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Priming of supernatural agent concepts and agency detection

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In evolutionary approaches to religion it is argued that belief in supernatural agents is strongly related to a perceptual bias to over-detect the presence of agents in the environment. We report five experiments that investigate whether processing concepts about supernatural agents facilitates agency detection. Participants were presented with point-light stimuli representing unscrambled or scrambled biological motion, or with pictures of unscrambled or scrambled faces, embedded in a noise mask. Participants were required to indicate for each stimulus whether it represented a human agent or not. Each trial was preceded by a supernatural agent prime, a human agent prime, or an animal prime. Our results showed that primes referring to humans facilitated the detection of agency. More importantly, however, results did not reveal a general effect of supernatural priming on agency detection. In three experiments, a moderating effect of religiosity was observed: supernatural agent primes had a differential effect for religious compared to non-religious participants on agency detection biases and the speed of responding to agent-like stimuli. These findings qualify the relation between supernatural beliefs and agency detection and suggest that when supernatural agent concepts have been acquired through cultural learning, these concepts can modulate agency-detection biases.

Keywords: agency detection; biological motion detection task; face/house categorization task; religion; semantic priming; supernatural beliefs

1. Introduction

One of the most remarkable characteristics of the human species is the ability to engage in religious thought and behavior. People of all times and cultures have built churches and temples, written religious stories, invented complex belief systems, and performed elaborate and often costly religious rituals, such as offering nutritious food, money or even one's life. Across the world, most people believe in a supernatural agent (e.g., God) and often report religious or spiritual experiences (e.g., Pollack, 2008), despite decades of secularization and an overall decline in church attendance. It has been found that religious faith has positive effects on mental and physical well-being (Koenig, McCullough, & Larson, 2001; Levin, 2009) and religiosity has also been associated with prosocial behavior (e.g., Saroglou, Pichon, Trompette, Verschueren, & Dernelle, 2005). As these examples illustrate, religion is often an important part of people's life and behavior.

The last decade has seen a renewed interest in understanding the cognitive and psychological basis of religious thought and behavior. The so-called *cognitive science of religion* (CSR) starts from an evolutionary account and describes religion as a byproduct of the functioning of our ordinary cognitive faculties (Atran & Norenzayan, 2004; Barrett & Burdett, 2011; Boyer & Lienard, 2006; Lawson, 2012; Pyysiainen, 2012). According

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to this account, religious beliefs, experiences, and rituals recruit similar cognitive resources as used in everyday practices (judgment, reasoning, action, and social interaction) that originally evolved because they directly conferred an adaptive advantage. With respect to the belief in supernatural agents, it is argued that these beliefs are related to basic cognitive mechanisms that foster the detection of agency.

From an evolutionary perspective, failing to detect the presence of a pattern and/or a specific agent (i.e., a false negative) is often more costly than incorrectly assuming the presence of a pattern or agent (i.e., a false positive). For instance, imagine yourself walking through a forest at night. If you were to see movement in the bushes you could infer that there is another agent (e.g., a predator) and take a different route. The costs associated with incorrectly inferring the presence of another agent (e.g., you take a different route but there is no other agent) are less than the costs associated with incorrectly inferring the absence of another agent (e.g., you follow the same path and there is a predator). As the example illustrates, in the case of ambiguous sensory information, the safest option is to infer the presence of other agents. Following this line of reasoning, it has been suggested that in our ancestral past a hyperactive agency detection device (HADD) evolved, such that our perceptual systems are biased toward detecting the presence of patterns and agents in the environment (Haselton & Nettle, 2006).

Theorists within CSR hypothesize that these perceptual and cognitive mechanisms to detect patterns and agency are associated with the experience of and belief in supernatural agency (Barrett, 2000, 2011; Guthrie, 1980, 1993). The perceived presence of agents in potentially threatening situations and the anthropomorphic interpretation of ambiguous information may reinforce people's belief in the presence of supernatural agents, such as ghosts, spirits, or gods. Examples of anthropomorphism in religion abound: people worship manmade and natural objects and invisible deities with human-like characteristics. Thus, religious beliefs in supernatural agents are considered a byproduct of the false positives that are generated by the HADD (Barrett & Lanman, 2008). Belief in supernatural agents may also facilitate the detection of agency (Barrett & Lanman, 2008). For instance, if someone tells you that you are about to enter a haunted house, you would probably be more prone toward perceiving agents. Accordingly, it has been suggested that a bidirectional relation should exist between supernatural beliefs and agency-detection biases (Barrett & Lanman, 2008).

Several empirical studies have indicated that situational factors can facilitate agency detection. These findings support the suggestion that the HADD is most likely activated in potentially threatening or ambiguous circumstances. For instance, anthropomorphism, i.e., the tendency to project human-like agency to the world, is enhanced when people are feeling lonely (Epley, Waytz, Akalis, & Cacioppo, 2008), or when the perceived predictability of a nonhuman entity is low (Waytz et al., 2010). Related findings were obtained by Valdesolo and Graham (2014), who found that the experience of awe induced belief in supernatural agents and that this effect was mediated by feelings of uncertainty (Valdesolo & Graham, 2014). Other studies focused on individual predictors of supernatural beliefs and agency-detection biases (Barnes & Gibson, 2013; Petrican & Burris, 2012; Riekki, Lindeman, Aleneff, Halme, & Nuortimo, 2013; van Elk, 2013; Willard & Norenzayan, 2013). These studies revealed that individual differences in paranormal beliefs are a reliable predictor of illusory perceptions of faces (Riekki et al., 2013) and agency detection (van Elk, 2013). A related finding is that the tendency to anthropomorphize is a predictor of paranormal beliefs (Willard & Norenzayan, 2013).

Although these studies provide tentative support for the relation between agency detection and supernatural beliefs, the notion that religious beliefs are a byproduct of

perceptual biases to detect patterns and agency has been challenged by several authors (Bulbulia, 2004; Lisdorf, 2007; Mckay & Efferson, 2010; Weingarten & Chisholm, 2009). First, it is often pointed out that there is no *direct* empirical evidence for the existence of a HADD and its presumed relation with religious beliefs (Barnes & Gibson, 2013; Saler, 2010). For instance, it has been found that agency detection and anthropomorphism were related to paranormal but not to religious beliefs (van Elk, 2013; Willard & Norenzayan, 2013). Without solid empirical evidence, the religion-as-byproduct hypothesis remains nothing more than a "just-so-story"; i.e., a possible but not necessarily correct interpretation of our evolutionary past (Gould, 1985).

Other evidence also casts doubts on the presumed relationship between HADD and religious beliefs. McKay and Dennett (2009) and McKay and Efferson (2010) argued that evolution had a major impact on human adaptive behavior but not necessarily on adaptive beliefs. Accordingly, humans could be characterized by behavioral biases to avoid potentially threatening situations, without the accompanying perceptual and cognitive biases or (supernatural) beliefs. Furthermore, the notion that supernatural beliefs are a byproduct of other cognitive processes stands in contrast to the view that religion provides a direct evolutionary advantage (Norenzayan & Shariff, 2008; Pyysiainen & Hauser, 2010; Sosis, 2003, 2004). For instance, belief in supernatural punishment may have developed because it provided an adaptive advantage by facilitating cooperation (Norenzayan & Shariff, 2008).

In sum, the hypothesized relation between agency-attribution biases and supernatural beliefs is based on a variety of evolutionary, anthropological, and philosophical arguments (Atran & Norenzayan, 2004; Bering, 2006; Boyer, 2003; Boyer & Lienard, 2006; Lawson & McCauley, 2000). However, the specific claim that supernatural agent concepts are associated with perceptual agency-detection biases still stands in need of empirical support. In the current work, we experimentally investigated the relation between supernatural agent concepts and perceptual agency detection by using well-established methods from social and cognitive psychology. In a series of studies, we investigated whether the activation of concepts related to supernatural agents results in agency-detection biases, which should be expected if indeed a bidirectional relation exists between supernatural agent concepts and agency-detection biases (Barrett & Lanman, 2008). We used semantic priming as a well-established method to activate concepts from semantic memory (Masson, 1995; Neely, 1991).[1] Participants were presented with words referring to supernatural agents (e.g., God or Devil) or natural agents (e.g., animals or humans). Typically, in semantic priming experiments the presentation of a word (i.e., the "prime") facilitates the processing of subsequently presented words, pictures, or concepts (i.e., the "target stimulus") that are related (Sperber, Mccauley, Ragain, & Weil, 1979; van Elk, van Schie, & Bekkering, 2009). Similarly, we expected that the presentation of words referring to supernatural agents should induce agency-detection biases.

Throughout the literature, different authors have used different operationalizations of the supposed relation between agency detection and supernatural beliefs. In his seminal work, Guthrie (1980, 1993) argues that *perceptual biases* to over-detect the presence of other agents (e.g., other humans or animals) are at the basis of belief in supernatural agents. Most of the examples discussed in Guthrie's work include classic cases of pareidolia; i.e., illusory face recognition, such as seeing faces in clouds or trees. With Barrett's introduction of the notion of a *hyperactive agency detection device* (HADD; Barrett, 2000) the definition of "agency detection" shifted from a perceptual level to a more *intentional level*, reflecting people's tendency to generate intentional explanations for phenomena. A classic example of intentional agency detection concerns the

attribution of intentions in response to the observation of moving geometrical figures (Heider & Simmel, 1944). In this case, the presence of an intentional agent and the attribution of intentions are inferred based on the movements observed (Blakemore & Decety, 2001). In line with this broader notion of agency detection, other authors have argued that supernatural beliefs are related to *anthropomorphism* (Epley et al., 2008), *teleological reasoning* (Kelemen, Rottman, & Seston, 2013), and *theory-of-mind reasoning* or *mentalizing* (Riekki, Lindeman, & Raij, 2014; Schjoedt, Stodkilde-Jorgensen, Geertz, & Roepstorff, 2009; Willard & Norenzayan, 2013). Each of these mechanisms may play a role in supernatural and religious beliefs. In our view, however, the evolutionary argument that supernatural beliefs can be considered a byproduct of the false positives generated by a cognitive decision-making process fits best with the notion of an agency-detection bias at a perceptual level (i.e., false positives reflect a perceptual bias that could confer an adaptive advantage).

