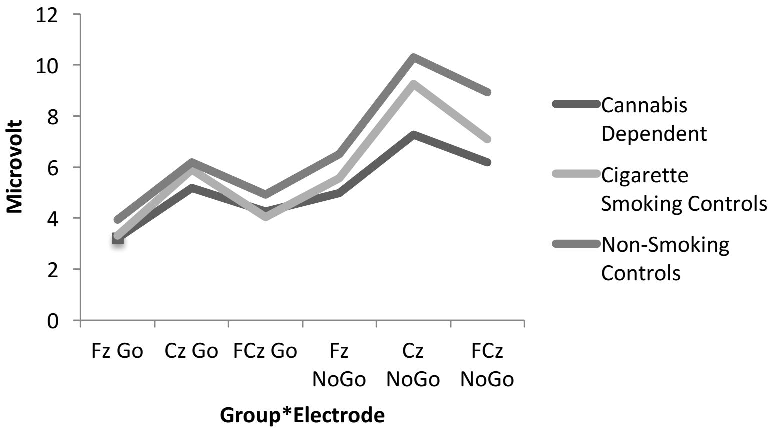
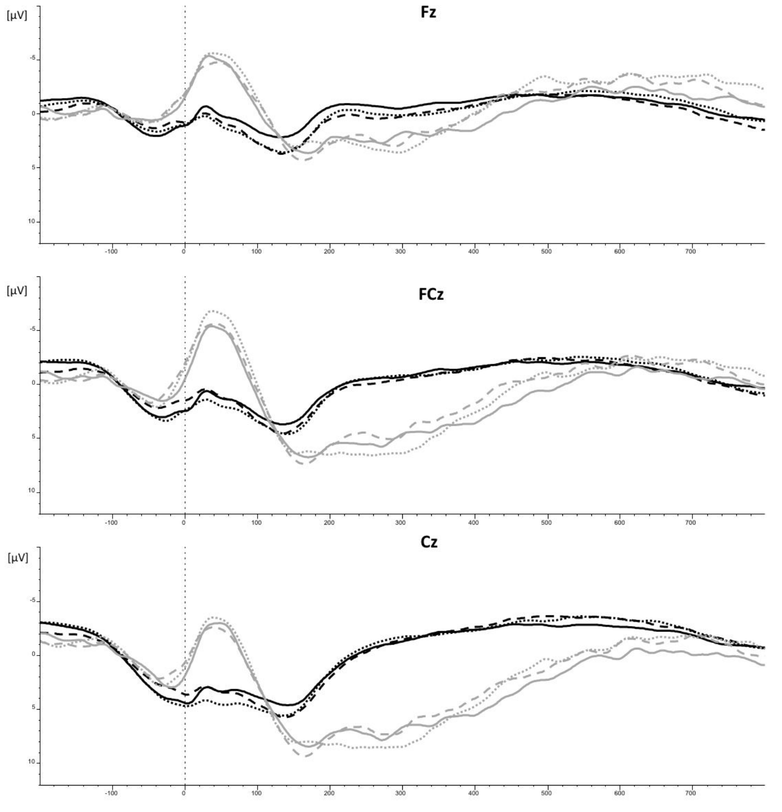


Figure 4. Mean amplitude of the P3 for each of the frontocentral electrodes for each group on the Go/NoGo Task

Eriksen Flanker Task. ***ERN amplitudes.*** Figure 5 shows the ERN and Pe amplitudes of the CUD patients and the control groups at the frontocentral electrode cluster. In line with previous studies, we found a larger ERN amplitude for incorrect than for correct trials, $F(1,109) = 211.79$, $p < .001$, $\eta^2 < .66$, $r = .81$, indicating that the paradigm provoked the intended result. Further, we did not find overall differences between the ERN amplitudes of CUD patients and either one of the control groups at the frontocentral electrode cluster, $F(2,109) = 0.03$, $p = .969$, $\eta^2 < .01$, $r = .03$. In contrast to our expectations, we did not find a Group × Response Type effect, $F(2,184.85) = 1.86$, $p = .161$, $\eta^2 = .03$, $r = .18$, which indicates that the group did not differ with respect to the size of the response type effect. Finally, we did not observe a Group X Response Type X Electrodes interaction, $F(3.39, 184.85) = 0.97$, $p = .416$, $\eta^2 = .02$, $r = .14$.

Pe amplitudes. In line with previous studies, we observed an increased Pe amplitude for incorrect compared to correct trials, $F(1,109) = 84.26$, $p < .001$, $\eta^2 = .44$, $r = .66$. Further, we did not find overall differences between the Pe amplitudes of CUD patients and either one of the control groups, $F(2,109) = 0.22$, $p = .807$, $\eta^2 < .01$, $r = .03$. We also did not observe a Group X Response Type interaction, $F(2,109) = 0.39$, $p = .678$, $\eta^2 = .01$, $r = .05$, so the Pe amplitude of the groups did not differ with respect tot the size of the response type effect. Finally, we did not observe a Group X Response Type X Electrodes interaction, $F(2.75,149.99) = 0.88$, $p = .446$, $\eta^2 = .02$, $r = .14$.



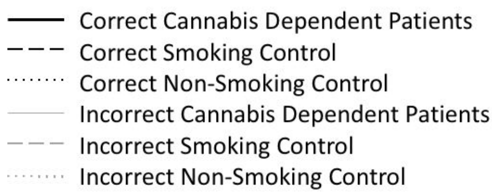


Figure 5. Grand-average response-locked waveforms at Fz, FCz and Cz of correct and incorrect trials on the Eriksen Flanker Task in cannabis use disorder patients, tobacco smoking controls and healthy controls.

