Consciousness and Cognition 106 (2022) 103418

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Believing is seeing: The link between paranormal beliefs and perceiving signal in noise

Kiley Seymour[b,*], Philipp Sterzer[c,d,e], Natalie Soto[a]

[a] School of Psychology, Western Sydney University, New South Wales, Australia
[b] The MARCS Institute for Brain, Behaviour and Development, New South Wales, Australia
[c] Department of Psychiatry and Psychotherapy, Charité Universitätsmedizin Berlin, Germany
[d] Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany
[e] University Psychiatric Clinics Basel, Switzerland

ARTICLE INFO

Keywords:
Paranormal beliefs
Mooney faces
Perceptual sensitivity
Predictive coding
Psychosis

ABSTRACT

Research suggests that at the core of paranormal belief formation is a tendency to attribute meaning to ambiguous stimuli. But it is unclear whether this tendency reflects a difference in perceptual sensitivity or a decision bias. Using a two-alternative forced choice task, we tested the relationship between paranormal belief and perceptual sensitivity. Participants were shown two stimuli presented in temporal succession. In one interval an ambiguous Mooney Face (i.e., signal) was presented, in the other interval a scrambled version of the image (i.e., noise) was presented. Participants chose in which of the two intervals the face appeared. Our results revealed that participants with stronger beliefs in paranormal phenomena were less sensitive to discriminating signal from noise. This finding builds on previous research using "yes/no" tasks, but importantly disentangles perceptual sensitivity from response bias and suggests paranormal believers perceive things differently.

1. Introduction

Our perception of the world is not merely determined by information conveyed through our senses but is strongly influenced by prior knowledge about the world (von Helmholtz, 1866). Signals registered by our sensory organs are inherently noisy and fragmented, so our percepts are generated through a process of unconscious inference. Thus, the brain is very efficient at inferring meaningful patterns from fragmented or ambiguous sensory information (Clark, 2013; Dayan et al., 1995; Friston et al., 2012; Gregory, 1980; Hohwy, 2013; Kanizsa, 1955; Rao & Ballard, 1999). This explains, for example, why we can so easily detect a face from the shadows, despite limited information provided to the retina. But it can also explain how in daily life, we sometimes make perceptual errors, such as in the case of face pareidolia, where we perceive inanimate objects as possessing a face (Caruana & Seymour, 2021; Keys et al., 2021; Palmer & Clifford, 2020; Partos et al., 2016; Wardle et al., 2017). This strong tendency for the brain to make sense of stimuli based on noisy or ambiguous sensory data is an adaptive and general function of the brain. Interestingly, a belief in paranormal phenomena is also thought to have evolved from a similar need to predict and explain sources of nonsensical sensory data in the world and to reduce uncertainty (Inzlicht et al., 2009; Irwin, 1994; Lange & Houran, 1999).

It has been proposed that a perceptual bias to detect meaningful patterns in ambiguous sensory noise may lie at the core of

* Corresponding author at: School of Psychology, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia.
E-mail address: k.seymour@westernsydney.edu.au (K. Seymour).

https://doi.org/10.1016/j.concog.2022.103418
Received 25 May 2022; Received in revised form 1 September 2022; Accepted 27 September 2022
Available online 14 October 2022
1053-8100/

paranormal belief formation (Barrett, 2000; Barrett, 2004; Barrett & Keil, 1996; Barrett & Lanman, 2008; Blackmore & Moore, 1994; Bressan, 2002; Guthrie, 1995; Krummenacher et al., 2010). There is indeed evidence that paranormal believers are more prone to jumping to conclusions on the basis of inadequate evidence (Blagrove et al., 2006) and perceive patterns in nonsensical sensory stimuli (Blackmore & Moore, 1994; Blackmore & Trościanko, 1985; Bressan, 2002; Brugger, 2001; Brugger et al., 1990; Gianotti et al., 2001; Krummenacher et al., 2010; Riekki et al., 2013; Riekki et al., 2014; van Elk, 2013; van Elk, 2015; van Elk et al., 2016; van Prooijen et al., 2018; Willard & Norenzayan, 2013; Wiseman & Watt, 2006). In the visual domain, research has shown that people who believe in paranormal phenomena have a strong tendency to erroneously identify faces in scrambled configurations (Krummenacher et al., 2010), to judge ambiguous motion displays as comprising of a human agent (Riekki et al., 2014; van Elk, 2013), and to evaluate pictures of landscapes as more face-like (Riekki et al., 2013).