In the present study, we used two perceptual decision-making tasks to measure the effects of supernatural priming on agency-detection biases: the biological motion detection task (Experiment 1 and 2) and the face/house categorization task (Experiment 3–5). In the biological motion detection task, participants were presented with point-light displays representing unscrambled or scrambled human motion under different levels of visual noise (for a similar method, see van Elk, 2013). Participants were required to indicate whether or not they believed a human agent was present in the display. Using signal detection analysis (Green & Swets, 1966; Macmilan & Creelman, 2005), their perceptual sensitivity and their response bias toward detecting human agency could be determined. In the face/house categorization task, participants were presented with pictures of faces or houses under different levels of visual noise (Heekeren, Marrett, Bandettini, & Ungerleider, 2004), and analysis focused on the percentage of correctly identified faces and houses as a measure of agency-detection biases (e.g., perceiving more faces in house stimuli).[2] By systematically manipulating the different levels of visual noise in our stimuli, the boundary conditions for illusory agency detection could be assessed (i.e., to determine whether illusory agency detection selectively occurs for ambiguous stimuli; cf. van Elk, 2013). In all our experiments we used a within-subjects priming manipulation; thus all participants were presented with both supernatural and control primes. A prime word from either category (i.e., supernatural or control) was presented on each trial and preceded the presentation of a target stimulus (i.e., a biological motion stimulus or a face/house picture). Following the hypothesized relation between belief in supernatural agents and agency detection (Barrett & Lanman, 2008), we predicted that primes referring to supernatural agents should result in more illusory agency detection, reflected in a response bias toward reporting human agents.

Next, we examined the role of individual differences in religiosity and supernatural beliefs in relation to agency detection and the effects of priming on agency detection. As discussed above, previous studies have shown that individual differences in religious and paranormal beliefs are associated with differential agency-detection biases (Barnes & Gibson, 2013; Petrican & Burris, 2012; Riekki et al., 2013; van Elk, 2013; Willard & Norenzayan, 2013). Other studies have indicated that supernatural priming can have a differential effect on believers and nonbelievers (e.g. Inzlicht & Tullett, 2010). Accordingly, by taking into account individual differences in religiosity, we investigated to what extent the effects of supernatural priming on agency detection are universal (i.e., reflecting general associations) or related to religious engagement (i.e., reflecting culture-specific learning experiences related to one's religious upbringing; Boyd & Richerson, 1988; Gervais, Willard, Norenzayan, & Henrich, 2011; Hood, Hill, & Spilka, 2009).

Furthermore, following the notion that individual differences in agency detection are related to supernatural beliefs (Barnes & Gibson, 2013; Riekki et al., 2013; van Elk, 2013), we investigated whether illusory agency detection was associated with belief in God – irrespective of the priming manipulation.

2. Experiment 1: biological motion detection task

2.1. Method

2.1.1. Participants

In the first experiment, 40 students at the École Polytechnique Fédérale de Lausanne in Switzerland participated (25 males; mean age = 22.6 years). Participants received 10 Swiss francs for their participation in the experiment.

2.1.2. Materials and procedure

As semantic primes, we used eight words referring to supernatural agents and eight words referring to animals (see Table 1). These stimuli were selected based on a pretest in which 15 students – who did not participate in the main experiment – were required to rate an initial list of words on a five-point Likert scale based on: (1) agency (i.e., "does the word represent an active or a passive agent?"; *1 = active agent, 5 = passive agent*); (2) valence (i.e., "does the word represent a positive or a negative agent?"; *1 = positive, 5 = negative*); and (3) religiosity (i.e., "does the word refer to a religious or a nonreligious agent?"; *1 = non-religious, 5 = religious*). Based on the pretest, the word categories (i.e., supernatural agents vs. animals) were matched for agency (supernatural agents: 4.3; animals: 4.3; $t(14) = 0.0$, $p = 1.0$) and valence (supernatural agents; 3.5; animals: 4.2; $t(14) = -1.3$, $p = .23$), while both categories differed in religiosity ratings (supernatural agents: 4.7; animals: 1.5; $t(14) = 15.5$, $p < .001$).

Point-light stimuli were generated using the software package PointLightLab. The target stimulus consisted of an animated point set of 12 points, representing a human avatar walking on a treadmill at a pace of about 1.5 steps per second (for examples of stimuli, see supplementary material online). Animated noise points were generated by using the motion drawn from the same animation source and by randomly scrambling the location of each individual dot across the display. In 50% of the stimuli an unscrambled walker was presented; in the other 50% a scrambled walker was presented. The walker could appear at five different horizontal locations (i.e., −10°, −5°, 0°, 5°, and 10° with respect to the center of the screen) and could be walking in a left or right direction. Six

Table 1. Prime stimuli used in Experiment 1, referring to supernatural agents or to animals.

Supernatural agents	Animal words
god	horse
angel	cat
demon	dog
ghost	pigeon
spirit	duck
devil	sheep
ghoul	goldfish
phantom	cow

different levels of animated noise points were added to each stimulus (12, 24, 48, 96, 192 and 384 noise points). A total of 120 different biological motion stimuli were used in the experiment. Stimuli were designed in terms of the following factors: Walker (Unscrambled vs. Scrambled); Location (−10°, −5°, 0°, 5°, 10°); Direction (Left vs. Right); and Noise Level (12, 24, 48, 96, 192, 384). Each stimulus was presented twice (i.e., once preceded by a supernatural agent prime and once preceded by an animal prime); so for each noise level and each experimental condition there were 10 trials in which a signal was present (unscrambled walker) and 10 trials in which no signal was present (scrambled walker). All stimuli were presented against a black background at a resolution of 1024 x 768 pixels and the experiment was programmed using Presentation software (Neurobehavioral Systems, Albany, CA, USA).

An overview of the experimental procedure is presented in Figure 1. Each trial started with the presentation of a prime word, to which subjects responded by a semantic categorization judgment (van Elk et al., 2009; van Elk, van Schie, & Bekkering, 2010). Participants were required to press a button with their index or middle finger depending on the word category (i.e., supernatural agent vs. animal words; the mapping of the response buttons was counterbalanced across participants). To allow the participant sufficient time to respond, the word was presented for a maximum duration of 4000 ms (Schoonbaert & Grainger, 2004). By using a semantic categorization task, we ensured deep semantic processing of the words.

Next, after a 500 ms blank screen, a point-light stimulus was presented for 2000 ms. Following the presentation of the point-light display, participants were required to indicate whether or not they believed a human agent was present by pressing a button with their index or middle finger. The response mapping (i.e., yes vs. no) was displayed on the screen to remind participants of the task instructions and the mapping of response buttons was counterbalanced across participants. The next trial was initiated after a variable interval of 2000–3000 ms.

At the beginning of the experiment, participants were instructed that they were going to see short movies in which a human walking figure may or may not be present. In order to establish that all participants were able to correctly identify the walker, before the start of the experiment an example movie of an unscrambled walker was shown until participants indicated that they recognized the human walking figure. Before the start of the experiment, participants performed 10 practice trials to familiarize themselves with the task. For some participants, practice was repeated if necessary. In total the experiment consisted of 240 trials (120 point-light stimuli x 2 different primes) that were presented in a random order and the experiment lasted about 45 minutes. At the end of the experiment, participants completed a question to assess their self-reported religiosity ("To what extent do you consider yourself to be religious?"; *1 = not at all, 7 = very much*) and their belief in God ("To what extent do you believe in God?"; *1 = not at all, 7 = very much*).[3]

Using signal detection analysis (Green & Swets, 1966; Macmilan & Creelman, 2005), we calculated *d'* as a measure of the perceptual sensitivity (i.e., how well do people distinguish signal from noise?) and the response criterion *c* as a measure of the response bias (i.e., to what extent are people biased toward saying "yes"?). The responses to the biological motion detection task were analyzed using a repeated measures analysis of variance (ANOVA) with the factors Prime (Supernatural Agent vs. Animal) and Noise Level (12, 24, 48, 96, 192, 384). The main analysis focused on the biological motion detection task to investigate whether supernatural agent compared to animal primes would make participants more biased toward seeing human agency. This bias

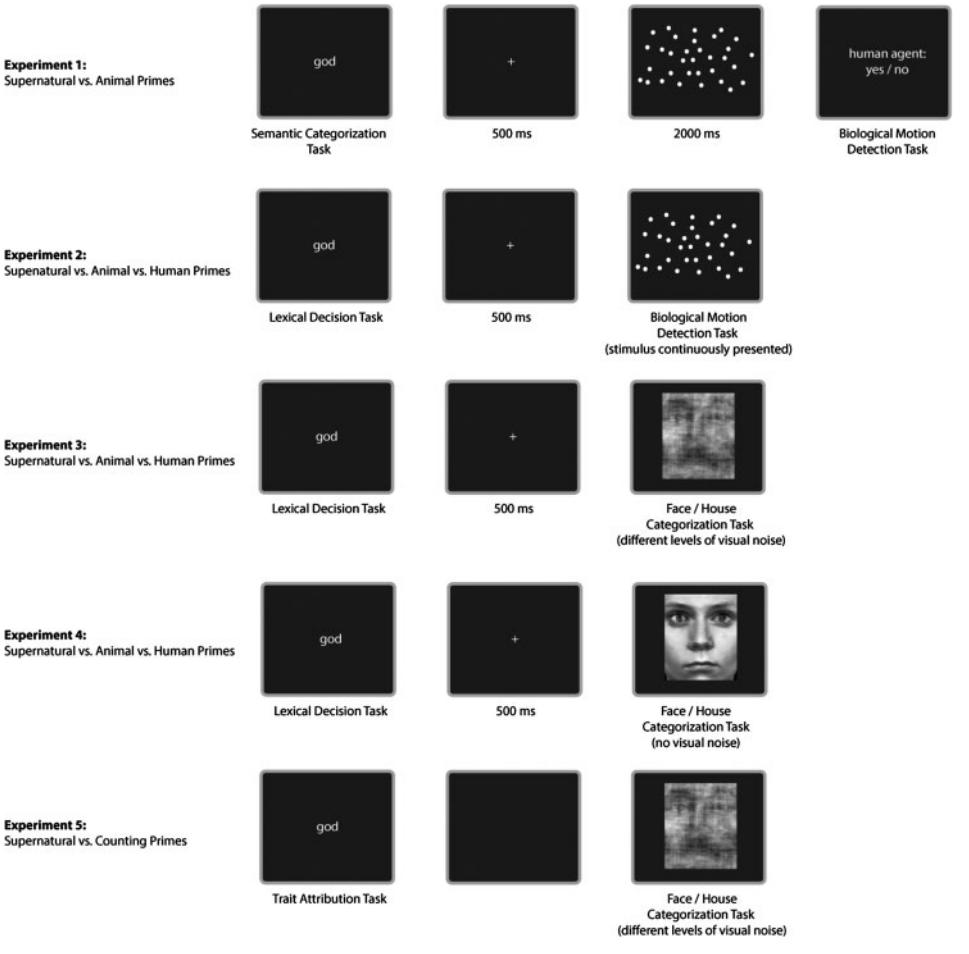

Figure 1. Overview of the experimental procedure in the different experiments.
Note: All experiments investigate the effects of priming individuals with supernatural agent concepts on agency detection. An overview of the different experimental paradigms is represented here. In Experiment 1, supernatural agent concepts were activated by using a semantic categorization task; in Experiments 2–4, supernatural agent concepts were activated by using a lexical decision task; and in Experiment 5, supernatural agent concepts were activated by using a trait attribution task. In Experiments 1 and 2, we used a biological motion detection task as our dependent measure and in Experiments 3–5 we used a face/house categorization task as our dependent measure. Experiment 3 was conducted twice: once with a student population (Experiment 3A) and once with visitors of a paranormal fair (Experiment 3B).

should become apparent in a main effect of prime and/or an interaction between prime and visual noise.