Discussion

The aim of our study was to identify whether CUD patients have response inhibition and performance monitoring deficits, two core features of the cognitive control system that have been emphasized in a number of contemporary models of drug addiction (e.g., Feil, Sheppard, Fitzgerald, Yücel, Lubman, & Bradshaw, 2010; Garavan & Stout, 2005). In line with our hypothesis, we observed a reduced P3 ERP component on the Go/NoGo Task for CUD patients compared to non-smoking controls. This finding adds to increasing evidence that mark the frontal P3 as an important electrophysiological correlate of SUDs (see for a review Luijten et al., 2014). The fact that we did not observe a difference between CUD patients and cigarette smokers highlights the urgency for future studies to more carefully control for the use of tobacco when investigating CUD patients. The reduced P3 was accompanied by longer response times on the go trials, which can be interpreted in terms of a speed-accuracy tradeoff. Arguably, the CUD patients had to decrease the responding speed in order to avoid inhibition-errors. All in all this suggests that the response inhibition of cannabis use patients is compromised. In contrast to our expectations we found no indications for problems in the error-monitoring of cannabis use patients. We will explain the findings in more detail below.

Response Inhibition

In contrast to the NoGo P3, we did not observe any overall differences between Go and NoGo stimuli on the N2 amplitudes suggesting that the N2 may not be an index of response inhibition (e.g., Bekker et al., 2004; Nieuwenhuis et al., 2003; Smith, Johnstone and Berry, 2007a) making interpretations with regard to response inhibition unwarranted. The results are more in line with the view that the NoGo-N2 is a non-motor inhibition process (e.g. Falkenstein et al., 2007) or reflects conflict monitoring (e.g., Nieuwenhuis et al., 2003). Importantly, we found a reduced NoGo-P3 in CUD patients as compared to non-smokers. We interpret this as that CUD patients are characterized by response inhibition deficits, which extends earlier studies investigating the link between cannabis and response inhbition (e.g., Hester et al., 2009; Ramaekers et al., 2006). This interpretation is strengthened by the behavioral outcomes, which showed that cannabis dependent patients had longer response times than both control groups on the Go trials. In our view, the CUD patients decreased the response speed in order to prevent inhibition-errors (i.e. a speed-accuracy tradeoff; Wickelgren, 1977). Thus, the cannabis dependent patients may have actively compensated for their deficits in response inhibition. Similarly, Hester et al. (2009) found CUD patients to have increased activity in the right inferior parietal lobe, putamen and middle cingulate gyrus and they suggested that this was indicative of compensatory processes that may have masked behavioral response inhibition deficits in their study. An alternative view could be that the direct cannabis effects may have caused these slower reaction times as response inhibition deficits can last up to six hours after ingestion (Rameakers et al., 2006). However, as outlined below under the limitations it is unlikely that the patients were under influence of cannabis. In addition, this would have probably resulted in prolonged reaction times on the Eriksen Flanker Task. However this we did not observe.

Another explanation could be that the NoGo-P3 is partially the electrophysiological reflection of motor impulsiveness (in the sense that lower NoGo-P3s reflect stronger motor impulsiveness) and not response inhibition per se. Our data are also in line with this view as CUD patients as well as cigarette smoking controls had significantly higher motor and non-planning impulsivity scores than healthy controls. This is suggestive of the idea that personality traits (i.e., impulsive personalities) may underlie reduced response inhibition (Chamberlain & Sahakian, 2007) and substances like cannabis and tobacco may be used as a form of self-medication (i.e. relaxation of impulsivity). However, we have to be cautious when drawing causal inferences, as prolonged cannabis or tobacco use may also underlie response inhibition deficits. Most likely, it is an interaction between vulnerable personality traits and the substance. Finally, in contrast to earlier findings from our lab (e.g., Luijten et al., 2011) we did not observe differences between cigarette smokers and healthy participants. However, these results have to be interpreted with caution as this may be due to reduced power because we used three groups instead of the more frequently used two-group design.

Performance Monitoring

With regard to performance monitoring did not observe any behavioural or electrophysiological differences between the groups, although we found the expected overall effects of errors on the ERN and Pe. The fact that we did not find differences in performance monitoring is in contrast with contemporary models of substance abuse disorders, that mark the importance of performance monitoring by proposing that people with SUDs are insensitive to future negative consequences (e.g., Feil, Sheppard, Fitzgerald, Yücel, Lubman, & Bradshaw, 2010; Garavan & Stout, 2005). This is especially striking since both CUD patients as well as cigarette smoking participants differed significantly from non-smoking controls on nearly all measured substances as well as on impulsivity. The ERN findings are in line with the findings of Fridberg et al. (2013), who also did not observe differences in the ERN between cannabis users and controls. A consideration that could be taken into account however, is that at the electrophysiological level cannabis use is associated with decreased performance monitoring but that this effect is masked by increased ERN and Pe amplitudes that are known to be associated with internalizing problems (Schellekens et al., 2010). A similar line of reasoning was proposed by Schellekens et al. (2010), who found alcohol use disorder patients with anxiety problems to have increased ERNs compared to healthy controls. For future studies, it may be fruitful to include measures of anxiety when investigating performance monitoring in SUDs. Another possibility is that we failed to observe significant differences due to power problems resulting from the fact that we had three groups. Thus, the null findings regarding the performance monitoring might be the result of too low statistical power. As can be seen from the behavioural accuracy rates, the average number of errors goes in the expected direction, with healthy controls having fewer errors than

CUD patients and cigarette smokers. But still, at most these differences on performance monitoring are weak and performance and performance monitoring seems relatively unaffected.

Limitations

Some limitations of the study should be addressed. First, it is very difficult, if not impossible, to control for other substance use. In our study, CUD patients differed from controls on the usage of other substances than only cannabis. Interestingly, the cigarette smoking controls used significantly more alcohol, GHB and cocaine than the CUD patients. This may seem to provide an explanation for an absence of differences between CUD patients and cigarette smokers, as the usage of these substances has also been related to response inhibition deficits (e.g., Luijten et al., 2014). Yet, on the other hand it is remarkable that these poly-substance using cigarette smokers did not significantly differ from healthy (non-substance using) controls.

