



Fear the unseen: supernatural belief and agency detection in virtual reality

Adam E. Tratner, Todd K. Shackelford, Virgil Zeigler-Hill, Jennifer Vonk, and
Melissa M. McDonald

Department of Psychology, Oakland University, Rochester, MI, USA

ABSTRACT

Belief in supernatural agents is ubiquitous, as evidenced by its prevalence in religion, folklore, and cultural practices. It is theorized that, given recurrent ancestral risks of predation and frequent contact with other dangerous agents, mechanisms for agency detection may have evolved and play an important role in facilitating belief in supernatural agents. Thus, agency detection and belief in supernatural agents may be correlated in modern populations. College students ($N = 107$) completed a survey assessing belief in various supernatural phenomena, and participated in a virtual reality (VR) task where they indicated the perceived presence of agents (agency detection). Results indicated that the VR task successfully induced false agency detection such that the majority of participants perceived the presence of an agent at least once where no agent was present. Women reported greater overall supernatural belief than men. False agency detection was not related to belief in supernatural agents, and was instead related to belief in Feng Shui. These findings were unanticipated, and inconsistent with the study's main hypothesis. Discussion emphasizes theoretical and methodological considerations for future research on agency detection and supernatural belief.

ARTICLE HISTORY

Received 23 April 2018
Accepted 13 September 2018

KEYWORDS

supernatural belief;
supernatural agents;
agency detection; evolution;
evolutionary psychology;
virtual reality

1. Introduction

Scholars have proposed that a key psychological mechanism that facilitates belief in supernatural agents is the ability to detect and infer the presence of autonomous organisms—agency detection (Atran, 2002; Barrett, 2004; Bertolotti & Magnani, 2010; Boyer, 2001; Guthrie, 1980; Pyysiainen, 2009; Sanderson, 2008). Humans possess agency detection mechanisms that frequently detect non-existent entities, such that dots moving on a screen, unanticipated auditory stimuli, sudden environmental changes, and ambiguous visual stimuli produce the perception of moving bodies, voices in the wind, and faces in the clouds (Barrett, 2000; Guthrie, 1993; Liu et al., 2014; van Elk, 2013). Agency detection may be activated when sensory information is unreliable, and perceiving ambiguous, quasi-intentional sensory input can result in the ascription of an agent. For humans, these percepts sometimes take the form of supernatural agents. Thus, the link between agency detection and belief in supernatural agents has generated scholarly interest and inspired several theoretical models exploring this link.

One theoretical model contends that belief in supernatural agents arises from an evolved *Hyperactive Agency Detection Device* (HADD)—a cognitive module that hyperactively attributes events in the environment to the behavior of agents (Barrett & Lanman, 2008). Because of the recurrent threat

to survival posed by predators (Brantingham, 1998; Blumenschine et al., 1987; Treves & Naughton-Treves, 1999), rival hominids (Bowles, 2009; Gat, 2015; Keeley, 1996), and other dangerous animals, humans may have evolved agency detection mechanisms to facilitate the avoidance of dangerous agents (Barrett, 2005). Discriminating agents from non-agents and distinguishing different kinds of agents (i.e., potential predator vs. familiar conspecific) can be difficult because sensory information is often ambiguous and fleeting in the natural world, and detecting a potential threat amidst ambiguous stimuli could mean the difference between life and death. As a result, it has been suggested that it may be prudent for humans to over-detect (false positive) rather than to under-detect (false negative) potentially dangerous agents. That is, the costs for failing to detect dangerous agents when they were present were likely greater than the costs of mistakenly detecting them when they were not present (see: Error Management Theory; Haselton & Buss, 2000; Haselton & Nettle, 2006). This benefit–cost asymmetry may have facilitated the evolution of agency detection mechanisms that are biased toward false-positives (i.e., hyperactive agency detection).

According to the HADD model, agency detection mechanisms facilitate beliefs in supernatural agents by predisposing humans to detect agency in the environment, and some of these experiences are interpreted as encounters with supernatural agents (Barrett, 2000; Barrett & Lanman, 2008). These experiences are also thought to reinforce pre-existing supernatural agent beliefs (e.g., religious deities). In sum, the HADD model provides an evolutionary account of how supernatural agent beliefs may stem from an innate, universal bias in agency detection.