2.2. Results

2.2.1. Perceptual sensitivity and response bias

Incorrect responses to the semantic categorization task occurred on average in 2.8% of all trials. Results from the first experiment are presented in Figure 2. As can be seen, perceptual sensitivity decreased with increased levels of visual noise ($F(5, 195) = 241.7$,

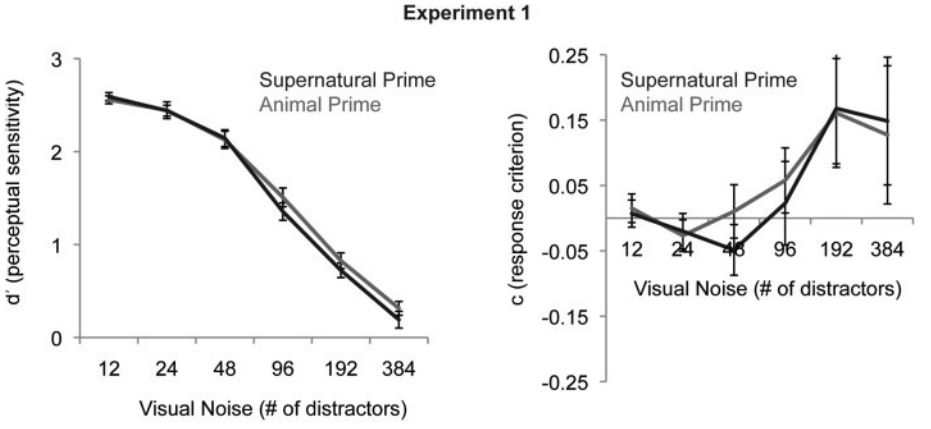

Figure 2. Results from Experiment 1.
Note: The left graph represents the perceptual sensitivity (*d'*) as a function of the number of visual distractors and according to whether the biological motion display was preceded by a supernatural agent prime (black line) or an animal prime (grey line). The right graph represents the response bias (*c*) as a function of the number of visual distractors and according to whether the biological motion display was preceded by a supernatural agent prime (black line) or an animal prime (grey line). Error bars represent standard errors.

$p < .001$, $\eta^2 = .86$). There was no effect of the semantic prime on the perceptual sensitivity ($F(1, 39) = 2.3$, $p = .14$, $\eta^2 = .06$), and the prime did not interact with visual noise ($F < 1$). For the response bias, a main effect of visual noise ($F(5, 195) = 3.3$, $p < .05$, $\eta^2 = .08$) indicated that with increased levels of visual noise participants showed a small bias toward reporting the absence of a human figure. Priming did not have an effect on response bias ($F < 1$).

2.2.2. Bayesian statistics

Because the ANOVA results do not warrant conclusions in favor of the null hypothesis, the effects of Prime on response bias were further analyzed using Bayesian statistics (Masson, 2011; Wagenmakers, 2007). Recently, the Bayesian approach has been proposed as an alternative to classical null-hypothesis testing, as it can directly assess the relative strength of evidence for the null and the alternative hypothesis ($p(H_0{:}D)$ and $p(H_1{:}D)$), rather than providing an estimate of the likelihood of the data given the null hypothesis ($p(D{:}H_0)$) (Masson, 2011). The Bayesian information criterion (BIC) is typically used to quantify a model's goodness of fit to the data (Wagenmakers, 2007), but the difference between the BIC values for two competing models (i.e., the null vs. the alternative hypothesis) can also be used to calculate the posterior probability favoring the null hypothesis. In this way, the plausibility of the null and the alternative hypothesis given the observed data can be assessed at a group level of analysis.

The posterior probability favoring the null hypothesis was $p_{BIC}(H_0{:}D) = .84$ for the main effect of Prime and $p_{BIC}(H_0{:}D) = 1.0$ for the interaction between Prime and Visual Noise. BIC values between .75 and .95 are considered positive evidence in favor of the null hypothesis and BIC values higher than .95 are considered to provide strong to very strong evidence in favor of the null hypothesis (Masson, 2011).[4] Thus, the data from the first experiment provide positive to strong evidence that supernatural agent primes do *not* have a general effect on agency detection.

2.2.3. Religiosity as moderator

Including self-reported religiosity as covariate in the analysis did not reveal a moderating effect of religiosity on our dependent measures ($F < 2.4$, $p = .13$). Including "belief in God" as a covariate in the analysis of the perceptual sensitivity revealed a marginally significant interaction between Prime and Belief in God ($F(1, 38) = 3.5$, $p = .069$, $\eta^2 = .08$) and between Noise and Belief in God ($F(5, 190) = 2.9$, $p < .05$, $\eta^2 = .07$). These effects reflected that believers compared to skeptics showed a reduced perceptual sensitivity following supernatural primes, and that believers compared to skeptics showed a reduced perceptual sensitivity for ambiguous stimuli.[5] No effects on the response bias were observed.

2.3. Discussion

In the first experiment, no effect of supernatural agent primes on agency detection was observed. Following each prime word, participants responded to a point-light stimulus that was presented for a fixed interval of 2000 ms and participants were required to make a decision about the presence or absence of a human agent. However, it could well be that this fixed interval was too short to allow for the induction of illusory pattern perception. This suggestion is supported by the relatively low proportion of false alarms (13.6% of all trials in which no human walker was present) compared to the proportion of misses (22.2% of all trials in which a human walker was present), indicating a conservative response tendency. Previous studies on illusory pattern perception have shown that a stimulus may need to be presented for a prolonged interval for superstitious or illusory perceptions to occur (Gosselin & Schyns, 2003; Whitson & Galinsky, 2008). To investigate whether the absence of a priming effect in the first experiment was related to the duration of the presentation of the point-light stimuli, in a second experiment the same stimuli were presented for a prolonged interval.

3. Experiment 2: biological motion detection task

3.1. Method

3.1.1. Participants

A total of 35 students of the University of Amsterdam participated (11 males; mean age = 24.6 years). Participants received €10 or course credits for their participation in the experiment.

3.1.2. Materials and procedure

As semantic primes, we used 14 Dutch words referring to supernatural agents, 14 words referring to human agents, and 14 words referring to animals (see Table 2). The inclusion of words referring to human agents in addition to animal words provides a proof-of-concept of the experimental paradigm (i.e., does semantic priming with words referring to human agents compared to animal agents bias the detection of human agents in a biological motion detection task?). The word stimuli were selected based on a pretest in which 18 students – who did not participate in the experiment – were required to rate an initial list of words on a five-point Likert scale based on: (1) valence (i.e., "does the word represent a positive or a negative agent?"; *1 = negative 5 = positive*); and (2) imaginability (i.e., "how easy is it to imagine the referent of the word?"; *1 = difficult to imagine, 5 = easy to imagine*). In addition, we used data from the Celex Lexical Database

Table 2. Prime stimuli used in Experiments 2–5, referring to supernatural agents, to humans or to animals.

Supernatural agent words	Human words	Animal words
demon (demon)	lawyer (advocaat)	eel (aal)
devil (duivel)	clown (clown)	bear (beer)
angel (engel)	dentist (tandarts)	snake (slang)
phantom (fantoom)	beggar (zwerver)	shark (haai)
spirit (geest)	dustbin man (vuilnisman)	cockroach (kakkerlak)
god (god)	landlord (huisjesmelker)	frog (kikker)
goddess (godin)	hunter (jager)	jelly fish (kwal)
golem (golem)	man (man)	ant (mier)
poltergeist (poltergeist)	soldier (soldaat)	scorpion (schorpioen)
satan (satan)	clown (nar)	bat (vleermuis)
Shade (schim)	drunk (dronkaard)	rat (rat)
Ghost (spook)	vandal (vandaal)	crocodile (krokodil)
Phantasm (verschijning)	junk (junk)	rabbit (konijn)
Zombie (zombie)	torturer (beul)	sheep (schaap)

to obtain information about the lexical frequency of the words (Burnage, 1990). Accordingly, the different word categories were matched for valence (supernatural agent words: 2.5; human words: 2.4; animal words: 2.5), for lexical frequency, and for word length. The word categories could not be matched for imaginability (supernatural agent words: 2.6; human words: 4.1; animal words: 4.7), as supernatural agents were typically more difficult to imagine than humans or animals. In addition to these stimuli, 42 pseudo-words were created for the lexical decision task that matched the target stimuli in word length and that adhered to Dutch orthographic rules.

Similar to the first experiment, point-light stimuli represented scrambled or unscrambled biological motion under different levels of visual noise. To shorten the total duration of the experiment, only four different noise levels were used (i.e., 24, 48, 96, and 192 visual distractors). These noise levels still allowed us to determine how perceptual sensitivity changes as a function of the level of visual noise.

An overview of the experimental procedure is presented in Figure 1. Participants were first presented with a word referring to a supernatural agent, a human, an animal, or with a pseudo-word. Participants performed a lexical decision task and were instructed to respond only to pseudo-words that were presented for 1500 ms or until the subject responded (Kerns & Berenbaum, 2000). In this way it was ensured that participants would pay attention to the target words, without having to respond to these critical words – thereby avoiding the possibility of response priming (i.e., bias to press the same button twice). Following the presentation of the word, a fixation cross appeared for 500 ms, followed by the presentation of a point-light display, which remained on the screen for a maximum of 1000 ms. Participants were instructed to indicate whether or not they believed a human agent was present, by pressing the left or the right response button. The mapping of response buttons was counterbalanced across participants.

