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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 (Experiments 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.

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1. Introduction

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.¹ Scholars within the cognitive science of religion (i.e., the research niche that investigates the [neuro-]cognitive foundations of supernatural beliefs; e.g., Xygalatas, 2014) have proposed that belief in supernatural agents may have its basis in 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

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hypersensitive agency detection device (HADD; e.g., Barrett, 2000, 2012; Barrett & Lanman, 2008; Bertolotti & Magnani, 2010; Bloom, 2007; Green, 2015; McKay & Whitehouse, 2015; Nieuwboer, van Schie, & Wigboldus, 2015; Nola, 2014; Norenzayan, Hansen, & Cady, 2008; Petrican & Burris, 2012; Riecki, Lindeman, & Raij, 2014; van Elk, 2013; van Elk, Rutjens, van der Pligt, & van Harreveld, 2016) – a hair-triggering device that responds over-actively 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 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 in which people should logically live their lives as if God exists. Pascal 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, 1993; Guthrie et al., 1980; 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 necessary for eliciting 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.

1.1. 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 encourage 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 et al.'s anthropomorphism account of religion (1980; Guthrie, 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, 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 & Burdett, 2011; Barrett & Lanman, 2008). 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 supporting 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). For instance, 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.² 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., 2016) have indicated that individual differences in religious and paranormal beliefs may be important moderators of agent detection biases. Therefore, we added the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004) and religiosity questions as possible covariates to the study.

1.2. 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 regard to automatic responses being a result of threatening situations, adults (Chouchourelou, Matsuka, Harber, & Shiffrar, 2006; Öhman, Flykt, & Esteves, 2001; Windmann & Krüger, 1998), young children (Lobue & DeLoache, 2008; LoBue & Matthews, 2014), 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 regard 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 believe that other players are human agents, rather than computers, when they are 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 seem to attribute more intentionality towards threatening phenomena (e.g., volcano eruption) than towards non-threatening phenomena (e.g., sunset; Nieuwboer et al., 2015).

All in all, the findings discussed here 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 question of whether 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, 2014b). 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.

1.3. 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 (Experiment 3; Heider & Simmel, 1944; Riekkki 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).

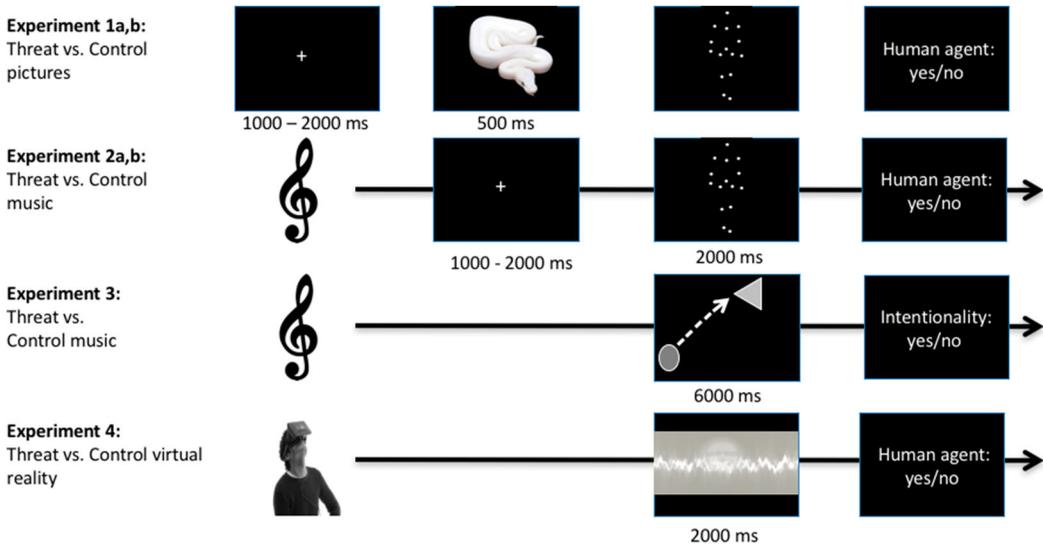


Figure 1. Schematic overview of the different experiments. In all experiments we investigated the effects of threat manipulation on agent detection. In Experiments 1a and 1b, threat was manipulated by presenting pictures of the international affective picture system; in Experiments 2a, 2b (between-subjects), 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.