Second, CUD patients were not screened on abstinence at the moment of the study. However, it is unlikely that patients had used cannabis just before they were tested: they had been told that they would be tested on being abstinent for at least 24 hours. The Antes treatment facility screens their patients routinely by urine drug screens. This leads us to the third limitation; we did not have objective quantifications (e.g., urine tests) to show the substance use of the participants, but had to rely on self-report measures. Although there may be individual differences in the accuracy of reporting, we tried to increase the reliability of their responses by stressing the anonymity of the survey (participants did not have to fill in their names anywhere). A final limitation is that we did not collect more precise data on the lifetime cannabis use. In the digital questionnaire, participants could fill in their lifetime cannabis use up till a maximum of 200 times, but of course all CUD patients used more cannabis in their lives. Therefore, we could not for example investigate the relationship between the amount of cannabis used on the one hand, and the reduction of the ERPs or the level of impulsivity on the other hand.

Finally, we purposefully did not counterbalance the order of the tasks. Essentially, to investigate performance monitoring a task was needed in which errors were made. Thus, by presenting the response inhibition task first, participants would be more mentally fatigued leading to an increase in the number of errors on the performance monitoring task. If the performance monitoring task would have been presented first for half of the participants, this may have led to within group differences on the number of errors made.

Conclusions

In conclusion, our results suggest that CUD patients have problems related to response inhibition as is evident from their reduced P3 ERPs and prolonged reaction times. No indications were found that cannabis patients are characterized by performance monitoring problems.

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Appendix 3

SUMMARY

Being a supernatural believer (i.e., believing in culturally specific unverifiable beliefs about non-physical phenomena that do not coincide with a naturalistic worldview) can be a costly venture, in terms of time, money and resources. Some fanatic believers are even willing to give up their lives for their faith. That seems to contradict with Darwinian laws (e.g., Darwin, 1871), as it makes it harder for our species to pass on our genes. So, how come, tens of thousands of years ago, groups of people independently started to hold supernatural beliefs (e.g., Bulbulia, 2004) and why do at least 80% of the people still believe in the supernatural today (Zuckerman, 2007)? The 'Cognitive Science of Religion' (from here on CSR) is an academic field of scholars from different disciplines that started explaining these questions from an evolutionary perspective (Xygalatas, 2014). The theories of the CSR can be broadly distinguished in theories in which supernatural beliefs are considered as an evolved adaption (e.g., by increasing cooperation among groups) or as by-product (Pyysiäinen & Hauser, 2010; Sosis, 2009). In theories relating to the by-product account, the main idea is that supernatural beliefs are a side effect of a set of adaptive cognitive functions[35]. The aim of the studies in the present dissertation was to empirically test the two main cognitive biases hypothesized to predispose people to adopt supernatural beliefs – the hypersensitive agency detection device (i.e., HADD) and mentalizing abilities.

The hypersensitive agency detection device (HADD from here on) is a hypothesized cognitive mechanism that responds over-actively to ambiguous information that could potentially signal the presence of other agents such as other humans, animals or creatures (Barrett, 2000; Barrett & Burdett, 2011; Guthrie, 1993). For instance, the sound of a branch breaking in a dark forest could potentially trigger the HADD, causing the false perception of an agent (e.g., "There's someone there"). Such a mechanism is evolutionary advantageous, because it allows organisms to prepare a fight or flight response before other organisms have been encountered. Quickly detecting other organisms (i.e., predator and prey) is often vital to survive. The idea is that the same process of interpreting events as being

[35] In contrast to the adaptation view, supernatural beliefs were not originally selected for to increase cooperation, but once all cognitive functions were in place, it could be selected for.

caused by agents could encourage people's belief that some events are caused by supernatural agents (e.g., Barrett, 2000). For example, flickering lights can be interpreted as being caused by a deceased relative. According to 'error management theory' the HADD evolved as a result from an imbalance between the costs and benefits associated with making specific decisions (Haselton & Nettle, 2006; Johnson, Blumstein, Fowler, & Haselton, 2013). Specifically, failing to detect the presence of another agent in a threatening situation (e.g., a dark and scary forest) is costlier (e.g., an agent can kill you) than incorrectly assuming the presence of another agent for which the potential costs are relatively small (e.g., you waste energy). Thus, the HADD is thought to be especially responsive to ambiguous and threatening situations, but this central hypothesis has never been investigated empirically.

Closely linked to the HADD is the ability to mentalize (Barrett & Lanman, 2008). According to Barrett and Lanman (2008), people first detect agency with the HADD and then the ability to mentalize causes you to attribute intentions to the agent. Thus, mentalizing is the ability to attribute intentions and beliefs to other minds, as for example, interpreting that your father is angry when he slams the door. Mentalizing is thought to be the most important cognitive mechanism underlying supernatural beliefs (e.g., Atran, 2002; Barrett, 2012; Barrett, 2000; Bering, 2002a; Bering, 2002b; Bering, 2006; Bloom, 2007; Boyer, 2003; Geertz, 2010; Gervais, 2013; Jong, 2013; McCauley, 2011; Norenzayan, Gervais, & Trzesniewski, 2012; Norenzayan et al., 2014; Willard & Norenzayan, 2013). The logic behind this prevailing hypothesis is that belief in a mind or belief in a supernatural agent's mind is processed by the same cognitive mechanism (Gervais, 2013; e.g., thinking that God is angry because something bad happened to you). In addition, over-mentalizing might result in attribution of intentions to inappropriate domains (Bering, 2002a, e.g., attributing intentions to tree or thunderclouds). Taking the HADD and mentalizing together, we might be able understand why so many different cultures had Gods of thunder (e.g., Zeus, Wodan and Indra); they detected the presence of agents in thunderclouds and attributed intentions to them.