Before the start of the experiment, participants performed 10 practice trials to familiarize themselves with the task. In total, the experiment consisted of 564 trials: 84 filler trials in which a pseudo-word was presented and 480 target-trials in which a word

referring to a supernatural agent, a human, or an animal was presented. For each word category, 160 stimuli were presented according to the following factors: Walker (Unscrambled vs. Scrambled); Location (−10°, −5°, 0°, 5°, 10°); Direction (Left vs. Right), Noise Level (24, 48, 96, 192) and each stimulus was repeated twice. Thus for each noise level and for each stimulus category (i.e., supernatural agent, human, or animal prime) there were 20 trials in which a signal was present and 20 trials in which a signal was absent. In total the experiment took about one hour. At the end of the experimental task, participants completed questions to assess their religiosity ("To what extent do you consider yourself to be religious?"; *1 = not at all, 7 = very much*) and their belief in God ("To what extent do you believe in God?"; *1 = not at all, 7 = very much*).

3.2. Results

3.2.1. Perceptual sensitivity and response bias

Missed responses to the lexical decision task occurred on average in 1.6% of all trials and false alarms occurred in less than 1% of all trials. Results from the second experiment are presented in Figure 3 and the data were analyzed using a repeated measures ANOVA with the factors Prime (Supernatural, Human, Animal) and Noise Level (24, 48, 96, 192 distractors). Analysis of the perceptual sensitivity (*d'*) revealed a main effect of Noise Level ($F(3, 102) = 108.7$, $p < .001$, $\eta^2 = .76$), indicating that perceptual sensitivity decreased with increased noise. There was a marginally significant effect of Prime ($F(2, 68) = 3.1$, $p = .052$, $\eta^2 = .08$), indicating that following human primes, participants showed a slightly reduced perceptual sensitivity ($d' = 1.57$) compared to supernatural primes ($d' = 1.63$) and animal primes ($d' = 1.66$). Prime did not interact with Noise Level ($F < 1$).

Overall, participants showed a response bias toward saying "yes" (reflected in negative values for the response criterion *c*), indicating that the longer stimulus

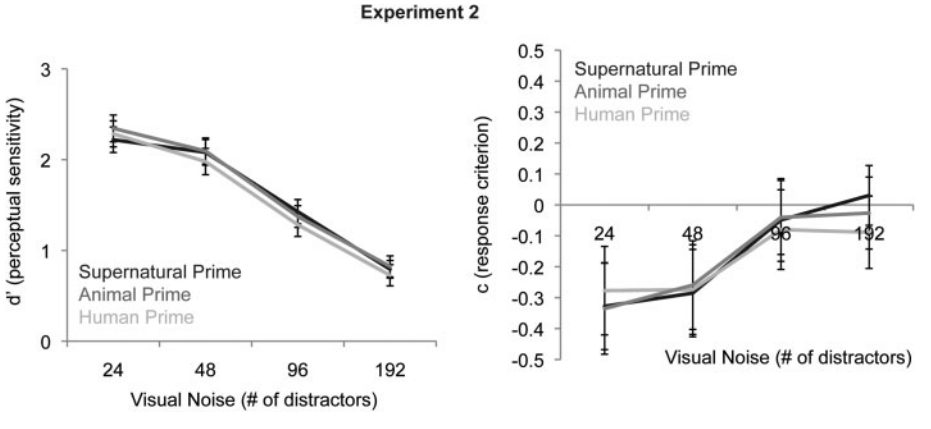

Figure 3. Results from Experiment 2.
Note: The left graph represents the perceptual sensitivity (*d'*) as a function of the number of visual distractors and according to whether the biological motion display was preceded by a supernatural agent prime (black line), an animal prime (dark grey line), or a human prime (bright grey line). The right graph represents the response bias (*c*) as a function of the number of visual distractors and according to whether the biological motion display was preceded by a supernatural agent prime (black line), an animal prime (dark grey line), or a human prime (bright grey line). Negative values indicate a response bias toward saying "yes." Error bars represent standard errors.

presentation induced more illusory pattern perception compared to the first experiment. For the response criterion, results showed a significant main effect of Noise ($F(3, 102) = 2.2$, $p < .001$, $\eta^2 = .34$), reflecting a reduced response bias for stimuli with an increased number of visual distractors. A significant interaction was found between Prime and Noise ($F(6, 204) = 2.3$, $p < .05$, $\eta^2 = .06$). As can be seen in Figure 3, this interaction was driven primarily by a stronger response bias for the "yes" response for ambiguous point-light displays (192 distractors) following human primes, as compared to supernatural agent primes ($t(34) = 2.9$, $p < .01$) and animal primes ($t(34) = 1.7$, $p = .09$).

These findings provide a "proof-of-concept" of our experimental paradigm, indicating that the perception of ambiguous stimuli can be influenced by semantic primes. More specifically, people showed a slightly stronger response bias toward detecting illusory human agents following the reading of words referring to a human agent, compared to words referring to supernatural agents or animals. It needs to be added, however, that we did not observe a priming effect for words referring to supernatural agents.

3.2.2. Bayesian statistics

As the main effects in this experiment seemed to be driven by human primes, we directly compared supernatural agent with animal primes on the response bias in an additional analysis. Results did not show any difference between these two primes on the response bias ($F < 1$). The posterior probability favoring the null hypothesis was $p_{BIC}(H_0{:}D) = .85$ for the main effect of prime and $p_{BIC}(H_0{:}D) = .99$ for the interaction between prime and visual noise. This provides positive evidence for the null hypothesis that supernatural priming did not modulate agency detection (Masson, 2011).

3.2.3. Religiosity as moderator

Including self-reported religiosity as a covariate to the analysis did not reveal any interactions between the covariate and the experimental task, neither for the perceptual sensitivity, nor for the response criterion ($F < 2.0$, n.s.). Including "belief in God" as a covariate also failed to reveal significant interactions between the covariate and the experimental task ($F < 1.9$, n.s.).

3.3. Discussion

In two experiments we did not find evidence for a priming effect of supernatural agent concepts on agency detection. The absence of a priming effect for supernatural agents may be related to the dependent measure that was used, representing *dynamic human motion*. It could be that supernatural agent concepts are primarily related to agency-detection biases for *static stimuli*, such as bodies or faces. Indeed, most of the anecdotal evidence for illusory agency detection involved seeing illusory faces, such as seeing the face of Jesus on a cheese sandwich or seeing the Virgin Mary in the windows of a building (Guthrie, 1993; Shermer, 2008, 2009). In a third experiment we used a different dependent measure to assess illusory agency detection, namely the face/house categorization task (Heekeren et al., 2004). In this task, participants are presented with pictures of faces or houses under different levels of visual noise and required to decide whether the picture represents a face or a house. The relative proportion of face and house responses provides a measure as to what extent subjects show a bias toward detecting human agents.

4. Experiment 3A: face/house categorization task

4.1. Method

4.1.1. Participants

A total of 35 students of the University of Amsterdam participated (14 males; mean age = 23.8 years). Participants received €5 or course credits for their participation in the experiment.

4.1.2. Materials and procedure

The same word stimuli were used as in Experiment 2. We used the original picture stimuli for the face/house categorization task, which are described in detail by Heekeren et al. (2004). For this study we selected 40 pictures of faces and 40 pictures of houses that were presented under intermediate to high levels of visual noise (i.e., 40%, 50%, 60%, and 70% of visual noise). As in the second experiment, each trial started with a lexical decision task in which participants were required to respond only to the presentation of pseudo-words. Next, a picture of a face or a house was presented and participants were required to indicate whether they believed the picture represented a face or a house by pressing the left or right key of the response box. The mapping of the keys was counterbalanced across participants. The picture remained on the screen for 1000 ms.

In Experiment 3A participants performed 10 practice trials before the start of the real experiment. In total, Experiment 3A consisted of 282 trials: 42 filler trials in which a pseudo-word was presented, and 240 target trials according to the following factors: Prime (Supernatural Agent, Human Agent, Animal); Picture (Face vs. House); Noise Level (40%, 50%, 60%, 70%). There were 10 repeated trials per condition. In total, Experiment 3A took about 30 minutes and as in the second experiment, participants completed a short questionnaire to assess their religious beliefs at the end of the study. Analysis focused on the percentage of correctly identified stimuli. More incorrect responses for house stimuli compared to face stimuli would reflect a bias for perceiving faces, and vice versa.

4.2. Results

4.2.1. Response bias

Missed responses on the lexical decision task occurred in 2.4% of all trials and false alarms occurred in 3.3% of all trials. Results from Experiment 3A are presented in Figure 4 and the proportion of correct responses was analyzed using a repeated measures ANOVA with the factors Prime (Supernatural, Human, Animal), Picture (Face vs. House), and Noise Level (40%, 50%, 60%, 70%).