A notable limitation of studies examining perceptual bias and paranormal beliefs is their failure to disentangle perceptual sensitivity from response bias. For example, most studies reporting that paranormal believers are more prone to 'seeing' human-like qualities in noise require subjects to make dichotomous "yes/no" judgments about whether those qualities are present (e.g., Riekki et al., 2013; Riekki et al., 2014; van Elk, 2013; van Elk et al., 2016). These judgments are confounded because a stronger tendency to say a feature is present does not necessarily indicate a stronger tendency to perceive it. For example, in a study that used ambiguous biological motion point light displays to examine illusory agency detection in paranormal believers and sceptics, participants were required to make a "yes" or "no" decision about whether a human walker was present (van Elk, 2013). It was reported that paranormal believers gave more 'yes' responses in this task. While this could indicate that paranormal believers had a higher sensitivity to perceiving human walkers in noise, the result might also reflect a greater tendency to say a human walker was present when uncertain. Sceptical individuals may also tend to say "no" when uncertain and exhibit a more conservative criterion to acknowledge the presence of a walker. There has been subsequent research aimed at eliminating this confound (e.g., by using categorisation tasks; van Elk et al., 2016), but unfortunately this has failed to resolve the issue (i.e., any categorisation task is also susceptible to response bias). Moreover, signal detection theoretic approaches suggest that believers are more liberal with their response criteria compared to sceptics, making more false alarm responses rather than correctly detecting a signal more often (Gianotti et al., 2001; Krummenacher et al., 2010; Riekki et al., 2013; Tsakanikos & Reed, 2005; van Elk, 2013). Thus, the reported findings that paranormal believers are hypersensitive to perceiving meaning from noise leaves open the question of whether this truly relates to sensitivity differences or more downstream processes, such as response bias.

In the current study, we use a two-interval forced choice (2IFC) task to directly test whether individuals holding paranormal beliefs show a difference in sensitivity to discriminating meaningful patterns from noise, removing the possibility of measuring a response bias to report that a pattern is present when uncertain. In a typical 2IFC experiment, stimuli are presented in two intervals. One interval contains the signal stimulus (e.g., an ambiguous face). In the other interval, a noise stimulus is presented (e.g., an ambiguous non-face). Participants are required to indicate in which interval the signal stimulus is present. Unlike the "yes/no" tasks used in previous research, the 2IFC task provides an estimate of perceptual sensitivity that rules out the possibility of a bias to report the presence of a signal when uncertain (Fechner, 1860/1966; Green & Sweets, 1966; Jogan & Stocker, 2014). This is because individuals are forced to choose between two stimuli, as opposed to being asked whether a signal is present or not. Thus, a bias to report having seen a meaningful pattern when a participant is uncertain will not interfere with task performance. With the 2IFC task, participants must prove they perceive the signal, and their claims can be checked. Given this advance over previous experiments, we hypothesised that, if paranormal belief is associated with a perceptual difference (rather than a response bias), a reduced sensitivity to discriminate a meaningful stimulus from noise would be observed in performance differences in our 2IFC task.

2. Method

2.1. Participants

The study received ethics approval from the Western Sydney University Research Ethics Committee (H12571). Participants were undergraduate psychology students, recruited through Western Sydney University's online participant recruitment platform. In total, 74 participants were recruited, and received course credit for their time. Data from 3 participants were removed due to non-serious attempts (e.g., 1 had more than 30 % responses <80 ms after stimulus onset and 2 had mean performance below chance). This resulted in data from a total of 71 participants (57 females, 12 males, 2 non-binary, mean age 21). All participants had normal or corrected-to-normal vision.

2.2. Paranormal belief assessment

We used a subset of questions from a self-rating questionnaire created by Fahrenberg & Cheetham, (2007), which we translated into English from German. This questionnaire has previously been used to assess various beliefs (e.g., brain and consciousness, free-will and determinism, a belief in God, meaning of life and morality) in a large population of undergraduate psychology students and has good test–retest reliability. For the purposes of our study, we focussed on the four items related to beliefs in paranormal phenomena, where we could calculate a PARA score (Fahrenberg & Cheetham, 2007). High PARA scores indicate a belief in paranormal phenomena, such as extrasensory perception, telepathy, miraculous mental healing, the validity of exorcism and horoscopes. Low scores reflect a sceptical attitude or rejection of such concepts. Participants were instructed to rate how much each question applied to them on a 6-point Likert scale. For example, for the item 'Parapsychic phenomena such as extrasensory perception and telepathy do really happen, at least in rare cases', participants were required to provide a response ranging from 1 (Strongly disagree) to 6 (Strongly agree).

2.3. Stimuli

Mooney face images created by Schwiedrzik et al. (2018) were used as signal images in the experiment. These images are freely available online and include a large range of ambiguity levels that allowed us to probe perceptual sensitivity to faces under high conditions of uncertainty and to avoid ceiling effects. Substantial individual differences in face detection have previously been measured with these stimuli (Schwiedrzik et al., 2018; Verhallen et al., 2014), providing us with an opportunity to measure a broad range of perceptual responses. Previous related research has used pareidolia images (e.g., a face in the clouds) (Riekki et al., 2013). Use of such stimuli is problematic because an accurate response cannot be verified as pareidolia faces are not real faces. Our stimuli were real, albeit degraded, face images, and thus correct answers could be verified in our task.

For our 2IFC task, we selected a subset of images from the original set (Schwiedrzik et al., 2018). Specifically, we chose a random selection of 170 Mooney face images in their upright and inverted form (Fig. 1). Upright and inverted images were presented as signal images in the experiment. The inclusion of inverted images was aimed at increasing stimulus ambiguity (Valentine, 1988). We also included 170 scrambled images (using 96 from the original set and creating an additional 74 based on the approach used by Schwiedrzik et al. (2018). The scrambled images were used as noise stimuli, designed to measure false alarms from our participants.