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).³ 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.

2. Methods

2.1. 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.

2.2. Participants

To determine the sample size, a power analysis was conducted using G-Power (version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007). 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.

3. 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 (mean valence rating = 3.3, SD = 0.4) than control pictures (mean valence rating = 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 (mean arousal rating = 6.65, SD = 0.59) than control pictures (mean arousal rating = 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).

3.1. Experiment 1a

3.1.1. Methods

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

3.1.1.2. 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 & Derryberry, 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.⁴

3.1.1.3. Questionnaires

3.1.1.3.1. 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.

3.1.1.3.2. 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.

3.1.1.4. 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, 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.

3.1.1.5. Data analysis. To analyze the Biological Motion Detection Task data, a signal detection analysis was used (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 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 factor 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).

3.1.2. 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 the 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 2(a), 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 2(a), 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.

3.1.3. 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 in three aspects. First, we used four blocks of 30 trials instead of two blocks of 60

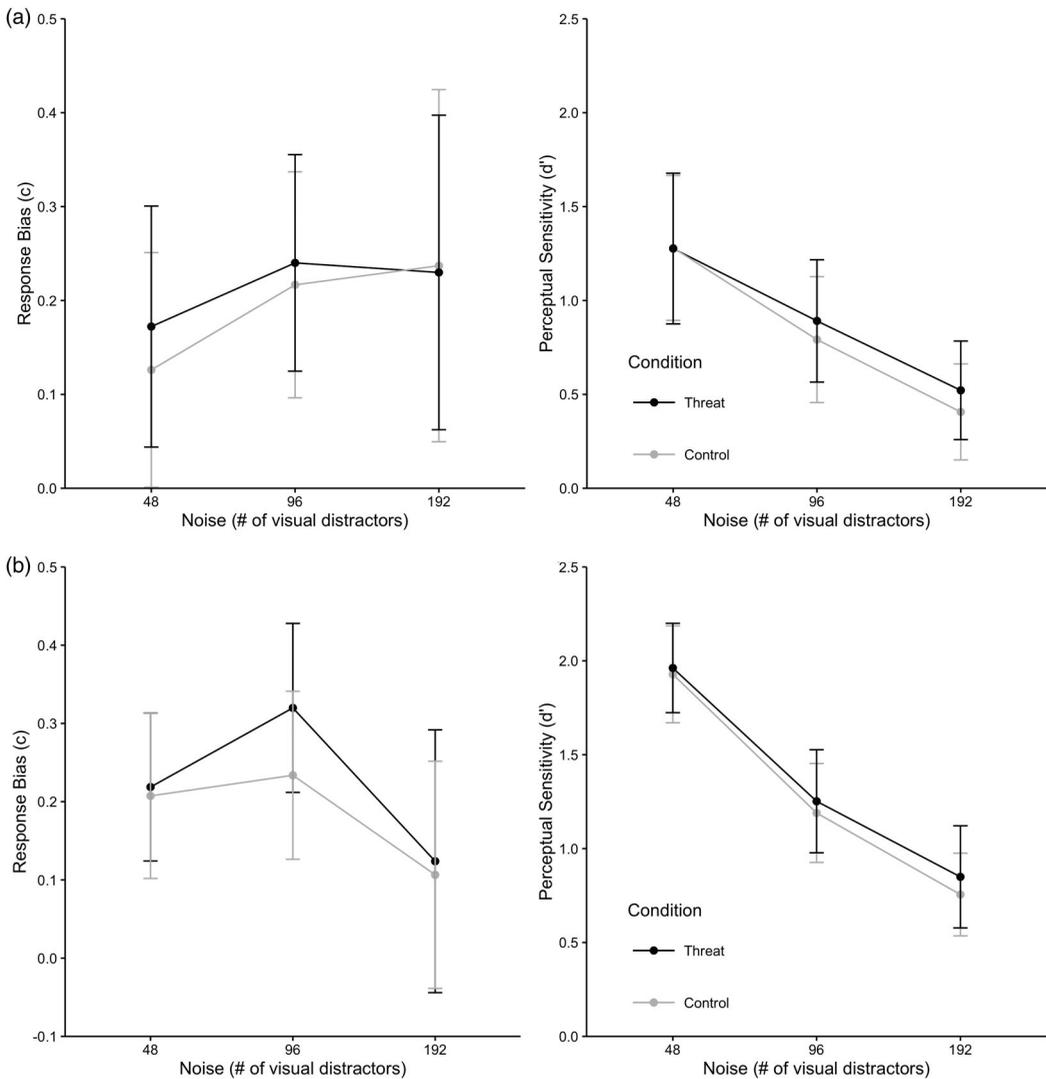


Figure 2. (a) Response bias (left graph) and perceptual sensitivity (right graph) as a function of the number of visual distractors in Experiment 1a. The dark lines represent the threat condition (i.e., trials preceded by threatening pictures of the IAPS) and the light line represents the control condition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

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 section 7, “Explorative analysis.”

3.2. Experiment 1b

3.2.1. Methods

3.2.1.1. Participants. In total, 33 participants⁵ were tested in Experiment 1b. One participant was excluded, because a different experiment was started accidentally, leaving 32 participants (24 females) with a mean age of 23.3 years ($SD = 5.7$; range = 18–50).