Recent work has generated alternative theoretical models for the link between agency detection and supernatural agent beliefs using a proximate level of analysis. For example, Andersen (2017) argued that humans are not equipped with an evolved hyperactive agency detection module *per se*, but rather agency detection is attuned to expectations of the presence (or absence) of agents, as well as the reliability of sensory information in certain environments. In this view, pre-existing supernatural agent beliefs create expectations for the presence of these agents in certain environments, and when paired with ambiguous sensory stimuli, humans may be prone to false agency detection, thereby reinforcing their supernatural agent beliefs. Alternatively, the Interactive Religious Experience Model (IREM; Van Leeuwen & van Elk, 2018) posits that humans are motivated by general supernatural beliefs acquired through culture (e.g., ghosts exist) to seek out experiences that validate personal supernatural beliefs (e.g., I saw a ghost). That is, believers in supernatural agents are more likely to seek out environments and situations that facilitate false agency detection, thereby reinforcing their personal supernatural agent beliefs. Rather than presupposing an evolved cognitive module that over-detects agents as a starting point for supernatural agent beliefs, both of these proximate models emphasize how beliefs in supernatural agents may instead calibrate the agency detection system to falsely detect agents or seek out experiences that facilitate false detection of agents.

2. Previous research

Previous research indicates that supernatural belief is related to a variety of perceptual and attentional biases (Blackmore & Moore, 1994; Fyfe, Williams, Mason, & Pickup, 2008; Gianotti, Mohr, Pizzagalli, Lehmann, & Brugger, 2001; Krummenacher, Mohr, Haker, & Brugger, 2010; van Elk, 2015; Whitson & Galinsky, 2008), and an emerging body of research has investigated the relationship between agency detection and supernatural belief. However, studies investigating the relationship between agency detection and supernatural belief have yielded mixed findings. For example, Riekkki, Lindeman, Aleneff, Halme, and Nuortimo (2013) documented that individuals who more accurately identify hidden faces in images, but also perceive more non-existent faces in images (i.e., false positive errors, over-detection), tend to report greater supernatural belief. Similarly, individuals who report greater supernatural belief more often mistakenly perceive bodies and moving forms in random sequences of moving dots (van Elk, 2013) and are more accurate than skeptics in categorizing ambiguous facial stimuli in a face-house categorization task (van Elk, 2015). Other studies, however, found no relationship between agency detection and individual differences in

supernatural beliefs (Maij, van Schie, & van Elk, 2017; Norenzayan, Hansen, & Cady, 2008; Willard & Norenzayan, 2013). Furthermore, agency detection is not affected by priming of supernatural agents (van Elk, Rutjens, van der Pligt, & Van Harreveld, 2016).

Taken together, these findings are mixed with regard to the theorized relationship between agency detection and supernatural belief. One prediction emphasized by previous scholars is a bidirectional relationship between agency detection and supernatural belief (Barrett & Lanman, 2008). This suggests the possibility that the link between agency detection and belief in supernatural agents manifests in individual differences, such that a greater tendency for over-detection of agency might be related to greater belief in supernatural agents. Another key prediction is that agency detection is activated in potentially threatening or ambiguous circumstances (Barrett, 2000). Using a novel research paradigm, the goal of the current study was to further investigate the link between agency detection and belief in supernatural agents by exploring whether individual differences in the over-detection of agency predicts individual differences in supernatural agent beliefs.

3. Current study

The current study investigated the relationship between agency detection and belief in supernatural agents using an individual difference approach (e.g., Barnes & Gibson, 2013; Willard & Norenzayan, 2013). We hypothesized a relationship between agency detection and self-reported supernatural belief, particularly belief in supernatural agents. We also hypothesized that women will report greater overall supernatural belief than men, in line with previous research (Aarnio & Lindeman, 2005; Rice, 2003). This study used Virtual Reality (VR) to produce a simulated naturalistic environment in which to investigate agency detection, similar to other recent studies (Andersen, Pfeiffer, Müller, & Schjoedt, 2017; Maij et al., 2017). VR technology has become increasingly sophisticated, realistic, and user-friendly, leading to its use in an emerging body of social science research. One advantage of VR is that it allows researchers to simulate real-world environments and situations, while maintaining a high degree of experimental control (Blascovich et al., 2002; Gillath, McCall, Shaver, & Blascovich, 2008; Navarrete, McDonald, Mott, & Asher, 2012; Renaud et al., 2014). We hypothesized that people who more often mistakenly perceive agency (i.e., false positives) in a dark, threatening VR outdoor environment will report greater overall supernatural belief and, particularly, greater belief in supernatural agents.