Participants were seated 57 cm away from a computer display and performed the experiment in a dark room. Stimuli were presented on a 15-inch gamma-corrected CRT monitor (refresh rate of 60 Hz, 1024 × 768-pixel resolution, background luminance: 50 cd/m). Stimuli subtended 7 × 10 deg of visual angle and were generated in Matlab (Mathworks, MA) and Psychtoolbox (Pelli, 1997). Responses were collected via a standard keyboard.

2.4. Procedure

The experiment was run in two parts. First, participants completed a 2IFC Mooney face discrimination task. They were shown examples of the stimuli prior to testing and were given opportunity to practice beforehand. On completing this task, we administered our questionnaire via Qualtrics to assess the extent of participants' beliefs in paranormal phenomena.

In the 2IFC Mooney face discrimination task, participants were presented with two ambiguous images in temporal succession displayed in the centre of the screen (Fig. 2). One image was an upright or inverted Mooney face (i.e., degraded signal). The other image contained a scrambled match of that image (i.e., noise). Each stimulus remained on the screen for 500 ms, separated by a blank period of 300 ms. After the two images were presented, a fixation dot appeared in the middle of the screen. Participants were then forced to indicate (via a keyboard response) which of the two intervals contained the Mooney face. The task was non-speeded. If participants were unsure about which interval contained the true signal, they were asked to guess. By forcing participants to choose from two stimulus intervals, the potential of response bias confounds related to reporting the presence of the signal when guessing was eliminated from our task. An inter-trial interval of 600 ms followed each response before introducing the next trial. A total of 340 trials were presented to each participant. The interval containing the face signal was selected at random on each trial. Participants were given a break half-way through testing. The order of the trials was randomized across participants, but each participant was presented with the same stimulus pairs. Accuracy data and response times were recorded on each trial.

Fig. 1. Example stimuli. Signal stimuli were Mooney Image presented either in upright (left) or inverted form (middle). Noise stimuli comprised of the same Mooney Image but in scrambled form (right).

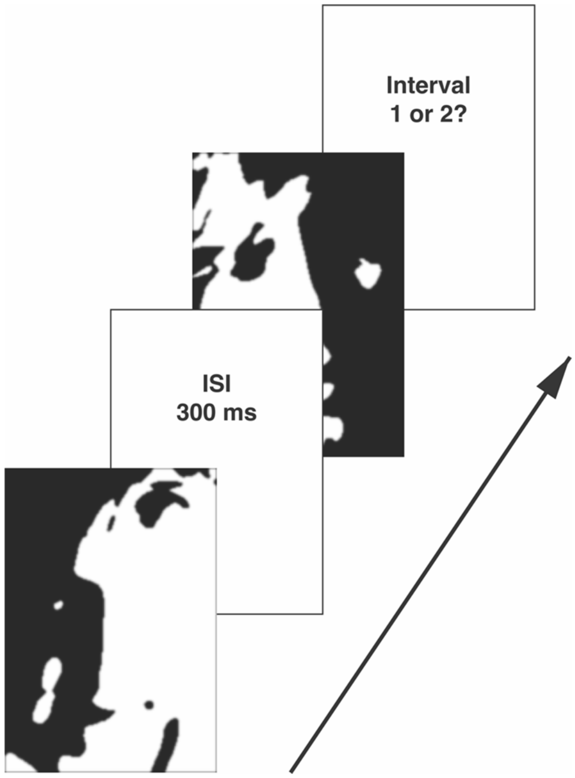

Fig. 2. Example of a single trial: One stimulus is presented (in this case noise: a scrambled Mooney image) followed by the second stimulus (signal: Upright Mooney face). Participants are forced to make a judgement about which of the two intervals contained the signal. This eliminates a potential bias to report the presence of a face when uncertain about the percept.

2.5. Analysis

The relationship between paranormal belief tendency (i.e., sum of PARA scores) and face vs non-face discrimination sensitivity (d') was explored using nonparametric Spearman's correlation analysis in JASP.

3. Results

Generally, our participants provided responses to our paranormal beliefs questionnaire that were in line with previous findings from a study on 540 first year undergraduate psychology students (Fahrenberg & Cheetham, 2007). Our participant sample provided a full range of responses. A summary is provided in Table 1.

Generally, participants performed well on the Mooney face discrimination task and in line with previous findings of face inversion effects (e.g., see Valentine, 1988). Mean sensitivity was d' 1.809 ± 0.473 sd. Participants were generally more sensitive at discriminating upright Mooney faces from noise (mean d' 2.469 ± 0.616 sd) compared to inverted Mooney faces from noise (mean d' 1.150 ± 0.417 sd), $t(70) = 24.153$, $p < 0.001$, $d = 2.866$. Our analysis found that paranormal beliefs were associated with poorer signal from

Table 1
Summary of participant responses to questions relating to beliefs in paranormal phenomena. Participants were instructed to rate how much each question applied to them on a 6-point Likert scale (6 = strongly agree).