First, a main effect of Picture ($F(1, 34) = 63.3$, $p < .001$, $\eta^2 = .65$) was reflected in more overall correct responses to houses (80% correct) compared to faces (70% correct). The effect of Prime was not significant ($F < 1$). A main effect of Noise ($F(3, 102) = 487.2$, $p < .001$, $\eta^2 = .94$) reflected a lower accuracy with increased levels of visual noise. An interaction was observed between Prime and Picture ($F(2, 68) = 62.1$, $p < .001$, $\eta^2 = .65$). As can be seen in Figure 4, this interaction reflected that the proportion of correct responses to face and house stimuli was modulated by the preceding prime: following human primes, participants perceived relatively more face stimuli as correct (87%) and house stimuli as incorrect (61%), whereas following animal and supernatural primes, participants perceived more house stimuli as correct (88% and 89%) and face stimuli as incorrect (60% and 61%). Finally, a significant three-way

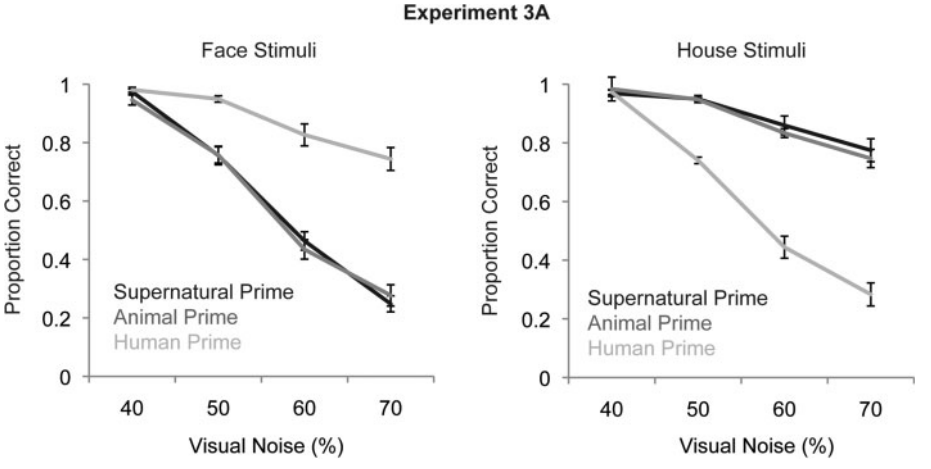

Figure 4. Results from Experiment 3A.
Note: The left graph represents the percentage of correct responses to face stimuli as a function of the level of visual noise. The right graph represents the percentage of correct responses to house stimuli as a function of the level of visual noise. Black lines represent responses preceded by a supernatural agent prime, dark grey lines by an animal prime, and bright grey lines by a human prime. Error bars represent standard errors.

interaction was observed between Prime, Picture and Noise ($F(6, 204) = 31.4$, $p < .001$, $\eta^2 = .48$). This interaction reflected that the effect of prime on perceptual decision-making was most pronounced for stimuli with relatively high compared to low levels of visual noise (see Figure 4).

These findings provide a proof of principle that semantic primes can modulate perceptual decision-making. Participants were more biased toward perceiving human faces following a prime referring to a human agent, compared to animal or supernatural agent primes. However, supernatural agent priming did not have an effect on agency detection.

4.2.2. Bayesian statistics

To obtain positive evidence for the null hypothesis that supernatural agent primes did not modulate agency detection, we conducted an additional analysis on the data of Experiment 3A involving only supernatural and animal primes. There was no main effect of Prime and Prime did not interact with the other variables ($F < 1$). The posterior probability favoring the null hypothesis, $p_{BIC}(H0:D) = .78$ for the main effect of Prime; $p_{BIC}(H0:D) = .85$ for the interaction between Prime and Stimulus; and $p_{BIC}(H0:D) = .99$ for the interaction between Prime, Stimulus, and Noise. This provides positive to strong evidence for the null hypothesis that supernatural primes did not have a general effect on agency detection (Masson, 2011).

4.2.3. Religiosity as moderator

Including self-reported religiosity as a covariate to the analysis did not reveal any interactions between the covariate and the experimental task, neither for the perceptual sensitivity, nor for the response criterion ($F < 1.0$, n.s.). Including "belief in God" as a

covariate also failed to reveal significant interactions between the covariate and the experimental task ($F < 1.0$, n.s.).

4.3. Discussion

In the first three experiments we did not find evidence for a priming effect of supernatural agent concepts on agency detection. In fact, by using Bayesian statistics we could show that there was positive to strong evidence for the null hypothesis that supernatural agent concepts do not prime agency detection at a group level of analysis. As the experiments were conducted at a university in northwestern Europe, the overall religiosity of our participants was quite low (mean religiosity in Experiment 2 = 2.4, SD = 1.9, range = 1–6; mean religiosity in Experiment 3A = 2.3, SD = 1.7, range = 1–6; *1 = not religious, 7 = very religious*). In order to include participants who more strongly endorsed supernatural beliefs compared to the student population at the University of Amsterdam, we replicated Experiment 3A by conducting the experiment at a paranormal fair (for a similar approach, see van Elk, 2013). In this way we aimed to establish whether religious beliefs could function as a possible moderator of the effect of supernatural primes on agency detection.

5. Experiment 3B: face/house categorization task and paranormal believers

5.1. Method

5.1.1. Participants

Study 3B was conducted as a field study a paranormal fair (i.e., Paraview) in the Netherlands. Visitors of the fair participated for €3.50 (for a similar approach, see van Elk, 2013). In total, 60 visitors participated in the experiment (22 males; mean age = 42 years).

5.1.2. Materials and procedure

In study 3B we used a similar experimental design as in study 3A. However, we reduced the number of trials in order to shorten the total duration of the experiment. In total, Experiment 3B consisted of 156 trials: 36 filler trials in which a pseudo-word was presented and 120 target trials according to the following factors: Prime (Supernatural Agent, Human Agent, Animal); Picture (Face vs. House); and Noise Level (40%, 50%, 60%, 70%). There were five repetitions per condition. In contrast to Experiment 3A, the time window for responding to the lexical decision task was adjusted from 1500 to 4000 ms, as a pilot session indicated that the presentation rate was too fast for most participants (i.e., they did not manage to respond to pseudo-words within 1500 ms; for a review of research on paranormal believers, see Lindeman & Aarnio, 2007a, 2007b). Experiment 3B took about 10–15 minutes. At the end of the experiment participants completed questions to assess their religiosity and belief in God, and the revised paranormal belief scale was administered (Tobacyk, 2004).

5.2. Results

5.2.1. Response bias

Missed responses on the lexical decision task occurred in 3.5% of all trials and false alarms to the lexical decision task occurred in less than 1% of all trials. Results of Experiment 3B are presented in Figure 5. The proportion of correct responses was analyzed by using a repeated measures ANOVA as a function of Prime (Supernatural,

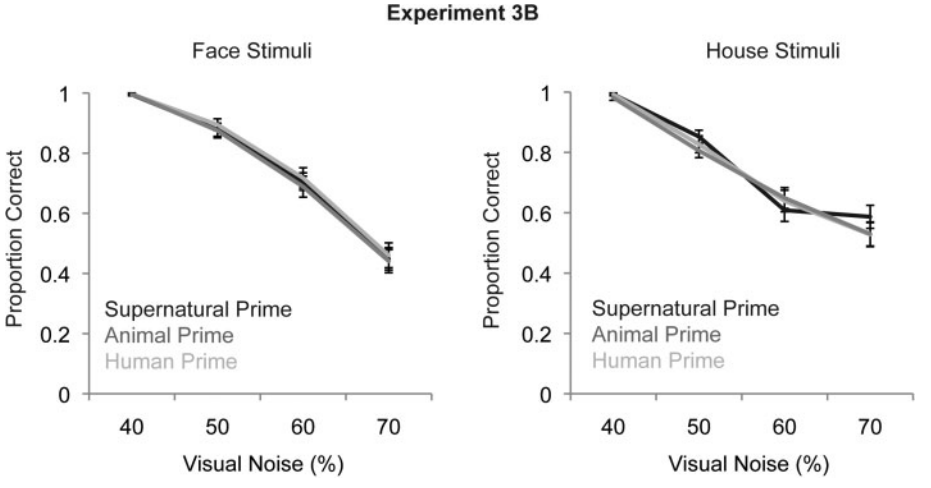

Figure 5. Results from Experiment 3B.
Note: The left graph represents the percentage of correct responses to face stimuli as a function of the level of visual noise. The right graph represents the percentage of correct responses to house stimuli as a function of the level of visual noise. Black lines represent responses preceded by a supernatural agent prime, dark grey lines by an animal prime, and bright grey lines by a human prime. Error bars represent standard errors.

Human, Animal), Picture (Face vs. House), and Noise Level (40%, 50%, 60%, 70%). A main effect of Noise ($F(3, 177) = 404.1$, $p < .001$, $\eta^2 = .87$) indicated that with increased levels of visual noise, participants made more errors in their categorization of the stimuli. An interaction was observed between Picture and Noise ($F(3, 177) = 6.4$, $p < .001$, $\eta^2 = .10$), which reflected that with increased levels of visual noise, participants made more incorrect responses for face stimuli compared to house stimuli (i.e., indicating an overall response bias toward detecting houses compared to faces for ambiguous stimuli). There was no effect of Prime on accuracy ($F < 1$).[6]

5.2.2. Bayesian statistics

To obtain positive evidence for the null hypothesis that supernatural agent primes did not have a general effect on agency detection, we conducted an additional analysis on the data of Experiment 3B involving only supernatural and animal primes. There was no main effect of Prime and Prime did not interact with the other variables ($F < 1$). The posterior probability favoring the null hypothesis was $p_{BIC}(H_0{:}D) = .85$ for the main effect of Prime, $p_{BIC}(H_0{:}D) = .85$ for the interaction between Prime and Stimulus, and $p_{BIC}(H_0{:}D) = .99$ for the interaction between Prime, Stimulus, and Noise. This provides positive to strong evidence for the null hypothesis that supernatural primes compared to animal primes did not have a differential effect on the categorization of face and house stimuli (Masson, 2011).

5.2.3. Religiosity as a moderator

As the experiment was conducted at a paranormal fair, on average participants scored relatively high on paranormal beliefs ($M = 103$; SD = 32.1; range: 26–182), but relatively low on religiosity ($M = 2.8$; SD = 1.7; *1 = not religious, 7 = very religious*). Including religiosity as a covariate in the analysis did not reveal significant effects. Including "belief

in God" as a covariate revealed a significant interaction between Prime, Stimulus, Noise, and Belief in God ($F(6, 348) = 2.5$, $p < .05$, $\eta^2 = .04$). Post hoc analyses for each of the three different primes indicated that belief in God only had a moderating effect for human primes (i.e., interaction between Stimulus, Noise, and Belief in God for human primes: $F(3, 174) = 2.7$, $p = .05$, $\eta^2 = .10$).[7]

5.3. Discussion

All experiments thus far indicated that supernatural agent primes do not have an effect on agency-detection biases. It could be that the effect of supernatural agents does not directly bias response *accuracy*, but merely affects the *speed* of responding in an agency detection task (Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010). In all experiments, participants were given no explicit instructions regarding the speed of responding, as the focus was on accurately detecting the presence or absence of a specific pattern in the stimulus. In a fourth experiment we used a classical word-picture priming paradigm (Sperber et al., 1979) to investigate if words referring to supernatural agents would prime the speed whereby participants respond to a picture representing a face compared to a house. If supernatural agent concepts are related to a perceptual representation of an agent-like figure, as predicted by theories of anthropomorphism (Guthrie, 1993) and the cognitive science of religion (Barrett, 2000; Barrett & Lanman, 2008), we should expect that participants respond faster to pictures of faces compared to houses following supernatural agent primes.[8]

6. Experiment 4: reaction time task

6.1. Methods

6.1.1. Participants

In the fourth experiment, 20 students participated (7 males; mean age = 22.9 years), who were all students at the University of Amsterdam. Participants received course credits or €5 for their participation.