The first studies

Next to addressing the relationship between the cognitive biases on the one hand, and supernatural beliefs on the other hand (i.e., Chapters 2-4 and 6), we tested some important assumptions underlying the theories that we described above. Do we actually have a bias to detect agents in the first place and do ambiguous and threatening situations increase agency detection as a result of increasing the hypersensitivity of the module (i.e., Chapters 2, 3 and 4)? Do we truly have a mentalizing bias causing us to over-interpret intentionality (i.e., Chapters 2 and 6)? With regard to agency detection, we observed that people indeed frequently infer the presence of agents on the basis of ambiguous stimuli. However, the supposed mechanism is different than would be expected based on HADD theorizing. According to the HADD logic, we predicted that threatening situations would increase agency detection. To examine this, we placed participants in different threatening situations, by using threatening pictures and threatening music (Chapter 2) and by letting them walk through a virtual threatening forest and a haunted house (Chapter 3). In the most threatening situations (i.e., virtual reality) this led to a small increase in agency detection. In addition, we observed that especially ambiguity increased agency detection – in both computerized tasks and virtual reality. Further, we did not observe a relationship between agency detection and supernatural beliefs across all our studies.

As we did not observe correlations between agency detection and supernatural beliefs in Chapters 2 and 3, we tried to experimentally manipulate supernatural beliefs and experiences in Chapter 4, to investigate their influence on agency detection. The relationship between agency detection and supernatural beliefs has been said to be mutually reinforcing (e.g., an agency experience could trigger the belief that there is a ghost out there, but vice versa: knowing that you are in a haunted house will likely increase the frequency of agency experiences; Barrett & Lanman, 2008). We manipulated supernatural beliefs and experiences by means of the so-called God-helmet (see Figure 1). This is a transformed scooter or skate helmet, of which we told participants that it is capable of stimulating parts of the brain that have been related to extraordinary experiences such as the 'out-of-body' experience (Blanke, Landis, Spinelli, & Seeck, 2004). In fact, the helmet was not attached to any electrical stimulator. Still, using this placebo brain stimulation, participants reported a wide range of extraordinary experiences. These experiences did not result in increased agency detection however, and again, agency detection was not related to supernatural beliefs. Thus, the 'hypersensitive' agency detection device seems not an adequate account of agency experiences and their role in fostering supernatural beliefs and experiences.

Figure 1. Picture of the God helmet and experimental set up with sham physiological recording.
The God helmet (i.e., placebo brain stimulation) depicted here was a transformed scooter helmet, at other times we used a futuristic looking metallic skate helmet. The helmet was attached to an analog to digital converter box with wires, and lights were flickering to indicate that the helmet was on. Participants were instructed about the supposed working and the effects of the helmet prior to the experiment. During the experiment, participants were sensory deprived by means of a sleeping mask and auditory white noise.

In Chapters 2 and 6, we investigated people's mentalizing abilities and their supposed relation with supernatural beliefs. Our findings were in line with the idea that people frequently ascribe intentions towards non-mental phenomena, so the characterization of a 'mentalizing bias' seems much more appropriate than in case of agency detection. People often ascribed intentions to moving geometrical figures that seemed to ‘chase’ or ‘tease’ each other (Heider & Simmel, 1944). This even occurred when the geometrical figures moved randomly. The relationship between mentalizing abilities and supernatural beliefs was harder to establish. We did not observe a relationship between intentionality-ratings on the Geometrical Figures Task and supernatural beliefs in Chapter 2 (however, we did test only a relatively low number of supernatural believers here), while we did observe the expected relation in Chapter 6. We further did not observe a relationship between scores on the Empathy Quotient (Baron-Cohen & Wheelwright, 2004; Wakabayashi et al., 2006), a measure thought to partially capture mentalizing abilities, and supernatural beliefs in The Netherlands and Switzerland, but we did observe the expected relation in the United States. In short, the relationship between mentalizing abilities and supernatural beliefs were inconsistent, though the cultural prevalence of supernatural beliefs could play a moderating role in the hypothesized relation.

To be able to put the significance of mentalizing abilities for supernatural beliefs in perspective, we compared it with another factor we believed was a strong predictor of supernatural beliefs – , namely social learning (i.e., this is where the socio- part in the title comes from). Social learning means that you learn from someone else. A specific type of social learning we investigated are so-called ‘credibility-enhancing displays’. This is the extent to which people observed credible acts for the existence of a supernatural realm during their upbringing (Gervais & Najle, 2015; Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017). The idea behind CREDs is intuitive and relates to social learning theory (e.g., Bandura & McDonald, 1963). If parents or caretakers act in according to what they believe, they are credible sources and their beliefs are more likely to be transmitted to their children. For example, if they say they believe in God, while also praying and frequently visiting church, their actions converge with their beliefs. If, however, they say they believe in God, while fighting, swearing, drinking or going to the hookers, their actions diverge from their beliefs, thereby decreasing the likelihood that beliefs are transmitted. Thus, CREDs provide a comprehensive proximal sociocultural explanation for the emergence of both theism and atheism. We observed that credibility-enhancing displays were a strong and robust predictor of supernatural beliefs (Chapter 6). Summing up, to predict whether somebody believes it is more important to look at the behaviour of the parents of an individual during their upbringing than to look at their mentalizing or agency detection abilities.