Questionnaire item	Range	Mean	Standard deviation	% Agree
1. *True miracle healing* (e.g., *as reported from places of pilgrimage) does happen in cases of serious and chronic physical illness.*	1–6	3.141	1.543	21.1 %
2. *Parapsychic phenomena like extrasensory perception* (i.e., *direct perception that occurs outside our sensory system) and telepathy* (i.e., *transmission of mental content) do happen, at least in rare cases.*	1–6	3.423	1.518	33.8 %
3. *In extreme cases, it may be appropriate for an experienced priest to perform an exorcism (ritual to counteract demonic influences).*	1–5	2.859	1.676	26.7 %
4. *Correct statements about the character of an individual and sometimes even predictions of life events* (i.e., *their destiny) can be derived from horoscopes.*	1–6	2.606	1.626	16.9 %
PARA total score	**4–21**	**12.056**	**4.828**	

noise discrimination performance. Specifically, a two-tailed Pearson's correlation found evidence for a significant negative relationship between one's tendency to believe in paranormal phenomena and one's sensitivity to discriminate signal from noise (Fig. 3). A statistically significant relationship was observed between PARA scores and d' measures for upright Mooney face trials, $r(71) = -0.242$, $p = 0.042$, 95 % bootstrapped CI: −0.430 – −0.042. This relationship was not observed for inverted Mooney face trials ($r(71) = -0.039$, $p = 0.747$, 95 % CI: −0.243 – 0.163). Consistent with a true perceptual effect measured using a 2IFC task, these findings suggests that a stronger tendency to believe in paranormal phenomena is associated with a poorer sensitivity to discriminate upright face signals from non-face noise.

Our results demonstrate a relationship between one's beliefs in paranormal phenomena and one's ability to discriminate upright faces from non-face noise, however, there is a possibility that idiosyncratic response preferences of participants (i.e., favouring one interval over another) may lead to performance differences across subjects. Research has shown that while a 2IFC experiment may eliminate biases to report the presence of a signal when uncertain, large sensitivity differences can be measured between the two intervals (e.g., Yeshurun et al., 2008). This poses a problem for the interpretation of our results because our signal was always randomly allocated to one of the two intervals as opposed to being equally balanced across trials (and therefore participants). Thus, our design could have inadvertently produced slight asymmetrical performance differences across participants, particularly if idiosyncratic response preferences exist across the sample.

To address this possibility, we used the approach by Yeshurun, et al. (2008) to determine whether differences in discrimination performance exist between trials where the signal is present in the first interval compared to the second interval. We found that indeed large differences in discrimination performance exist, with trials that present the Mooney face signal in the first interval producing a larger d' than the second interval. This was observed for both upright ($t(70) = 5.873$, $p < 0.001$, $d = 0.697$) and inverted trials ($t(70) = 2.702$, $p = 0.009$, $d = 0.321$), and is consistent with other findings from 2IFC experiments (e.g., see Yeshurun et al., 2008).

Based on the above findings, we looked at whether the relationship between task performance and PARA scores could be explained by asymmetric signal–noise configurations across participants and different preferences for favouring one interval over the other. Our analyses revealed no significant relationship between PARA scores and differences in the proportion of first-interval trials displaying the signal, $r(71) = 0.024$, $p = 0.839$, 95 % bootstrapped CI: −0.210 – 0.256. We also found no evidence for a relationship between differences in PARA scores and the proportion of first interval responses made by participants, $r(71) = 0.140$, $p = 0.243$, 95 % bootstrapped CI: −0.096 – 0.362. These analyses indicate that a stronger tendency to believe in paranormal phenomena is associated with greater difficulty in discriminating upright face signals from non-face noise, which cannot be explained by biases to favour one interval over another or slight differences in the proportion of first-interval trials displaying the signal.

4. Discussion

This study investigated whether there is a relationship between the tendency to believe in paranormal phenomena and a sensitivity to discriminate meaningful patterns from noise. Based on previous studies showing paranormal believers are more inclined to report the presence of signal in noise (Krummenacher et al., 2010; Riekki et al., 2014; van Elk, 2013; van Elk et al., 2016), we hypothesised that if this reflects a perceptual difference (rather than a response bias), a reduced sensitivity to discriminate signals from noise would be observed. Consistent with this hypothesis, we show that participants with stronger beliefs in paranormal phenomena are less

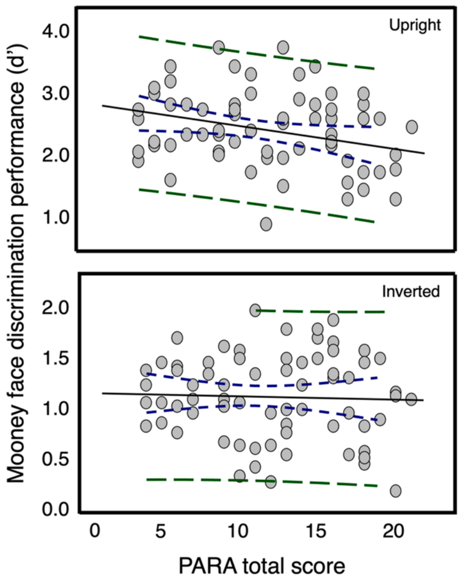

Fig. 3. People's tendency to believe in paranormal phenomena negatively correlates with their sensitivity to discriminate upright faces from non-face noise. Sensitivity is shown separately for upright and inverted face trials. 95% prediction and confidence intervals are plotted.

sensitive to discriminating face signals from non-face noise, suggesting differences in perceptual experience are linked to differences in beliefs.