6.1.2. Materials and procedure

The same word stimuli were used as in Experiments 2 and 3. As picture stimuli, we used pictures representing faces and houses (Heekeren et al., 2004). In contrast to Experiment 3, picture stimuli were not presented with different levels of visual noise, but pictures always consisted of a clear photograph representing a face or a house (see Figure 1). In this way it could be investigated whether the presentation of a semantic prime directly affects the speed whereby a visual stimulus is recognized (i.e., word-picture priming; cf. Sperber et al., 1979). Similar to Experiments 2 and 3, each trial started with a lexical decision task and participants responded only to the presentation of pseudo-words (see Figure 1). Next, a picture of a face or a house was presented and participants were required to categorize the stimulus by pressing the left or right key of the response box. Participants were instructed to respond as fast and as accurately as possible. The mapping of the keys was counterbalanced across participants. The picture remained on the screen for a maximum of 2000 ms.

Participants performed 10 practice trials before the start of the real experiment. In total, the experiment consisted of 210 trials: 42 filler trials in which a pseudo-word was presented and 168 target trials according to the following factors: Prime (Supernatural

Agent, Human Agent, Animal); and Picture (Face vs. House). There were 28 repetitions per condition. In total, the experiment took about 25 minutes and at the end participants completed a short questionnaire to assess their religious and spiritual beliefs. Incorrect responses and responses exceeding a participant's average reaction time by more than two standard deviations were excluded from the reaction time analysis, as is common practice in reaction time experiments (Craje et al., 2010; van Elk et al., 2009). This resulted in an average exclusion of 6.6% of all trials.

6.2. Results

6.2.1. Reaction times

Missed responses to the lexical decision task occurred in 1.1% of all trials and false alarms in the lexical decision task were observed in 4.9% of all trials. On average, participants incorrectly classified a face/house stimulus in 1.4% of all trials and analysis of the error rates did not reveal significant effects ($F < 1$). The reaction time data from Experiment 4 are presented in Figure 6. Reaction times were analyzed using a repeated measures ANOVA with the factors Prime (Supernatural Agent, Human Agent, Animal) and Picture (Face vs. House). Analysis of the reaction time data indicated that there were no significant main effects ($F < 1.1$) and no significant interactions ($F(2, 38) = 1.4$, $p = .26$). Even though the data seem to suggest faster responses to faces compared to houses following supernatural agent primes, post hoc *t*-tests indicated that this effect was not significant ($t(19) = -1.7$, $p = .11$).

6.2.2. Bayesian statistics

The main effect of Prime and the interaction between Prime and Stimulus were further analyzed using BIC (Masson, 2011; Wagenmakers, 2007). The posterior probability favoring the null hypothesis was $p_{BIC}(H_0{:}D) = .93$ for the main effect of Prime and $p_{BIC}(H_0{:}D) = .91$ for the interaction between Prime and Stimulus. These findings provide positive to strong evidence for the null hypothesis that supernatural agent words do not prime the reaction times in a word-picture priming task (Masson, 2011).

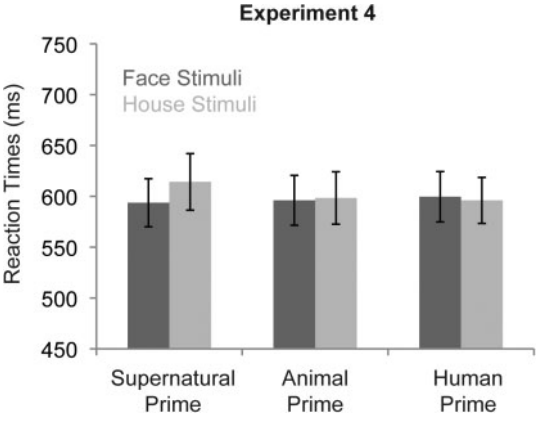

Figure 6. Reaction time data from Experiment 4.
Note: This shows reaction times to the word-picture priming task for face stimuli (dark bars) and house stimuli (bright bars), according to whether the picture was preceded by a supernatural agent prime, a human prime or an animal prime. Error bars represent standard errors.

6.2.3. Religiosity as moderator

Including self-reported religiosity of the participant as a covariate in the analysis revealed a significant interaction between Prime, Stimulus, and Religiosity ($F(2, 36) = 5.0$, $p < .05$, $\eta^2 = .22$). This interaction reflected that participants scoring relatively high on religiosity were characterized by a stronger priming effect for faces compared to houses, following supernatural agent words. Including "belief in God" as a covariate did not reveal significant effects.

6.3. Discussion

In four different studies we failed to find evidence for a general effect of supernatural agent primes on agency detection. In all experiments we relied on semantic primes, consisting of words referring to supernatural agents or to humans. Previous studies have used similar experimental manipulations involving religion-related words to activate supernatural agent concepts (Pichon, Boccato, & Saroglou, 2007; Preston, Wegner, & Aarts, 2008; Shariff & Norenzayan, 2007; Van Cappellen, Corneille, Cols, & Saroglou, 2011). However, we only found an effect of human primes on agency detection, thereby showing the feasibility of the experimental paradigm to detect priming effects.

It could be argued that the mere presentation of words referring to supernatural agents was not sufficient to bias participants' perception toward the detection of agents. Therefore, in a final study, a different priming procedure was used. Participants were required to conduct a trait attribution task by indicating whether words referring to specific traits applied to supernatural agents (Han et al., 2008). In a control condition, participants were required to simply count the number of syllables of the trait words. Following these tasks, participants conducted the face/house categorization task to measure their bias toward detecting human agents and this sequence was repeated. It was hypothesized that deciding whether specific traits applied to supernatural agents would result in a strong activation of the mechanisms involved in thinking and reasoning about supernatural agents (Han et al., 2008; Kapogiannis et al., 2009), which in turn should facilitate the detection of agency (Gobbini, Koralek, Bryan, Montgomery, & Haxby, 2007).

7. Experiment 5: face/house categorization task and trait attribution task

7.1. Methods

7.1.1. Participants

A total of 36 subjects participated in Experiment 5 (21 males; mean age = 20.5 years). All were students at the University of Amsterdam who received course credits or €10 for their participation.

7.1.2. Materials and procedure

For the trait attribution task, we selected 12 words referring to supernatural agents (see Table 1). Furthermore, we used a list of trait adjectives consisting of 360 words (Ganesh, van Schie, de Lange, Thompson, & Wigboldus, 2012). The words were subdivided into six sub-lists, each consisting of 30 positive words (e.g., "loving," "kind") and 30 negative words (e.g., "mean," "revengeful").

An overview of the experimental procedure is presented in Figure 7. As can be seen, the experiment consisted of four blocks: two blocks in which participants conducted a

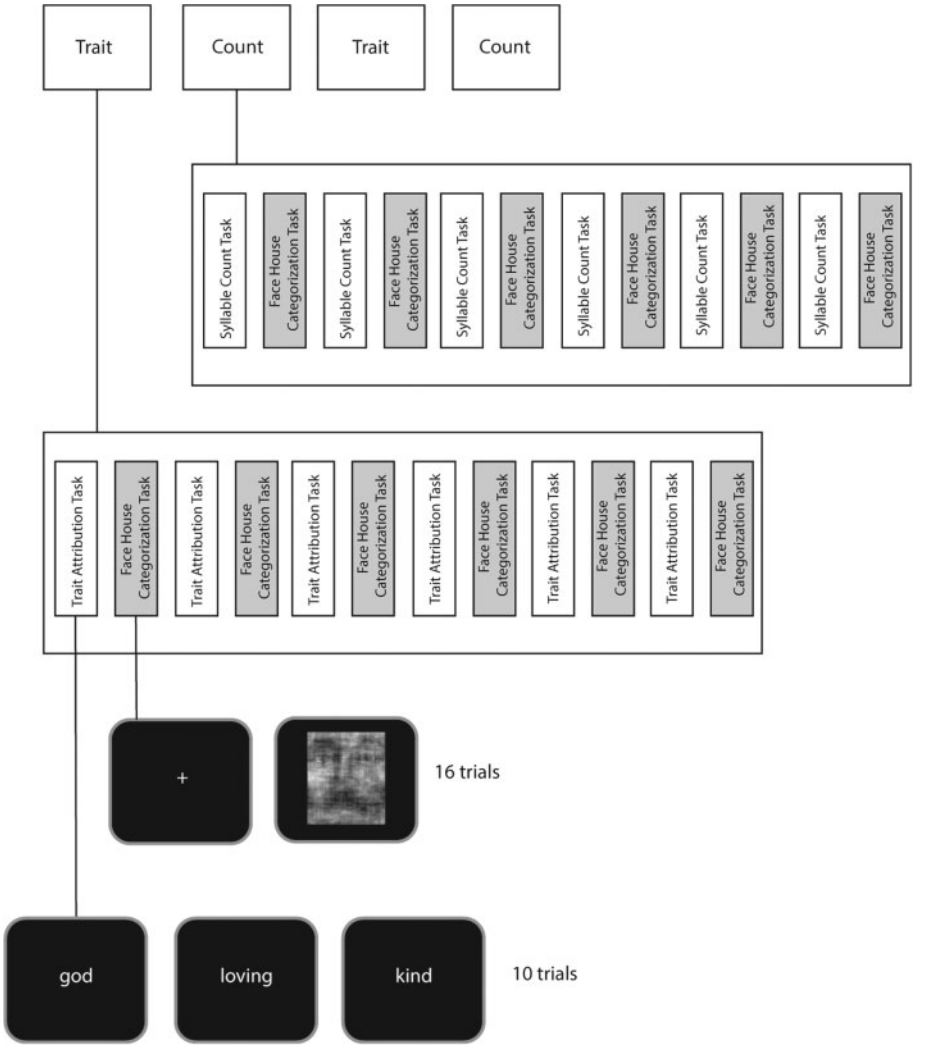

Figure 7. Overview of the experimental procedure in Experiment 5.
Note: The experiment consisted of four blocks in which participants were primed with supernatural agent concepts by conducting a trait attribution task. As a control condition they conducted a syllable count task. Each block consisted of 12 mini-blocks in which the trait attribution/syllable count task was alternated with the face/house categorization task.

trait attribution task and two blocks in which they conducted a syllable count task. Block order was counterbalanced across participants. Each block consisted of 12 mini-blocks in which subjects alternately conducted the trait attribution/syllable count task and the face/house categorization task (see Figure 7).