A new theory

We also discussed an alternative theoretical framework, which is currently dominant in the field of cognitive neuroscience - the theory of predictive processing (Andersen, 2017a; Andersen, Pfeiffer, Müller, & Schjoedt, 2017; Van Leeuwen & van Elk, 2017, Chapters 4 and A1). Using this framework, we could more adequately explain agency detection occurrences (Chapters 2, 3 and 4) as well as expectancy induced extraordinary experiences elicited with placebo brain stimulation (Chapters 4 and 5). The general idea of predictive processing is that the way we, and all other agents, perceive and make judgements about the environment is not a passive process. It rather results from a combination of top-down prior predictions and bottom-up sensory processing (Friston, 2005; Friston & Kiebel, 2009; and see Firestone & Scholl, 2016 for a discussion on the role of top-down effects on perceiving vs judging). The brain's predictions are based on cognitive models, which are the result of life-long interactions with the environment. These predictions are compared to the incoming sensory input. This all happens in a hierarchical fashion, whereby models of higher layers try to predict the input of lower layers (Friston, 2005; Friston & Kiebel, 2009). Discrepancies between predictions and sensory input result in prediction errors, by which the prediction models are updated (Clark, 2013).

Thus, what you perceive does not only depend on sensory input from the surroundings, but also from your expectations. As a result, strong expectancies combined with very ambiguous sensory input can result in interpretations that deviate from the sensory input. For example, if you just watched a horror movie in a dark home, this results in a stronger likelihood that you will interpret a squeaking stairs as a killer (i.e., agency detection), than in case you did not watch the movie and it is light (Chapter 3). On the basis of the predictive processing framework, we could also explain how some people can get extraordinary experiences while using the God helmet (Andersen, Schjoedt, Nielbo, & Sørensen, 2014 and Chapter 5). We boosted their expectations by showing them fancy looking scientific apparatus (i.e., the fMRI-scanner), experimenters wore white medical lab coats, participants were attached to electrical wires and apparatus, they received information explaining the supposed working of the helmet and they viewed a clip of a professor describing her experiences with the God helmet. In addition, we reduced sensory input: participants were blindfolded and they listened to white noise. The strong expectancies in combination with the decreased sensory input, reducing the strength of prediction errors, resulted in a minority of the participants having extraordinary experiences (Chapters 4 and 5). We further learned that the tendency to get absorbed (i.e., getting fully immersed in internal or external stimuli; Chapter 4) and spiritual beliefs (Chapter 5) predicted whether participants had extraordinary experiences.

Now try to picture situations in which people get extraordinary experiences in real-life, like during spiritual séances, in abandoned 'haunted'-houses or when influenced by charismatic spiritual leaders. Extraordinary experiences are frequently encountered in situations where expectancies about extraordinary experiences are increased and sensory input is being decreased (e.g., darkness, Barnes & Gibson, 2013). Thus, the predictive processing framework can adequately explain why people sometimes have extraordinary experiences, but also why we sometimes detect the presence of other beings (Andersen, 2017).

Conclusion

We investigated two cognitive processes that have been marked as being important in predisposing supernatural beliefs. We observed that in contrast to what the name suggests, hypersensitive agency detection is not that hypersensitive, so we should stop naming it as such. The participants in our studies did tend to explain phenomena in terms of human intentions, so it seems reasonable to say we have a mentalizing bias. Nevertheless, both cognitive biases were not consistently related to supernatural beliefs, which is in contrast to the by-product account of supernatural beliefs. However, the cognitive biases are still very useful in explaining why certain elements, such as intentional agents, are so widespread among supernatural beliefs. Why we believe in the supernatural nowadays seems to be especially well explained by social learning, such as credibility enhancing displays. Yet, social learning does not adequately explain why people started believing in the first place, it can only explain how beliefs are transmitted from one generation to other, as soon as they have been formed. Thus, we could not provide a satisfactory solution to the ultimate question how religious beliefs originated in the first place. We do acknowledge that we zoomed in on only two hypothesized biases supposed to play a role in supernatural beliefs, albeit that they were considered the most important cognitive biases in explaining religion (e.g., Lindeman & Lipsanen, 2016). Finally, we discussed that the predictive processing framework can explain why people frequently detect the presence of others and why they are prone to having extraordinary experiences. Due to our life-long interactions with the surrounding world, we created mental models that strongly influence how we interpret, perceive and experience sensory events and self-generated mental imagery.

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Appendix 4

NEDERLANDSE SAMENVATTING

DUTCH SUMMARY

De vraag en de theorie

Geloven in het bovennatuurlijke kan een kostbare onderneming zijn (e.g., Sterelny, 2017). Als het zich beperkt tot een jaarlijks bezoekje aan waarzegster Ria op de paranormaalbeurs is het leed te overzien, maar wanneer je bereid bent je leven op te offeren voor een onzichtbaar opperwezen wiens bestaan per definitie niet geverifieerd kan worden, dan lopen de kosten wel een beetje uit de hand. Laten we eerst het begrip 'bovennatuurlijk geloof' nader definiëren. Hiermee bedoelen we geloof in niet-fysieke fenomenen die boven natuurlijke wetten uitstijgen en die zodoende onverifieerbaar, onzichtbaar en onmeetbaar zijn (Hoofdstuk 1). Dus, de verschrikkelijke sneeuwman, Mickey Mouse, *chemtrails*, marsmannetjes en atomen zijn niet bovennatuurlijk, we kunnen hun bestaan immers verifiëren of falsificeren. God, geesten en telepathie zijn wel bovennatuurlijk.