A lower sensitivity to discriminate ambiguous face signals from similar looking noise suggests that paranormal believers experience their environment differently to sceptics. Previous studies have suggested a hypersensitivity of paranormal believers to perceive patterns in noise, however, these studies have typically employed 'yes/no' tasks that are confounded by a potential bias (or reduced criterion) to report a signal being present when uncertain (Krummenacher et al., 2010; Riekki et al., 2014; van Elk, 2013; van Elk et al., 2016). By forcing participants to choose a Mooney face from a similar looking non-face distractor, our study eliminated this possible bias and could verify perceptual sensitivity. Thus, our study makes a significant advance over previous research, by disentangling differences in *perceptual sensitivity* from biases to report the presence of a meaningful signal when forced to guess.

While our results of reduced sensitivity to discriminate signal from noise are consistent with the idea that paranormal believers treat noise as meaningful information (Barrett, 2004; Blackmore & Moore, 1994; Guthrie, 1995) and may experience "perceptual hallucinations" from noise (Barrett, 2000; Blackmore & Moore, 1994; Gianotti et al., 2001; Krummenacher et al., 2010; van Elk, 2013; van Elk et al., 2016), an alternative account is that believers find our task more difficult due to a weakened sensitivity to detect face information and as a result make more guesses. Unfortunately, our study cannot adjudicate on whether errors from our participants arise from false alarms or misses, as both signal and noise are present in each trial. However, related studies using signal detection analysis on yes/no task data report an increase in false alarm rates for paranormal believers (e.g., Riekki et al., 2013; van Elk, 2013). While this may reflect a response bias, these studies do not report fewer hits or more misses, which might otherwise indicate higher detection thresholds. Indeed most studies report that paranormal believers show a reduced criterion to acknowledge the presence of a signal (Blackmore & Moore, 1994; Blackmore & Trościanko, 1985; Bressan, 2002; Brugger, 2001; Brugger et al., 1990; Gianotti et al., 2001; Krummenacher et al., 2010; Riekki et al., 2013; Riekki et al., 2014; van Elk, 2013; van Elk, 2015; van Elk et al., 2016; van Prooijen et al., 2018; Willard & Norenzayan, 2013; Wiseman et al., 2003; Wiseman & Watt, 2006). Nonetheless, the present data alone cannot clarify whether believers are more prone to perceptual hallucinations of faces in noise or worse at detecting faces altogether but do suggest a difference in perceptual experience.

Our finding of reduced perceptual sensitivity in paranormal believers is consistent with predictive coding accounts of perception that suggest beliefs and perceptual experience are inextricably linked (Clark, 2013; Dayan et al., 1995; Friston et al., 2012; Gregory, 1980; Hohwy, 2013; Rao & Ballard, 1999; von Helmholtz, 1866). Predictive coding models state that the brain makes sense of noisy sensory input based on prior beliefs and expectations, which in turn drives a cycle that reinforces one's beliefs (Fletcher & Frith, 2009; Hohwy, 2013; von Helmholtz, 1866). When sensory evidence is weak, the brain is thought to rely more on prior beliefs to generate percepts. Thus, perception has be described as a "controlled hallucination" (Clark, 2013).

In recent years, predictive coding accounts of perception have been used to explain the positive symptoms of psychosis (Adams et al., 2013; Corlett et al., 2009; Fletcher & Frith, 2009; Sterzer et al., 2018). It is posited that an overweighing of prior beliefs relative to sensory information generates false perceptions, leading to drastic effects on the patient's worldview, which characterises psychotic states (i.e., delusions and hallucinations). Importantly, a tendency to hold paranormal beliefs is a common feature of psychosis (e.g., Thalbourne, 1994) and is strongly correlated with delusion proneness (e.g.,Pechey & Halligan, 2011; Pechey and Halligan, 2012) and schizotypy in healthy participants (i.e., a nonclinical analogue of positive psychotic symptoms) (Eckblad & Chapman, 1983). Research on hallucination proneness also suggests a bias to report faces in noise (Abo Hamza et al., 2021; Mavrogiorgou et al., 2021; Partos et al., 2016; Rolf et al., 2020; Stuke et al., 2021). Given that psychotic symptoms have also been associated with poor discrimination between signal and noise (e.g., confusion between perception and imagination (Brébion et al., 2008), disrupted self–other differentiation (Hemsley, 1998), our present findings offer support for current models of psychosis and may have implications for clinical psychiatry.