In the trait attribution task, participants were first presented with a word referring to a supernatural agent. Next, 10 adjectives (five positive and five negative) were presented and for each adjective participants were required to indicate to what extent the trait applied to the supernatural agent. After 10 trait attribution trials, participants conducted 16 trials for the face/house categorization task, in which they were required to indicate whether pictures under various levels of visual noise represented a face or a house

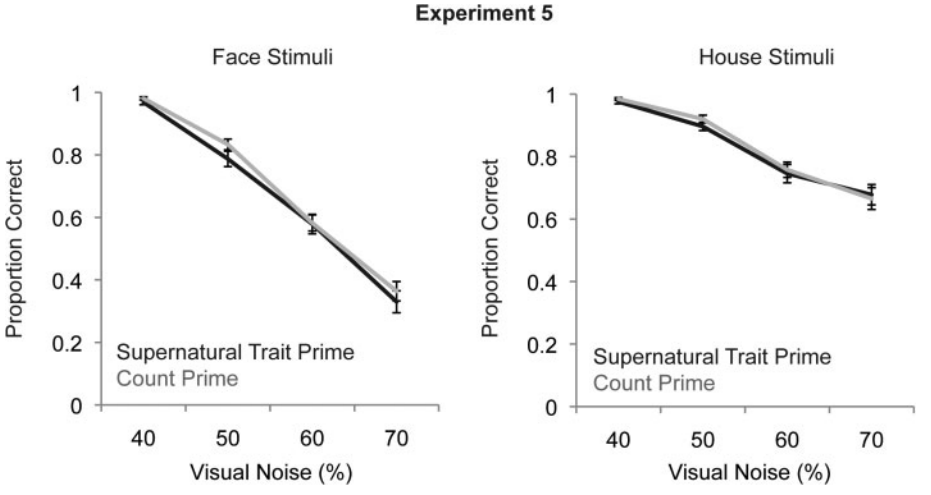

Figure 8. Results from Experiment 5.
Note: The left graph represents the percentage of correct responses to face stimuli as a function of the level of visual noise. The right graph represents the percentage of correct responses to house stimuli as a function of the level of visual noise. Black lines represent responses in blocks that were preceded by a supernatural trait attribution task. Dark grey lines represent responses in blocks that were preceded by a syllable count task. Error bars represent standard errors.

(Heekeren et al., 2004). This sequence of mini-blocks of trait attribution trials followed by mini-blocks of the face/house categorization task was repeated six times in a row, each time with a different supernatural word (see Figure 7). As a control condition, we used a syllable count task. In this task, participants were presented with trait adjectives and they were required to count the number of syllables. After counting the syllables for 10 trait adjectives, participants conducted 16 trials of the face/house categorization task. This sequence was also repeated six times.

In total, the experiment consisted of 384 trials in which participants made a response to the face/house categorization task. Trials were designed in terms of: Preceding Task (Trait attribution vs. Syllable Count); Stimulus (Face vs. House); and Noise Level (40%, 50%, 60%, and 70% of visual noise). There were 24 repetitions per category. The analysis focused on the percentage of correctly identified faces and houses for each category. At the end of the experiment, participants completed a short questionnaire to assess their religious beliefs.

7.2. Results

7.2.1. Response bias

Analysis focused on the percentage of correctly identified faces and houses (see Figure 8). As can be seen, with increased levels of visual noise the accuracy in detecting faces and houses decreased ($F(3, 108) = 1035.2$, $p < .001$, $\eta^2 = .97$). Furthermore, a main effect of Stimulus indicated overall lower accuracy for the perception of faces compared to houses ($F(1, 36) = 23.7$, $p < .001$, $\eta^2 = .40$). A main effect of Task ($F(1, 36) = 7.1$, $p < .05$, $\eta^2 = .17$) indicated that the accuracy in the face/house categorization task was slightly reduced following the trait attribution task (accuracy = 74.5%) compared to the syllable count task (accuracy = 76.1%).[9] An interaction between Stimulus and Noise

($F(3, 108) = 24.3$, $p < .001$, $\eta^2 = .40$) indicated that the accuracy for face stimuli was more strongly affected by increased levels of visual noise than for house stimuli (see Figure 8). However, no significant interactions were found with Task ($F < 1.6$).

In Experiment 5 all participants conducted a trait attribution task for supernatural agents or a syllable count task. Due to carry-over effects between experimental blocks, it could be that participants were continuously primed with supernatural agent concepts – irrespective of the specific experimental block (i.e., counting syllables or making a trait attribution). To control for this potential confound, in an additional post hoc analysis we only analyzed the data from the first experimental block, by using an additional between-subjects factor in our analysis (i.e., syllable count group vs. supernatural trait attribution group). No significant differences between these groups were observed on the face/house categorization task ($F < 1$), thereby indicating that between-subjects priming of supernatural agency did not modulate agency-detection biases.

7.2.2. Bayesian statistics

As the ANOVA results do not warrant conclusions in favor of the null hypothesis, the interaction between Task and Stimulus, and Task, Stimulus, and Noise Level were further analyzed using BIC (Masson, 2011; Wagenmakers, 2007). The posterior probability favoring the null hypothesis was $p_{BIC}(H_0{:}D) = .84$ for the interaction between Task and Stimulus, and $p_{BIC}(H_0{:}D) = .99$ for the interaction between Task, Stimulus, and Noise. These findings provide positive to strong evidence for the null hypothesis that the trait attribution task did not bias responses in the face/house categorization task (Masson, 2011).

7.2.3. Religiosity as moderator

Including self-reported religiosity in the analysis did not reveal significant interactions with the other variables ($F < 1.8$). Including "belief in God" as a covariate revealed a significant interaction between Task, Noise, and Belief in God ($F(3, 105) = 3.3$, $p < .05$, $\eta^2 = .09$), reflecting that participants who strongly believe in God made more incorrect categorizations for ambiguous stimuli following the supernatural priming task. In addition, an interaction was observed between Task, Stimulus, Noise, and Belief in God ($F(3, 105) = 3.4$, $p < .05$, $\eta^2 = .09$), indicating that this effect was most pronounced for face stimuli.

8. Meta-analysis

In sum we did not find an overall effect of supernatural priming on agency detection in a total of six experiments. In two meta-analyses, the data from the different experiments were combined to establish to what extent the effects observed in the different studies converged.

8.1. Biological motion detection task

We combined the data from Experiments 1 and 2 involving the biological motion detection task and conducted an ANOVA with the within-subjects factors Prime (Supernatural vs. Animal) and Noise Level (24, 48, 96, and 192 distractors), and Experiment (Experiment 1 vs. Experiment 2) as a between-subjects factor. The effects of Prime on the response criterion were not significant ($F < 1.0$) and Prime did not interact with Noise ($F(3,219) = 1.2$). A main effect of Noise ($F(3, 119) = 21.9$, $p < .001$, $\eta^2 = .23$)

indicated that the response bias was reduced with increased levels of visual noise, and an interaction between Noise and Experiment ($F(3, 219) = 3.6$, $p < .05$, $\eta^2 = .05$) indicated that this effect was most pronounced for Experiment 2. No other effects were found to be significant.

Including self-reported religiosity as a covariate in the analysis did not reveal significant interactions between religiosity and the other effects ($F(1, 73) = 2.2$, $p = .14$). Including "belief in God" as a covariate in the analysis also did not reveal a significant interaction with the other effects ($F(3, 219) = 2.2$, $p = .09$).

8.2. Face/house categorization task

In a second meta-analysis, we combined the data from Experiments 3A, 3B, and 5[10] involving the face/house categorization task and conducted a repeated measures ANOVA with the within-subjects factors Prime (Supernatural vs. Control)[11], Picture (Face vs. House), and Noise (40%, 50%, 60%, 70%), and Experiment (Experiments 3A, 3B, 5) as between-subjects factor. Prime did not interact with any of the other variables ($F(2, 129) < 1.6$, $p = .20$), indicating that supernatural priming did not modulate agency detection. We only observed a main effect of Picture ($F(1, 129) = 59.3$, $p < .001$, $\eta^2 = .32$) and a main effect of Noise ($F(3, 387) = 937.6$, $p < .001$, $\eta^2 = .88$). Both main effects were qualified by an interaction between Picture and Noise ($F(3, 387) = 48.2$, $p < .001$, $\eta^2 = .27$) and an interaction between Picture, Noise, and Experiment ($F(6, 387) = 9.9$, $p < .001$, $\eta^2 = .13$). These findings revealed a general tendency for our participants to make more incorrect categorizations for faces than for houses, especially for stimuli with high levels of visual noise. Moreover, this effect was most pronounced in Experiments 3A and 5, and less in Experiment 3B.

Including self-reported religiosity as a covariate in the analysis did not reveal an interaction between religiosity and the other effects ($F < 1.6$, n.s.). Including "belief in God" as a covariate in the analysis also showed no significant interaction with the other effects ($F < 2.4$, n.s.).

9. General discussion

In five different experiments involving both students and visitors of a paranormal fair, we found overall that concepts referring to supernatural agents did not have a priming effect on agency detection, as measured with a biological motion detection task and a face/house categorization task. Although null findings have to be interpreted with caution, by using Bayesian statistics we were able to show that there was positive to strong evidence for the null hypothesis that priming with supernatural agent concepts does not facilitate agency detection at a group level of analysis. These findings are in line with previous work showing that there is no relation between agency detection and supernatural beliefs (Norenzayan, Hansen, & Cady, 2008; Willard & Norenzayan, 2013), and in accord with the general criticism of the notion that supernatural agent beliefs are related to a HADD (Bulbulia, 2004; Lisdorf, 2007; Mckay & Efferson, 2010; Weingarten & Chisholm, 2009).