Een vraag waar filosofen (zie voor reviews, Meister, 2015; Whitmarsh, 2016) en onderzoekers (zie voor een review, Guthrie et al., 1980), zich al lang het hoofd over buigen, is hoe het komt dat tientallen duizenden jaren geleden, mensen over de hele wereld uit allemaal verschillende culturen, onafhankelijk van elkaar zijn gaan geloven in het bovennatuurlijke (Bulbulia, 2004). Wetenschappers die zich met deze vraag bezig houden hebben zich verenigd in een vakgebied genaamd 'De Cognitieve Wetenschap van Religie' (Xygalatas, 2014). Volgens deze wetenschappers hebben mensen als gevolg van evolutionaire processen aangeboren psychologische mechanismen (oftewel cognitieve mechanismen; daar komt dus het woord 'cognitive' uit de titel vandaan) ontwikkeld die hen vatbaar maken voor geloof in het bovennatuurlijke (Atran & Norenzayan, 2004; J. L. Barrett, 2000; Guthrie et al., 1980; Norenzayan, 2013). Deze theorie komt voort uit de observatie dat er elementen zijn die constant zijn over de vele verschillende vormen van bovennatuurlijk geloof (Bulbulia, 2004). Het idee is dus dat die elementen misschien een natuurlijk of logisch 'bijproduct' zijn van de menselijke cognitie (Boyer, 2003). Één element dat misschien niet volledig constant is over alle verschillende vormen van geloof, maar die wel enorm wijdverspreid is, is het geloof in bovennatuurlijke intentionele wezens, zoals goden of de ronddwalende geesten van overleden familieleden (Pyysiainen, 2009). Wetenschappers hebben tenminste twee psychologische mechanismen geïdentificeerd die mogelijk zouden kunnen verklaren waarom geloof in bovennatuurlijke wezens zo wijdverspreid is. Het doel van dit promotietraject was om deze psychologische mechanismen en hun relatie met geloof in het bovennatuurlijke nader te onderzoeken.

Het eerste psychologisch mechanisme is het 'overactieve aanwezigheidsdetectie-mechanisme' (e.g., J. L. Barrett, 2000; J. L. Barrett, 2004). Dit is een mechanisme dat de aanwezigheid van andere mensen, dieren of wezens detecteert. Dit mechanisme laat zich het best uit leggen aan de hand van een voorbeeld. Stel je bent alleen thuis, het is donker en je hoort opeens de trap kraken. Je kunt dan het beangstigende gevoel krijgen dat er iets of iemand in je huis is. Evolutionair gezien is deze interpretatie van het geluid enorm handig. Immers, hoe sneller je ontdekt dat er een ander mens, dier of wezen aanwezig is, hoe eerder je je hierop kunt voorbereiden en actie kunt ondernemen (H. C. Barrett, 2005). Vanuit evolutionair perspectief was het detecteren van andere mensen en dieren van groot belang. Het te laat detecteren van gevaarlijke dieren of tegenstanders die jou iets aan kunnen doen zou je je leven kunnen kosten. Daarnaast moet je ook dieren detecteren om aan voedsel te komen. Het idee is daarom dat er over duizenden jaren evolutie een mechanisme is ontstaan die bij het minste of geringste alarmeert dat er iets of iemand in de buurt is onder het motto – beter voorkomen dan genezen.

Een tweede psychologisch mechanisme waarvan wordt gedacht dat het mensen mogelijk vatbaar maakt om te geloven in bovennatuurlijke wezens is ons vermogen om te 'mentaliseren' (e.g., Bering, 2002; Norenzayan, Gervais, & Trzesniewski, 2012; Willard & Norenzayan, 2013). Dit houdt in dat we de intenties en gedachten van anderen proberen af te lezen aan de hand van hun gedrag (Baron-Cohen & Wheelwright, 2004). Als ik in gesprek ben met iemand en diegene loopt opeens vuurrood aan, terwijl die met een vuist op de tafel slaat, dan kan ik uit dit gedrag afleiden dat diegene boos is. Mensen schrijven voortdurend intenties en gedachten aan andere mensen toe. Ook wanneer dat totaal niet op zijn plaats is. Zo schrijven we vaak onterecht menselijke eigenschappen en intenties toe aan dieren ("Niet zo boos doen Benno!") en soms zelfs aan objecten ("K*t computer!"). Dit wordt ook wel antropomorfiseren genoemd en het stond centraal in de allereerste 'cognitieve theorie van religie' (Guthrie et al., 1980).

Dus, enerzijds detecteren we razendsnel de aanwezigheid van andere wezens en anderzijds schrijven we daar intenties en gedachten aan toe. Neem die twee psychologische mechanismen samen en je begrijpt wellicht waarom mensen vroeger geloofden dat natuurlijke fenomenen werden veroorzaakt door bovennatuurlijke mensen, oftewel goden (J. L. Barrett, 2012; J. L. Barrett & Lanman, 2008). Zo werd in vele culturen geloofd dat onweer veroorzaakt werd door een boze God. Voor de Oude Grieken was dit bijvoorbeeld Zeus, voor de Oude Germanen Wodan en in de Indiase Oudheid was het Indra. Volgens de aanhangers van de bijproduct theorie, zou het wel eens zo kunnen zijn dat die Goden zijn ontstaan omdat mensen de donderwolken interpreteerden als intentionele wezens.

Het eerste onderzoek

Voordat we de relatie konden onderzoeken tussen de twee psychologische mechanismen en geloof in het bovennatuurlijke, wilden we eerst een aantal assumpties die ten grondslag liggen aan die mechanismen nader onderzoeken. Detecteren we werkelijk zo snel de aanwezigheid van anderen (Hoofdstukken 2, 3 en 4) en schrijven we echt overal direct intenties aan toe (Hoofdstukken 2 en 6)? Wat we vonden is dat mensen wel snel de aanwezigheid van anderen kunnen detecteren, maar dat dit iets anders gebeurt dan je zou verwachten aan de hand van de overactieve-aanwezigheidsdetectiemechanismetheorie. Aan de hand van die theorie zou je namelijk mogen verwachten dat mensen in bedreigende situaties sneller de aanwezigheid van anderen detecteren. Dit zou namelijk de gevoeligheid van het mechanisme verhogen (J. L. Barrett, 2004). Om dit te onderzoeken plaatsten we mensen op verschillende manieren in bedreigende situaties (zie Hoofdstuk 2 en 3). Zo moesten ze naar dreigende plaatjes kijken, dreigende muziek luisteren of door een dreigend virtueel bos lopen. Alleen bij de meest dreigende situaties verhoogde dit een klein beetje de mate waarin mensen de aanwezigheid van anderen detecteerden. Belangrijker echter, we vonden dat de mate waarin mensen de aanwezigheid van anderen detecteerden helemaal niet samenhing met geloof in het bovennatuurlijke.