4. Material and methods

4.1. Participants and procedure

Participants were 113 undergraduate students (34 men, 79 women) who were at least 18 years of age ($M = 20.3$, $SD = 3.6$) and enrolled in psychology classes at a university in the Midwestern region of the United States. The racial/ethnic background of the sample was African American (15.0%), Asian (5.3%), Caucasian (69.0%), Latino/a (1.8%), Pacific Islander (1.8%), Middle Eastern (6.2%), and "Other" (0.9%). Participants identified as Christian (74.2%), Jewish (0.9%), Muslim (2.7%), Buddhist (1.8%), Atheist (3.5%), Agnostic (2.7%), or no religious affiliation (14.2%). The responses for six participants were excluded from analyses due to prior experience with the video game task, having provided responses that were significant outliers (greater than 3 standard deviations above or below the mean), and/or for failing to complete the study tasks, resulting in a final sample of 107 participants (34 men, 73 women). Participants were compensated with credit toward their research participation requirement in a psychology course.

Upon arrival at the laboratory, participants provided informed consent, completed a computerized survey, and participated in the VR video game task. The order in which participants completed the latter two tasks was counterbalanced by random assignment.

4.2. Survey

Participants completed an online survey during the laboratory session, which required approximately 30 minutes. The survey consisted of demographic questions (e.g., age, sex, ethnicity, religious affiliation), the HEXACO-60 personality inventory (for exploratory analyses¹ and to obscure the research hypothesis; Ashton & Lee, 2009), and an extended version of the Revised Paranormal Belief Scale (RPBS; Tobacyk, 2004; Lindeman & Aarnio, 2007).

The extended version of the RPBS is a validated measure that assesses the extent to which individuals believe in various supernatural phenomena. These phenomena include religious beliefs (e.g., belief in God, the devil), psychic powers (e.g., levitation, mind reading), witchcraft, superstitions (e.g., black cats bring bad luck), spiritualism (e.g., reincarnation, astral projection), precognition (e.g., psychics predicting the future), and extraordinary life forms (e.g., belief in the abominable snowman or Loch Ness monster). The extended RPBS is comprised of 22 items from Tobacyk's (2004) RPBS and 33 additional items created by Lindeman and Aarnio (2007) to assess a broader range of superstitious, magical, paranormal, and religious beliefs. For the purpose of this study, two items assessing belief in extraordinary life forms (paranormal agents) were retained from the original RPBS that Lindeman and Aarnio (2007) discarded, because inclusion of these items allowed for further assessment of belief in supernatural agents. In addition, we retained two items from the original RPBS pertaining to paranormal abilities because they reflect other dimensions of supernatural belief. The final result was a 59-item measure that consisted of seven subscales. Responses were recorded on a 7-point Likert scale (e.g., 1 = strongly disagree, 7 = strongly agree; see Appendix C) for the 59 adapted items because a 7-point scale (as opposed to a 5-point scale; Lindeman & Aarnio, 2007) allows participants to more precisely describe the extent of their beliefs, and decreases restrictions on the range of responses (Tobacyk, 2004).

Our version of the extended RPBS includes additional items addressing *belief in supernatural agents* (16 items; e.g., ghosts, witches, extraterrestrials; $\alpha = .89$), *belief in supernatural abilities* (12 items; e.g., psychokinesis; $\alpha = .88$), *religious beliefs* (4 items; e.g., belief in God; $\alpha = .92$), *luck beliefs* (9 items; e.g., charms that produce good fortune; $\alpha = .91$), *belief in astrology* (5 items; e.g., the influence of the position of stars at the time of birth on personality; $\alpha = .96$), *belief in Feng Shui* (5 items; e.g., how arrangement of furnishings produces good health and energy balance; $\alpha = .82$), and *belief in lunar effects* (8 items; e.g., people are more violent than usual during a full moon; $\alpha = .82$). The responses to all 59 items can be aggregated to compute a score for overall supernatural belief ($\alpha = .96$; Lindeman & Aarnio, 2007). Belief in supernatural agents was assessed using the paranormal agents subscale of the extended RPBS.