3.2.1.2. Experimental manipulation and paradigm. Again, participants were primed with pictures from the IAPS from two categories: threat pictures (picture # 1120, 1050, 1300, 1726, 1321, 6260, 6230, 6300, 6510, and 2120), where examples 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 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.

3.2.1.3. Questionnaires

3.2.1.3.1. 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, $\alpha = .95$.

3.2.1.3.2. 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).

3.2.1.3.3. Paranormal beliefs. Paranormal beliefs were again measured with the RPBS and the reliability was adequate, $\alpha = .97$.

3.2.1.3.4. 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, $\alpha = .94$.

3.2.1.3.5. Anthropomorphism. The individual differences in the tendency to anthropomorphize were measured with the Anthropomorphization 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, $\alpha = .93$.

3.2.1.3.6. Negativity bias. The negativity bias was measured with the three-item (e.g., “I often fear for my own safety”) Beliefs in the Dangerousness of the World Scale (Fessler, Pisor, Navarrete, & Mesoudi, 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, $\alpha = .74$.

3.2.1.3.7. 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, $\alpha = .81$.

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

3.2.1.5. Data analysis. Data analysis was conducted in a similar fashion as in Experiment 1a, using an 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.

3.2.2. 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 as 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 2(b), 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 2(b), 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.

3.2.3. 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.

4. 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.

4.1. Experiment 2a: within-subjects

4.1.1. Methods

4.1.1.1. 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.

4.1.1.2. Experimental manipulation and paradigm. In order to contextually manipulate the feeling of threat, threat-eliciting classical music (Penderecki, 2012/1960) was contrasted with neutral music (Grieg, 1993/1875). 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.

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

4.1.2. 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 3(a), 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.