Finally, our sample was comprised primarily of female undergraduate students. As age, gender, and education are factors mediating paranormal beliefs (Aarnio & Lindeman, 2005; Fahrenberg & Cheetham, 2007; Vitulli et al., 1999), future studies with a more generalizable sample will prove insightful. Similarly, our study reports a relatively small effect size and did not look at factors that covary with paranormal beliefs. For instance, a growing body of evidence shows that individual differences in perception can be linked to different personality traits (Antinori et al., 2017; Partos et al., 2016), mood (Sterzer et al., 2011), and cultural background (Kitayama et al., 2003; Nisbett & Miyamoto, 2005). These factors are known to influence paranormal ideation also, so future studies should be aimed to examining whether beliefs per se are driving the results.

CRediT authorship contribution statement

Kiley Seymour: Conceptualization, Methodology, Formal analysis, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing. **Philipp Sterzer:** Funding acquisition, Resources, Writing – review & editing. **Natalie Soto:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

A link to our data and JASP analysis files is here: https://osf.io/jwzkf/?view_only=4d6808bfa15c4e56958dabe1065fdcc5

Acknowledgements

We thank Dr Robert Ross for his feedback on an early version of this manuscript.

References

Aarnio, K., & Lindeman, M. (2005). Paranormal beliefs, education, and thinking styles. *Personality and Individual Differences, 39*(7), 1227–1236. https://doi.org/10.1016/j.paid.2005.04.009

Abo Hamza, E. G., Keri, S., Csigo, K., Bedewy, D., & Moustafa, A. A. (2021). Pareidolia in Schizophrenia and Bipolar Disorder. *Frontiers in Psychiatry, 12*, 746734. https://doi.org/10.3389/fpsyt.2021.746734

Adams, R. A., Stephan, K. E., Brown, H. R., Frith, C. D., & Friston, K. J. (2013). The computational anatomy of psychosis. *Frontiers in Psychiatry, 4*, 47. https://doi.org/10.3389/fpsyt.2013.00047

Antinori, A., Carter, O. L., & Smillie, L. D. (2017). Seeing it both ways: Openness to experience and binocular rivalry suppression. *Journal of Research in Personality, 68*, 15–22. https://doi.org/10.1016/j.jrp.2017.03.005

Barrett, J. L. (2000). Exploring the natural foundations of religion. *Trends in Cognitive Sciences, 4*(1), 29–34. https://doi.org/10.1016/S1364-6613(99)01419-9

Barrett, J. L. (2004). *Why would anyone believe in god?* Lanham: Alta Mira.

Barrett, J. L., & Keil, F. C. (1996). Conceptualizing a nonnatural entity: Anthropomorphism in God concepts. *Cognitive Psychology, 31*(3), 219–247.

Barrett, J. L., & Lanman, J. A. (2008). The science of religious beliefs. *Religion, 38*(2), 109–124. https://doi.org/10.1016/j.religion.2008.01.007

Blackmore, S., & Moore, R. (1994). Seeing things: Visual recognition and belief in the paranormal. *European Journal of Parapsychology, 10*, 91–103.

Blackmore, S., & Trościanko, T. (1985). Belief in the paranormal: Probability judgements, illusory control, and the 'chance baseline shift'. *British journal of Psychology, 76*(4), 459–468.

Blagrove, M., French, C. C., & Jones, G. (2006). Probabilistic reasoning, affirmative bias and belief in precognitive dreams. *Applied Cognitive Psychology, 20*(1), 65–83. https://doi.org/10.1002/acp.1165

Brébion, G., Ohlsen, R. I., Pilowsky, L. S., & David, A. S. (2008). Visual hallucinations in schizophrenia: Confusion between imagination and perception. *Neuropsychology, 22*(3), 383–389.

Bressan, P. (2002). The connection between random sequences, everyday coincidences, and belief in the paranormal. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 16*(1), 17–34.

Brugger, P. (2001). From haunted brain to haunted science: A cognitive neuroscience view of paranormal and pseudoscientific thought. *Hauntings and Poltergeists: Multidisciplinary Perspectives*, 195–213.

Brugger, P., Landis, T., & Regard, M. (1990). A 'sheep-goat effect'in repetition avoidance: Extra-sensory perception as an effect of subjective probability? *British journal of Psychology, 81*(4), 455–468.

Caruana, N., & Seymour, K. (2021). Objects that induce face pareidolia are prioritized by the visual system. *British Journal of Psychology*. https://doi.org/10.1111/bjop.12546

Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and Brain Sciences, 36*(3), 181–204. https://doi.org/10.1017/S0140525X12000477

Corlett, P. R., Frith, C. D., & Fletcher, P. C. (2009). From drugs to deprivation: A Bayesian framework for understanding models of psychosis. *Psychopharmacology (Berlin), 206*(4), 515–530. https://doi.org/10.1007/s00213-009-1561-0

Dayan, P., Hinton, G. E., Neal, R. M., & Zemel, R. S. (1995). The Helmholtz machine. *Neural Computation, 7*(5), 889–904. https://doi.org/10.1162/neco.1995.7.5.889

Eckblad, M., & Chapman, L. J. (1983). Magical ideation as an indicator of schizotypy. *Journal of Consulting and Clinical Psychology, 51*(2), 215–225. https://doi.org/10.1037//0022-006x.51.2.215

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

Fechner, G. (1860/1966). Elements of psychophysics. New York: Holt, Rinehart and Winston. (Original work published 1860).