In hoofdstuk 2 en 3 keken we dus naar de ‘samenhang’ (ook wel correlatie genoemd), tussen geloof in het bovennatuurlijke en het hyperactieve aanwezigheids-detectiemechanisme. De heilige graal van experimenteel psychologisch onderzoek is echter om een variabele te manipuleren en vervolgens te kijken of het een causaal gevolg heeft op een andere variabele. Daarom probeerden we in Hoofdstuk 4 bovennatuurlijk geloof te manipuleren in het lab, om vervolgens te kijken of dit resulteerde in verhoogde aanwezigheidsdetectie. We manipuleerde bovennatuurlijk geloof met de zogenaamde ‘Godhelm’ (zie Figuur 1). Dit is een omgebouwde scooterhelm waarvan we deelnemers vertelden dat die het brein stimuleerde. Zogenaamd stimuleerden we specifieke hersengedeelten die in voorgaand onderzoek geassocieerd waren met bovennatuurlijke ervaringen, maar in feite was het een placebo manipulatie. Het brein werd dus überhaupt niet gestimuleerd. Toch kreeg een gedeelte van de deelnemers een bovennatuurlijke ervaring (in hoofdstuk 5 probeerden we dit percentage te verhogen door op Lowlands beschonken deelnemers te onderzoeken), zoals een ‘out-of-body experience’. Dit is het verschijnsel dat mensen het gevoel krijgen uit hun lichaam te treden en dit is ook echt met hersenstimulatie op te roepen (Blanke, Landis, Spinelli, & Seeck, 2004). Ondanks dat we met de helm in staat waren bovennatuurlijke ervaringen op te roepen, resulteerde dit niet in verhoogde aanwezigheidsdetectie. We vonden dus geen bewijs dat mensen een ‘overactief’ aanwezigheidsdetectiemechanisme hadden en ook bleek aanwezigheids-detectie niet gerelateerd aan bovennatuurlijk geloof of bovennatuurlijke ervaringen.

Figuur 1. Afbeelding van de manier waarop de Godhelm werd gebruikt in het lab.

Figuur 1 vervolg. De Godhelm was in dit geval een omgebouwde scooterhelm, op andere momenten een metallic skatehelm die er futuristisch uitzag. De placebohelm werd met elektrische bedradingen aan kastjes vastgemaakt, waarop lampjes knipperden. Voor aanvang van het experiment werden deelnemers uitvoerig geïnstrueerd over de zogenaamde werking van de helm en gerelateerde verschijnselen. Tijdens het experiment kregen deelnemers een slaapmasker voor de ogen en via oordopjes kregen ze witte ruis te horen, ter verhoging van sensorische deprivatie.

In hoofdstuk 2 en 6 onderzochten we de relatie tussen het tweede psychologische mechanisme, ons vermogen om te mentaliseren, en geloof in bovennatuurlijke krachten. We vonden bewijs voor de theorie dat mensen boven proportioneel vaak intenties toeschrijven aan zaken die niet eens intenties hebben. Zo lieten we mensen kijken naar filmpjes waarop geometrische figuren bewogen. Mensen bleken heel snel te denken dat die figuren elkaar 'achterna zaten' of 'pestten', zelfs als ze volledig random bewogen (Heider & Simmel, 1944). De relatie tussen mentaliseren en geloof in het bovennatuurlijke was moeilijker te bepalen. Zo vonden we in hoofdstuk 2 geen relatie tussen intentionaliteits-ratings op de geometrische figuren taak en geloof in bovennatuurlijke krachten, maar in hoofdstuk 6 wel. Verder vonden we in Nederland en Zwitserland geen relatie tussen een vragenlijst die het vermogen tot mentaliseren zou moeten weerspiegelen en geloof in bovennatuurlijke krachten, maar in Amerika vonden we wel een kleine samenhang. Echter, we vonden het voorbarig om op basis van deze bevindingen te concluderen dat het vermogen om te mentaliseren bijdraagt aan geloof in het bovennatuurlijke.

Om het belang van mentaliseren voor geloof in het bovennatuurlijke beter in perspectief te kunnen plaatsen besloten we het te vergelijken met een andere factor waarvan we er meer vertrouwen in hadden dat die bovennatuurlijk geloof beïnvloedt, namelijk sociaal leren (hier komt dus het 'socio-' in de titel vandaan). Sociaal leren houdt in dat je leert door te kijken naar een ander. Een specifiek onderdeel van sociaal leren wordt in de literatuur *'credibility enhancing displays'* (ofwel, geloofwaardigheidsverhogende handelingen) genoemd. Dit zijn gedragingen of handelingen van mensen die het geloof in het bovennatuurlijke meer of minder geloofwaardig maken. Het idee is dat wanneer mensen zich gedragen in lijn met wat ze geloven, de kans groter is dat observeerders van deze gedragingen het geloof overnemen. Dus, als je vader zegt dat hij gelooft, bidt en naar de kerk gaat, vergroot dit de kans dat jij ook gaat geloven. En omgekeerd, wanneer hij zegt te geloven, maar ondertussen vloekt met 'godverdomme' en zich immoreel gedraagt door naar de hoeren te gaan, verkleint dit de kans dat jij ook gaat geloven. Wij vonden in verschillende landen dat geloofwaardigheids-verhogende acties een zeer sterke voorspeller waren van of mensen geloven in het bovennatuurlijke. Oftewel, om te bepalen of iemand gelooft is het veel belangrijker om naar het gedrag van diens ouders te kijken dan naar diens vermogen om aanwezigheid te detecteren of te mentaliseren.