It could be argued that the absence of a priming effect for supernatural agents is related to the priming procedure that was used. Merely reading words referring to supernatural agents might not be sufficient to activate the corresponding agency-detection biases. However, previous studies reported strong effects of reading religious words on subsequent performance (Carpenter & Marshall, 2009; Pichon et al., 2007; Saroglou,

Corneille, & Van Cappellen, 2009; Shariff & Norenzayan, 2007; Van Cappellen et al., 2011). Furthermore, in Experiment 5 a different priming procedure was used, in which participants were required to reflect on the mental traits that could apply to a supernatural agent. Despite this more explicit manipulation, still no effect on agency detection was observed. These findings indicate that even when supernatural agent concepts were explicitly processed, there was no effect on agency detection.

We would like to add that we used words referring to humans and animals as a control category in the semantic priming for Experiments 1–4. The selection of these words was based on a pretest in which word categories were matched for lexical frequency, imaginability, and valence. Unfortunately, the use of words referring to animals in comparison to supernatural agent primes may have been suboptimal; animals also qualify as agents, and some supernatural agents are often depicted with animal-like features (e.g., the Devil as a goat or serpent). Accordingly, the absence of a priming effect for supernatural agent concepts may be partly related to the control word stimuli that were used.

However, in two experiments we found that semantic priming modulates agency detection, thereby providing a proof-of-concept of our experimental paradigm. When participants were presented with words referring to human agents compared to animals, they were more biased toward detecting human agents in an ambiguous point-light display (Experiment 2) and toward detecting faces compared to houses in a noisy picture (Experiment 3A). However, no general effect of primes referring to supernatural agents on agency detection was observed. These findings rule out the possible confound that the absence of a priming effect may be related to the experimental paradigm that was used (i.e., *semantic priming*).

It could be that the absence of a priming effect for supernatural agents is related to the dependent measures. Both the biological motion detection task and the face/house categorization task measure the detection of *human-like agency*, but not necessarily *supernatural agency*. However, at least three lines of evidence suggest that we should expect supernatural concepts to be primarily related to the detection of human-like agency. First, following the evolutionary argument of the HADD, supernatural beliefs originate from an overactive mechanism to detect human agency in ambiguous or threatening situations (Barrett, 2000; Barrett & Lanman, 2008). Second, both anthropological (Guthrie, 1980, 1993) and psychological studies (Barrett, 1998; Barrett & Keil, 1996) indicate that people's god concepts are strongly and inherently anthropomorphic (i.e., gods being represented with human- and animal-like features). Third, previous studies using a biological motion detection task and a face detection task have shown that these measures are strongly related to individual differences in supernatural and paranormal beliefs (Riekki et al., 2013; van Elk, 2013). Thus, it seems warranted to conclude that our measures were well suited to capture any effects of supernatural priming on agency detection.

Further support for this claim is provided by the fact that in three experiments it was found that participant's religiosity and belief in God had a moderating influence on the effect of supernatural priming on agency detection. It was found that the perceptual sensitivity to detect human agents of religious participants was affected by supernatural primes (Experiment 1), that religious participants were faster in detecting faces compared to houses following supernatural primes (Experiment 4), and that following a supernatural priming task religious participants showed a differential response bias for detecting faces (Experiment 5). Thus, it could well be that priming supernatural concepts has differential effects on believers compared to nonbelievers (for similar religion-specific

priming effects, see Inzlicht & Tullett, 2010). These findings indicate that religious education and socialization may shape the relation between supernatural beliefs and cognitive biases (Gervais et al., 2011; Willard & Norenzayan, 2013). Supernatural agent concepts can modulate agency-detection biases, but *only* when these concepts have been acquired through an extensive process of cultural learning.

A moderating effect of religiosity on our experimental manipulations was observed primarily in experiments that used the face/house categorization task as the dependent measure (Experiments 4 and 5). This finding may have interesting implications for the operationalization of agency detection in relation to supernatural beliefs. As discussed in the Introduction, several authors have proposed that supernatural beliefs are related to agency-detection biases at either a perceptual or an intentional level (Barrett, 2000; Kelemen et al., 2013; Lindeman & Aarnio, 2007b; Riekki et al., 2014; Schjoedt et al., 2009; Willard & Norenzayan, 2013). The finding that for religious participants, the presentation of words referring to supernatural agents may modulate the detection of faces fits well with Guthrie's proposal that belief in supernatural agents is related to pareidolia-like perceptual biases (Guthrie, 1980, 1993), rather than the attribution of intentions to physical objects (Kelemen & Rosset, 2009; Kelemen et al., 2013). Although the over-attribution of intentions is likely to play an important role in generating supernatural explanations for unexplainable events (e.g., attributing a thunderstorm to the punishment of God), this teleological bias should be distinguished from the perceptual bias that was studied in the present research. Previous studies have related such perceptual biases to over-detect agency to paranormal beliefs (e.g., belief in Psi, telekinesis etc.; cf. Krummenacher, Mohr, Haker, & Brugger, 2010; Riekki et al., 2013; van Elk, 2013), but the present study is the first to show a moderating effect of religiosity on supernatural priming and agency detection. However, we note that these findings need to be interpreted with caution as the effects were only observed in three out of six studies and a meta-analysis across the different studies did not provide unequivocal evidence for a moderating effect of religiosity on the effects observed.

The absence of a consistent effect of religiosity across the different studies may be related to the fact that we relied on relatively simple self-report measures for belief in God and religiosity. Our measures did not distinguish different aspects of religiosity (e.g., intrinsic vs. extrinsic religiosity; Gorsuch & Mcpherson, 1989), differences in supernatural beliefs between religions (e.g., monotheism vs. polytheism), and differences in God image (Lawrence, 1997). It could be, for instance, that the effects of supernatural priming on agency detection are most pronounced for believers with a concrete and anthropomorphic representation of God (Barrett & Keil, 1996), whereas believers with a more symbolic or abstract view of God would be less prone to these effects. Accordingly, an important challenge for future research is to use these well-developed scales derived from studies on the psychology of religion in relation to the more cognitively oriented experimental approach in the present studies.

A central question is how these results advance our understanding of the evolutionary origins of religion. The present study underlines the more general problem faced by the claims made by evolutionary psychology, which are often difficult to falsify (Conway & Schaller, 2002; Ketelaar & Ellis, 2000). That is, it could well be that in the distant past the proposed agency-detection biases may have ultimately contributed to supernatural beliefs, but this does not entail that these beliefs are still rooted in the same cognitive biases. In fact, it is far more likely that supernatural beliefs are primarily acquired through a process of socialization, cultural learning, and education (Boyd & Richerson, 1988; Gervais et al.,

2011; Hood et al., 2009). These culture-specific learning experiences may in fact underlie the learned association between supernatural agent beliefs and agency-detection biases.

10. Conclusions

In sum, our results did not reveal an overall effect of supernatural priming on agency detection. In three experiments a moderating effect of religiosity was observed: for religious participants supernatural primes did have an effect on agency and face detection, but this effect was not observed for non-religious participants. These findings qualify the relation between supernatural beliefs and agency detection and suggest that when supernatural agent concepts have been acquired through cultural learning, these concepts can modulate agency-detection biases.

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Supplemental data

Supplemental data for this article can be accessed here.

Notes

1. It is important to note that explicit semantic priming differs from implicit conceptual priming methods. The latter have typically been used to investigate the effects of the activation of religious concepts (Carpenter & Marshall, 2009; Pichon et al., 2007; Saroglou et al., 2009; Shariff & Norenzayan, 2007; Van Cappellen et al., 2011). A major methodological difference between semantic priming and conceptual priming is that the first allows the use of primes from different conceptual categories as a *within-subjects manipulation* (the same participant is subjected to all experimental manipulations), whereas the latter typically relies on *between-subjects manipulations* (i.e., different groups of participants are presented with different experimental manipulations). Given the strong sensitivity of our dependent measure to individual differences (i.e., individual differences in agency detection; Riekki et al., 2013; van Elk, 2013), semantic priming was preferred over conceptual priming, as it should result in increased statistical power to detect differences between primes (Greenwald, 1976).
2. We preferred using these cognitive measures of agency detection over alternative measures (e.g., the snowy pictures task; cf. Whitson & Galinsky, 2008), because in this way we could specifically test for effects of the activation of supernatural agent concepts on agency detection rather than on mere pattern perception.
3. In all experiments we also measured church attendance (i.e., "How often do you visit a church / mosque / temple?"; *1 = never, 7 = very often*). This measure is more closely related to extrinsic than to intrinsic religiosity, and was not included in the analyses.
4. The posterior probability favoring the alternative hypothesis, $p(H_1|D)$, can be derived by subtracting the posterior probability favoring the null hypothesis, $p(H_0|D)$, from 1 (i.e., $p(H_0|D) + p(H_1|D) = 1$).
5. This finding may seem contrary to our initial expectations (i.e., enhanced agency detection expected for supernatural prime words). However, we note that religiosity only moderated the *perceptual sensitivity* (i.e., indicating how well participants distinguished signal from noise) and not the *response bias* (i.e., indicating to what extent participants were biased toward saying "yes") – which was the measure of agency detection for which we primarily expected effects in our experiments.
6. Thus, in contrast to Experiment 3A, we did not observe an effect of human primes on the categorization of face/house stimuli. The absence of a priming effect may be related to the less controlled experimental setting (i.e., the study was conducted as a field experiment in a noisy

environment) and the specific population that was tested in this study (i.e., paranormal believers may differ on a number of variables from the students that were tested in the other experiments).

7. The interaction reflected that for believing participants, human primes affected the categorization of face/house stimuli of low levels of visual noise, whereas for non-believing participants, human primes affected the categorization of face/house stimuli of high levels of visual noise.
8. In fact, the design of the experiment was similar to Experiments 3A and 3B, but instead of including pictures representing different levels of visual noise, we included only undistorted pictures of faces and houses.
9. Please note that the directionality of this effect is contrary to our expectations (i.e., we expected that supernatural priming should facilitate rather than impair agency detection). Several potential mechanisms could underlie this effect (e.g., the trait attribution task may be attentionally more demanding, thereby resulting in impaired performance on subsequent tasks; the trait attribution task may induce a negativity bias, as some supernatural agents clearly have negative associations, thereby impairing subsequent performance). However, given the small size of the effect, the lack of specificity of the effect (i.e., a general impairment in the detection of both faces and houses), we believe that this effect does not warrant strong conclusions regarding the relation between religious priming and agency detection.
10. Data from Experiment 4 was not included in the meta-analysis as only stimuli without visual noise were included in that experiment and the dependent measure consisted of reaction times rather than categorization of the stimuli.
11. For Experiment 3A and 3B we defined animal prime words as a control category and for Experiment 5 we defined the syllable count task as a control category.

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