Fletcher, P. C., & Frith, C. D. (2009). Perceiving is believing: A Bayesian approach to explaining the positive symptoms of schizophrenia. *Nature Reviews Neuroscience, 10*(1), 48–58. https://doi.org/10.1038/nrn2536

Friston, K., Adams, R. A., Perrinet, L., & Breakspear, M. (2012). Perceptions as hypotheses: Saccades as experiments. *Frontiers in Psychology, 3*, 151. https://doi.org/10.3389/fpsyg.2012.00151

Gianotti, L. R. R., Mohr, C., Pizzagalli, D., Lehmann, D., & Brugger, P. (2001). Associative processing and paranormal belief. *Psychiatry and Clinical Neurosciences, 55*(6), 595–603. https://doi.org/10.1046/j.1440-1819.2001.00911.x

Green, D., & Sweets, J. (1966). *Signal detection theory and psychophysics*. New York: Wiley.

Gregory, R. L. (1980). Perceptions as hypotheses. *Philosophical Transactions of the Royal Society of London. Series B, Biological sciences, 290*(1038), 181–197. https://doi.org/10.1098/rstb.1980.0090

Guthrie, S. E. (1995). *Faces in the clouds: A new theory of religion.* Oxford University Press.

Hemsley, D. R. (1998). The disruption of the 'sense of self' in schizophrenia: Potential links with disturbances of information processing. *British Journal of Medical Psychology, 71*(Pt 2), 115–124. https://doi.org/10.1111/j.2044-8341.1998.tb01373.x

Hohwy, J. (2013). *The predictive mind.* UK: Oxford University Press.

Inzlicht, M., McGregor, I., Hirsh, J. B., & Nash, K. (2009). Neural markers of religious conviction. *Psychological Science, 20*(3), 385–392. http://www.jstor.org/stable/40575029.

Irwin, H. J. (1994). Paranormal belief and proneness to dissociation. *Psychological Reports, 75*(3), 1344–1346. https://doi.org/10.2466/pr0.1994.75.3.1344

Jogan, M., & Stocker, A. A. (2014). A new two-alternative forced choice method for the unbiased characterization of perceptual bias and discriminability. *Journal of Vision, 14*(3), 20. https://doi.org/10.1167/14.3.20

Kanizsa, G. (1955). Margini Quasi-percettivi in Campi con Stimolazione Omogenea.

Keys, R. T., Taubert, J., & Wardle, S. G. (2021). A visual search advantage for illusory faces in objects. *Attention, Perception, & Psychophysics, 83*(5), 1942–1953. https://doi.org/10.3758/s13414-021-02267-4

Kitayama, S., Duffy, S., Kawamura, T., & Larsen, J. T. (2003). Perceiving an object and its context in different cultures: A cultural look at new look. *Psychological Science, 14*(3), 201–206. https://doi.org/10.1111/1467-9280.02432

Krummenacher, P., Mohr, C., Haker, H., & Brugger, P. (2010). Dopamine, paranormal belief, and the detection of meaningful stimuli. *Journal of Cognitive Neuroscience, 22*(8), 1670–1681. https://doi.org/10.1162/jocn.2009.21313

Lange, R., & Houran, J. (1999). The role of fear in delusions of the paranormal. *The Journal of Nervous and Mental Disease, 187*(3).

Mavrogiorgou, P., Peitzmeier, N., Enzi, B., Flasbeck, V., & Juckel, G. (2021). Pareidolias and creativity in patients with mental disorders. *Psychopathology, 54*(2), 59–69. https://doi.org/10.1159/000512129

Nisbett, R. E., & Miyamoto, Y. (2005). The influence of culture: Holistic versus analytic perception. *Trends in Cognitive Sciences, 9*(10), 467–473. https://doi.org/10.1016/j.tics.2005.08.004

Palmer, C. J., & Clifford, C. W. G. (2020). Face Pareidolia recruits mechanisms for detecting human social attention. *Psychological Science, 31*(8), 1001–1012. https://doi.org/10.1177/0956797620924814

Partos, T. R., Cropper, S. J., & Rawlings, D. (2016). You don't see what i see: Individual differences in the perception of meaning from visual stimuli. *PLoS ONE, 11*(3), e0150615.

Pechey, R., & Halligan, P. (2011). The prevalence of delusion-like beliefs relative to sociocultural beliefs in the general population. *Psychopathology, 44*(2), 106–115. https://doi.org/10.1159/000319788

Pechey, R., & Halligan, P. (2012). Prevalence and correlates of anomalous experiences in a large non-clinical sample. *Psychology and Psychotherapy: Theory, Research and Practice, 85*(2), 150–162. https://doi.org/10.1111/j.2044-8341.2011.02024.x

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision, 10*, 5.

Rao, R. P. N., & Ballard, D. H. (1999). Predictive coding in the visual cortex: A functional interpretation of some extra-classical receptive-field effects. *Nature Neuroscience, 2*, 79–87.

Riekki, T., Lindeman, M., Aleneff, M., Halme, A., & Nuortimo, A. (2013). Paranormal and religious believers are more prone to illusory face perception than skeptics and non-believers. *Applied Cognitive Psychology, 27*(2), 150–155.