Een nieuwe theorie

In dit proefschrift staat ook een theorie uit de neurowetenschap centraal, de voorspellingstheorie, die de cognitieve wetenschap van religie recentelijk beïnvloed heeft (Andersen, Schjoedt, Nielbo, & Sørensen, 2014; Schjoedt & Andersen, 2017; Taves & Asprem, 2017; van Elk & Aleman, 2016; van Elk & Wagenmakers, 2017; Van Leeuwen & van Elk, 2017 en Hoofdstuk 3). Deze theorie kon gedetailleerder dan het 'hyperactieve aanwezigheids- detectiemechanisme' verklaren waarom mensen soms het gevoel hebben dat er een ander dier of mens aanwezig is (Andersen, 2017; Andersen, Pfeiffer, Müller, & Schjoedt, 2017). Daarnaast bood het ook nog eens een verklaring voor de vreemde ervaringen die mensen kregen tijdens het dragen van de God helm (Andersen et al., 2014 en Hoofdstuk 5). In deze voorspellingstheorie wordt ervanuit gegaan dat je brein een soort voorspellingsmachine is. Waar men vroeger dacht dat je brein vrij passief inkomende sensorische informatie zoals licht en geluid verwerkt, begrijpt men tegenwoordig dat je brein aan de hand van eerder opgeslagen informatie constant de sensorische informatie probeert te voorspellen (Clark, 2013; Friston, 2005; Friston & Kiebel, 2009). Die opgeslagen informatie stapelt zich al op vanaf je geboorte omdat je brein interacteert met de omgeving. Zo wordt een steeds beter model gevormd van hoe de wereld werkt en hoe het eruit ziet. Dat model wordt vervolgens gebruikt om voorspellingen te maken over de sensorische informatie die je waarneemt. Dat is heel energie-efficiënt, want op deze manier hoeft je brein niet constant alle informatie te verwerken, maar alleen het verschil te berekenen tussen het model en de inkomende informatie. Dit verschil, ook wel de voorspellingsfout genoemd, wordt vervolgens weer gebruikt om het model aan te passen.

Wat je waarneemt hangt dus niet alleen af van sensorische input uit de omgeving, maar ook van je model en je verwachtingen. Dit kan als gevolg hebben dat wanneer je model een heel sterke verwachting heeft, terwijl de sensorische informatie onduidelijk is, je dingen anders kunt interpreteren dan ze daadwerkelijk zijn. Dus als ik net een horrorfilm heb gekeken en het is donker in huis, dan is de kans groter dat ik een krakende trap interpreteer als de aanwezigheid van een moordenaar, dan wanneer ik geen film heb gekeken en het licht is (zie Hoofdstuk 3). Aan de hand van het voorspellingsmodel kun je ook verklaren waarom mensen bovennatuurlijke ervaringen kunnen krijgen door de Godhelm (Andersen et al., 2014 en Hoofdstuk 5). We verhoogden namelijk enorm de verwachtingen van deelnemers. Ze werden rondgeleid langs een fMRI-scanner door onderzoekers die witte medische jassen droegen, ze werden met draden verbonden aan apparaten, ze kregen tekst en uitleg over hoe de helm zogenaamd werkt en ze kregen een filmpje te zien van een professor die vertelde over haar ervaringen met de helm. Daarnaast reduceerde we de sensorische input. Deelnemers werden geblinddoekt en ze luisterden naar witte ruis. De combinatie van sterke voorspellingen en gereduceerde sensorische input waardoor voorspellingsfouten uitbleven en de focus geconcentreerd bleef op gedachten, resulteerde bij een gedeelte van de deelnemers in bovennatuurlijke ervaringen.

Probeer nu eens situaties voor te stellen waarin mensen bovennatuurlijke ervaringen krijgen, zoals tijdens spirituele seances, in verlaten ‘spook’-huizen en bij charismatische spirituele leiders. Vrijwel altijd worden de verwachtingen voor bepaalde ervaringen verhoogd zodat je brein sterke voorspellingen maakt, terwijl de mogelijkheid voor je brein om de voorspellingen te controleren drastisch wordt verlaagd door de sensorische input te vertroebelen. Het is dan ook niet vreemd dat onderzoekers vonden dat bovennatuurlijke ervaringen meestal op enge en donkere plekken voorkwamen (Barnes & Gibson, 2013). De voorspellingstheorie kan dus verklaren waarom mensen soms bovennatuurlijke ervaringen krijgen, maar ook waarom we soms denken dat er iets of iemand anders aanwezig is.

Conclusie

We onderzochten twee psychologische mechanismen die mogelijk hebben bijgedragen aan de mate waarin intentionele wezens voorkomen in de verschillende vormen van bovennatuurlijk geloof. We vonden dat aanwezigheidsdetectie eigenlijk helemaal niet zo hyperactief is. Wel vonden we dat mensen vaak geneigd zijn te mentaliseren. Voor mentaliseren lijkt het dus aannemelijker dat het bijdraagt aan waarom het geloof in intentionele wezens zo wijdverspreid zijn. Beide psychologische mechanismen bleken echter niet gerelateerd aan waarom mensen geloven in het bovennatuurlijke, in tegenstelling tot wat onderzoekers verwachtten aan de hand van de bijproduct theorie. De reden waarom mensen überhaupt geloven blijkt vooral goed verklaard te worden door sociaal leren. Alleen kun je daar niet mee verklaren waarom mensen ooit zijn begonnen met geloven. Op die vraag konden we dus geen bevredigend antwoord vinden. Dat we soms de aanwezigheid van anderen waarnemen, vaak mentaliseren en sommige mensen bovennatuurlijke ervaringen denken te hebben kon vooral goed verklaard worden door de voorspellingstheorie. Door ons leven lang interacteren met de wereld hebben we mentale modellen ontwikkeld, en die modellen beïnvloeden op hun beurt hoe we de wereld interpreteren.

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