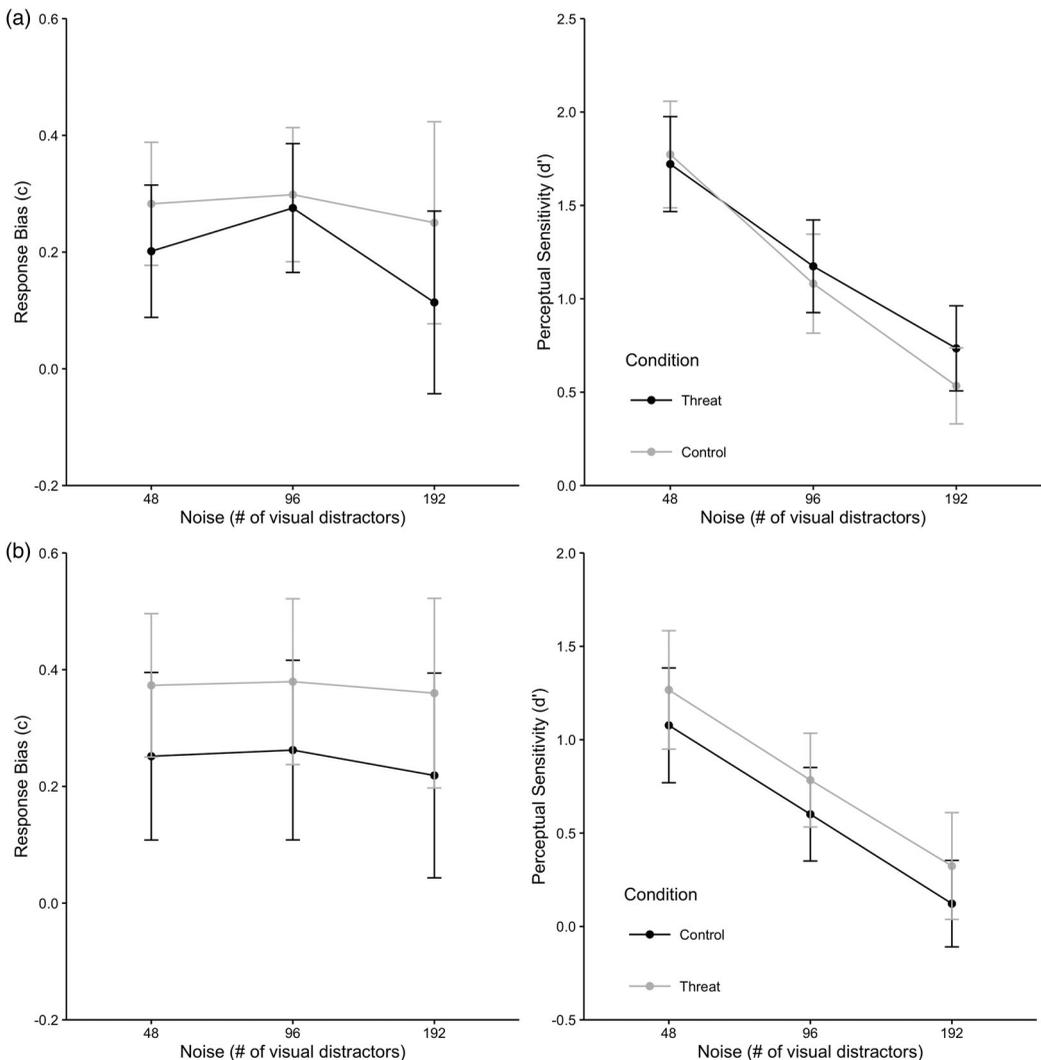


Figure 3. (a) The response bias (c ; left graph) and perceptual sensitivity (d' ; right graph) as a function of the number of visual distractors in Experiment 2a. The dark lines represent the threat condition (i.e., classical horror music) and the light lines represent the control condition (i.e., elevator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

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 3(a), 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.

4.1.3. 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 in the response bias or the perceptual sensitivity. Although no participants could guess the hypothesis of this experiment when asked, a within-subjects 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-subjects design.

4.2. Experiment 2b: between-subjects

4.2.1. Methods

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

4.2.1.2. 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.

4.2.1.3. 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.

4.2.1.3.1. Supernatural beliefs. Supernatural beliefs were measured with the supernatural belief scale (Johnson et al., 2013). The scale consists of 10 items (e.g., “There exists an all-powerful, all-knowing, loving God”) and had an excellent reliability, $\alpha = .96$. Items were scored on a nine-point Likert scale (1 = totally disagree, 8 = totally agree).

4.2.1.4. Data analysis. We conducted an 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).

4.2.2. 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 regard 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 3\(b\)](#), 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 3\(b\)](#), 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.

4.2.3. 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.

5. Experiment 3: threatening music vs. control music

5.1. Methods

5.1.1. 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).

5.1.2. 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.

5.1.3. Experimental paradigm

We operationalized perceived intentionality by means of a Geometrical Figures Task, originally developed by Heider and Simmel (1944). We used an adapted version of the Geometrical Figures Task developed by Riekkari 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 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 Riecki 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-second 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.

5.1.4. 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 into 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.

5.1.5. 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 an 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-ANOVAs 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).