Riekki, T., Lindeman, M., & Raij, T. T. (2014). Supernatural believers attribute more intentions to random movement than skeptics: An fMRI study. *Social Neuroscience, 9*(4), 400–411. https://doi.org/10.1080/17470919.2014.906366

Rolf, R., Sokolov, A. N., Rattay, T. W., Fallgatter, A. J., & Pavlova, M. A. (2020). Face pareidolia in schizophrenia. *Schizophrenia Research, 218*, 138–145. https://doi.org/10.1016/j.schres.2020.01.019

Schwiedrzik, C. M., Melloni, L., & Schurger, A. (2018). Mooney face stimuli for visual perception research. *PLoS ONE, 13*(7), e0200106.

Sterzer, P., Adams, R. A., Fletcher, P., Frith, C., Lawrie, S. M., Muckli, L., Petrovic, P., Uhlhaas, P., Voss, M., & Corlett, P. R. (2018). The predictive coding account of psychosis. *Biological Psychiatry, 84*(9), 634–643. https://doi.org/10.1016/j.biopsych.2018.05.015

Sterzer, P., Hilgenfeldt, T., Freudenberg, P., Bermpohl, F., & Adli, M. (2011). Access of emotional information to visual awareness in patients with major depressive disorder. *Psychological Medicine, 41*(8), 1615–1624. https://doi.org/10.1017/S0033291710002540

Stuke, H., Kress, E., Weilnhammer, V. A., Sterzer, P., & Schmack, K. (2021). Overly strong priors for socially meaningful visual signals are linked to psychosis proneness in healthy individuals [Brief Research Report]. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.583637

Thalbourne, M. A. (1994). Belief in the paranormal and its relationship to schizophrenia-relevant measures: A confirmatory study. *British Journal of Clinical Psychology, 33*(1), 78–80. https://doi.org/10.1111/j.2044-8260.1994.tb01097.x

Tsakanikos, E., & Reed, P. (2005). Seeing words that are not there: Detection biases in schizotypy. *British Journal of Clinical Psychology, 44*(Pt 2), 295–299. https://doi.org/10.1348/014466505X28757

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British journal of Psychology, 79*(4), 471–491. https://doi.org/10.1111/j.2044-8295.1988.tb02747.x

van Elk, M. (2013). Paranormal believers are more prone to illusory agency detection than skeptics. *Consciousness and Cognition, 22*(3), 1041–1046. https://doi.org/10.1016/j.concog.2013.07.004

van Elk, M. (2015). Perceptual biases in relation to paranormal and conspiracy beliefs. *PLoS ONE, 10*(6), e0130422.

van Elk, M., Rutjens, B. T., van der Pligt, J., & van Harreveld, F. (2016). Priming of supernatural agent concepts and agency detection. *Religion, Brain & Behavior, 6*(1), 4–33. https://doi.org/10.1080/2153599X.2014.933444

van Prooijen, J.-W., Douglas, K. M., & De Inocencio, C. (2018). Connecting the dots: Illusory pattern perception predicts belief in conspiracies and the supernatural. *European Journal of Social Psychology, 48*(3), 320–335. https://doi.org/10.1002/ejsp.2331

Verhallen, R. J., Bosten, J. M., Goodbourn, P. T., Bargary, G., Lawrance-Owen, A. J., & Mollon, J. D. (2014). An online version of the Mooney Face Test: Phenotypic and genetic associations. *Neuropsychologia, 63*, 19–25. https://doi.org/10.1016/j.neuropsychologia.2014.08.011

Vitulli, W. F., Tipton, S. M., & Rowe, J. L. (1999). Beliefs in the paranormal: Age and sex differences among elderly persons and undergraduate students. *Psychological Reports, 85*(3 Pt 1), 847–855. https://doi.org/10.2466/pr0.1999.85.3.847

von Helmholtz, H. (1866). Treatise on physiological optics. *Trans. James P. Cocke, Mineola (New York): Dover Publications Inc,1962 and repr. 2005., 3*.

Wardle, S. G., Seymour, K., & Taubert, J. (2017). Characterizing the response to face pareidolia in human category-selective visual cortex. *bioRxiv*, 233387. https://doi.org/10.1101/233387

Willard, A. K., & Norenzayan, A. (2013). Cognitive biases explain religious belief, paranormal belief, and belief in life's purpose. *Cognition, 129*(2), 379–391. https://doi.org/10.1016/j.cognition.2013.07.016

Wiseman, R., Greening, E., & Smith, M. D. (2003). Belief in the paranormal and suggestion in the seance room. *British Journal of Psychology, 94*(Pt 3), 285–297.

Wiseman, R., & Watt, C. (2006). Belief in psychic ability and the misattribution hypothesis: A qualitative review. *British journal of Psychology, 97*(3), 323–338.

Yeshurun, Y., Carrasco, M., & Maloney, L. T. (2008). Bias and sensitivity in two-interval forced choice procedures: Tests of the difference model. *Vision Research, 48*(17), 1837–1851. https://doi.org/10.1016/j.visres.2008.05.008