4.3. Virtual reality (VR) video game task

For the laboratory task, participants used an Oculus Rift VR video game device to play an exploration-themed video game. The Oculus Rift is a VR apparatus best described as an enclosed headset that includes headphones and a visor that cover the user's eyes and ears, respectively, and produces realistic visual and auditory sensations within a digital world (Chessa, Maiello, Borsari, & Bex, 2016). The Oculus Rift affords individuals highly responsive and relatively unrestricted visual movement in video game environments. This development allows users to rapidly shift their field of vision and adjust their gaze in a way that closely resembles naturalistic head movements, and permits visual control so that the user can freely engage with virtual environments and respond to stimuli with the help of a keyboard and mouse. Participants wore the Oculus Rift while seated at a computer desk and used a keyboard and mouse to play an exploration-themed computer game that included an agency detection task. Unbeknownst to participants, the agency detection task assessed false agency detection.

Participants engaged in the VR-based video game task, using the Oculus Rift, for approximately 30 minutes (including set-up and troubleshooting). The computer game used in this study was

Slender: The Arrival, and was accessed through the *STEAM VR* application. *Slender: The Arrival* is a survival-horror-exploration themed video game in which individuals navigate various menacing environments while avoiding a supernatural creature known as the Slenderman. Participants were set up to play only a small portion of the first level of this video game, during which there was no contact with the Slenderman. That is, participants were alone throughout the duration of the video game task, and explored the environment without any appearance of the Slenderman. Nonetheless, this first portion of the game took place in an ominous outdoor environment—an eerie and foreboding forest setting with various obstacles such as dense foliage, hills, woods, scattered man-made obstacles, and an abandoned house. Participants were deceived about the nature of the video game and were told that this game was created for the purpose of this research (for detailed instructions used in the VR task, see Appendix B).

The game was described to participants as a virtual reality hike, with a perceptual task component. The experimenter explained to participants that they would explore the outdoor video game environment for 15 minutes, and that they could do so at their own pace. Participants were also instructed that, throughout their exploration of the environment, they should click the right button of the mouse every time they 1) saw someone or something else in the environment, or 2) saw someone or something in their environment following them. Participants were instructed to attend to visual and auditory cues that might indicate the presence of a living, moving entity, but were not instructed specifically as to what they were looking for so as not to guide their responses. After 15 minutes from the participant's start of the video game task, the researcher reentered the laboratory room and exited the video game program, then assisted the participant in the removal of the Oculus Rift equipment. Frequency of participants' right-clicks (false positives) were recorded for analyses, serving as a measure of false agency detection.

5. Results

Prior to conducting the main analyses, we inspected the distribution of agency detection scores, operationalized as the number of mouse clicks in-game (false positives; $M = 12.8$, $SD = 14.4$).² Using boxplots, two significant outliers were identified (>3 SD s above the mean) in the distribution of agency detection scores and were excluded from further analyses. A histogram indicated positively skewed data, and a log transformation was performed to normalize the distribution of agency detection scores (Tabachnick & Fidell, 2013). The log-transformed agency detection scores ($M = 0.9$, $SD = 0.5$) were used in further analyses and presented in tables (see Appendix A).

5.1. Preliminary analyses

5.1.1. Sex differences

Independent samples t -tests were conducted to examine sex differences in agency detection scores, belief in supernatural agents, and overall supernatural belief (aggregate score of supernatural belief subscales). The results indicated no sex difference in agency detection. Men and women also did not differ in belief in supernatural agents. However, women ($M = 3.7$, $SD = 0.9$) reported greater overall supernatural belief than men ($M = 3.1$, $SD = 0.9$, $t [105] = 3.6$, $p < .001$), in line with the results of previous research (e.g., Aarnio & Lindeman, 2005; Rice, 2003).

5.1.2. Correlations

Descriptive statistics and zero-order correlations for agency detection, the seven subscales of the extended RPBS measure, and overall supernatural belief are presented in Table A1. Using a Bonferroni correction, we adjusted the alpha level for multiple comparisons and thus accepted as significant only those results for which $p \leq .006$ (Shieh, 2009). Results indicated that agency detection was positively but not significantly correlated with overall supernatural belief ($r = .25$, $p = .008$), was not significantly correlated with belief in supernatural agents ($r = .17$, $p = .08$), and therefore failed to

provide initial support for the study's main hypothesis. However, agency detection was found to be correlated with belief in Feng Shui ($r = .35, p = .001$).

5.2. Moderated multiple regressions

To examine the relationships between agency detection, sex, and the supernatural belief variables of interest, we conducted a series of three moderated multiple regression analyses. We included overall supernatural belief and belief in supernatural agents as outcome variables to further test the study's main hypothesis. In addition, we included belief in Feng Shui as an outcome variable based on the results of preliminary analyses showing that it was correlated with agency detection (reported above). For each regression, we included agency detection and sex as predictor variables in Step 1. We then entered the two-way interaction between agency detection and sex in Step 2. We adjusted the alpha level for multiple analyses using a Bonferroni correction and thus accepted as significant results for which $p \leq .016$ (Shieh, 2009). These results are summarized in Table A2.