5.2. 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 as similarly negative in

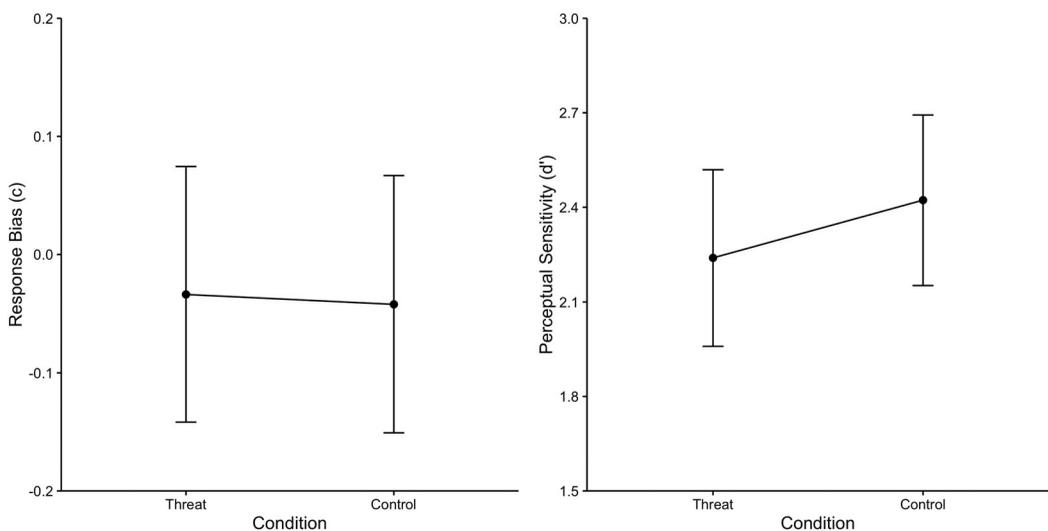


Figure 4. Response bias (left graph) and perceptual sensitivity (right graph) as a function of the type of condition (threat vs. control) in Experiment 3. The dark lines represent the difference between the threat condition (i.e., threatening music) and the control condition (i.e., neutral music). Error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

the threat condition ($M = 7.69$, $SD = 0.48$) as in the control condition ($M = 5.49$, $SD = 1.84$), Wilcoxon's $t = 10$, $p = .125$, $d = 1.74$, $\omega^2 = 0.72$, 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 $t = 86.50$, $p = .352$, $d = 0.25$, $\omega^2 < 0.01$.

5.3. 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 Geometrical Figures Task 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 negatively 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 negatively 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 detect agents.

6. Experiment 4: horror virtual reality vs. control virtual reality

6.1. Methods

6.1.1. Participants

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

6.1.2. 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*,”⁶ 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*,”⁷ participants were able to walk around in a desert environment and they were told that it would be a neutral scenario.

6.1.3. 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, USA). The stimuli were presented with over-ear headphones. In between stimuli was a variable interval of 1000–1500 ms.

6.1.4. 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.

6.1.5. 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%).

6.2. 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 $t = 170$, $p = .130$, $d = 0.16$, $\omega^2 < 0.01$. 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

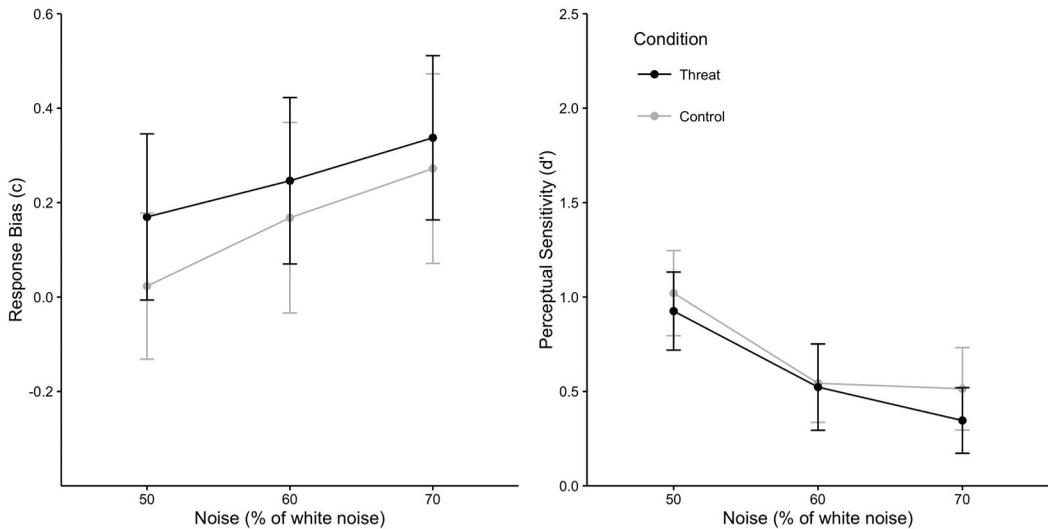


Figure 5. The response bias (left graph) and perceptual sensitivity (right graph) as a function of the percentage of white noise in Experiment 4. The dark lines represent the threat condition (i.e., threatening virtual reality scenario) and the light lines represent the control condition (i.e., neutral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

control in the threat condition ($M = 3.87$, $SD = 0.54$) than in the control condition ($M = 4.90$, $SD = 1.38$), Wilcoxon's $t = 19$, $p < .001$, $d = 0.71$, $\omega^2 = 0.32$, 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.

6.3. 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 Anthropomorphization Scale, the Short Intolerance of Uncertainty Scale, and the Negativity Bias Scale) were associated with human agent or intentionality detection.

7. Explorative analysis

In the explorative analysis, we investigated whether the measures explained in Experiment 1b (i.e., religiosity, the RPBS, the Anthropomorphization 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 Experiments 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 Anthropomorphization 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 anthropomorphization relates to biased agent detection. Furthermore, we expected higher anthropomorphization 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, 2014a). 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 game⁸ 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.

7.1. 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. An 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

Table 1. Within-subjects effects of the repeated measures analysis of covariance, with condition as within-subjects factor and measures associated with agent detection as covariates, and the response bias (*c*) as repeatedly measured dependent variable.

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	<i>d</i>	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.

1.06 is slightly higher than 1, another LN transformation did not change the interpretation of the results.

7.2. 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 regard to the between-subjects effects, the type of experiment, as well as the Negativity Bias 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 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.

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	<i>d</i>	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.

7.3. 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 regard 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, 2000, 2008, 2012). 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., 2016). 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, & Young, 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 (van 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.

8. 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., Gosselin

& Schyns, 2003; Liu et al., 2014; Nees & Phillips, 2015; Scholl & Gao, 2013; van Elk, 2013; van Elk et al., 2016): 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 Experiments 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 et al., 2004; Mogg et al., 2004; Schimmack & Derryberry, 2005; Van Damme et al., 2008; Yiend & 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 utilized 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 the error management theory can 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 regard 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., 2016). 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 et al., 2014; Morewedge, 2009; van 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.

Notes

1. For the purpose of this article, we are specifically interested in the belief in supernatural agents, i.e., human-like entities, that are often invisible and that can exert a causal influence on our world. We note that our definition

- of supernatural beliefs hinges strongly on an ethnocentric and Western conception of the supernatural – a focus that has also been prevalent in the cognitive science of religion literature (see, for instance, Norenzayan's *Big Gods*, 2013). This does not preclude the notion that other non-ethnocentric definitions of the supernatural may be useful to distinguish as well (see, for instance, Horton, 1993), but our focus is primarily on the evolutionary psychological claim that agency detection biases play a causal role in shaping belief in supernatural entities.
2. The hypothesized relation between the HADD and supernatural beliefs has been discussed elsewhere (van Elk et al., 2016) and is not the topic of the present study.
 3. For explorative purposes, we added three questionnaires to the experiments (except for Experiments 1a and 2b as the chronological order of the experiments in the article differs from the order in which the experiments were conducted): the Anthropomorphization 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.
 4. www.pointlightlab.com.
 5. We anticipated that some participants would need to be excluded and therefore collected somewhat more data than the desired 30 participants.
 6. <https://share.oculus.com/app/teratophobia>.
 7. <https://share.oculus.com/app/alien-desert>.
 8. An ultimatum game is an economic decision game in which one player needs to divide money with a second player, who in its turn can either accept or reject the proposal. As a result, the money is split or neither player receives anything.

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