5.2.1. Overall supernatural belief

We found a main effect for sex ($\beta = -.28, t = -2.93, p = .004$) on overall supernatural belief, such that women reported greater overall supernatural belief than men, corresponding to 0.26 points on the revised RPBS scale. The two-way interaction of sex and agency detection was not statistically significant.

5.2.2. Belief in supernatural agents

The results of the regression on belief in supernatural agents did not indicate a significant model fit. Agency detection was not related to belief in supernatural agents, and there was no sex difference in reported belief in supernatural agents, thereby failing to provide support for our hypothesis.

5.2.3. Belief in Feng Shui

We found a main effect for agency detection ($\beta = 0.31, t = 3.35, p = .001$) on belief in Feng Shui, such that a one standard deviation change in agency detection scores was associated with a 0.37 increase in reported belief in Feng Shui. There was no main effect of sex on belief in Feng Shui nor did sex moderate the association that agency detection had with belief in Feng Shui. In sum, higher agency detection scores predicted greater belief in Feng Shui.

6. Discussion

6.1. General discussion

Results indicated that over 90% of individuals falsely perceived the presence of an agent at least once, suggesting that the VR task successfully elicited false agency detection. Thus, the current study adds to the existing literature and provides additional evidence that VR tasks are a useful methodological tool for future agency detection research (Andersen et al., 2017; Maij et al., 2017). Nonetheless, the findings of our analyses present a complicated picture with regard to the study's main hypothesis. The primary goal of this research was to investigate the relationship between agency detection and belief in supernatural agents. This line of inquiry has been pursued by various scholars (e.g., Atran, 2002; Barrett, 2000, 2004) who contend that individual differences in agency detection should predict individual differences in supernatural agent beliefs. Our results failed to support this hypothesis because they did not indicate an association between agency detection and belief in supernatural agents. However, our results indicated an unexpected relationship between agency detection and belief in Feng Shui.

Feng Shui teaches that proper arrangement of furnishings balances the flow of energy, bringing health and good fortune, and, conversely, that erroneously-placed furnishings may absorb vital life

force, leading to negative outcomes such as misfortune, divorce, and illness. This dimension of supernatural belief involves engaging in behaviors intended to facilitate positive outcomes or prevent negative outcomes. One possible explanation for the relationship between agency detection and belief in Feng Shui is that this dimension of belief is a manifestation of *compensatory control*. Compensatory control occurs when personal control over an unpredictable situation is threatened; individuals engage in behaviors and adopt beliefs that restore a sense of personal control (Kay, Whitson, Gaucher, & Galinsky, 2009; Laurin, Kay, & Moscovitch, 2008; Whitson & Galinsky, 2008). Participants who felt an inability to control environmental events, such as avoiding threatening agents in the VR environment, may have been more prone to false agency detection and simultaneously reported greater belief in Feng Shui. Another, more parsimonious, explanation is that the significant relationship between agency detection and belief in Feng Shui emerged due to chance, reflecting a Type I error. Thus, we suggest that this finding may be spurious, and must therefore be interpreted with caution.

Although individual differences in agency detection were not related to individual differences in supernatural agent beliefs in this sample of adults, this finding does not necessarily negate the possibility that agency detection facilitated belief in supernatural agents over the course of human evolution. Furthermore, agency detection is theorized to be a necessary component for the phenomenology of “paranormal” encounters with supernatural agents, whereby individuals mistakenly perceive an agent among ambiguous stimuli and attribute the encounter to a culturally-transmitted supernatural agent (e.g., a ghost). However, the general tendency toward false perception of agency may be unrelated to the *degree* to which people believe in supernatural agents, as suggested by the present results as well as the findings of other related studies (Maij et al., 2017; Norenzayan et al., 2008; Willard & Norenzayan, 2013). Whether supernatural agents are ascribed to such encounters—and the extent to which individuals are convinced that they exist—may depend on individuals’ own supernatural beliefs, owing to cultural influences and education (Aarnio & Lindeman, 2005; Gervais, Willard, Norenzayan, & Henrich, 2011).

Recent scholarly work has reconceptualized the link between agency detection and belief in supernatural agents. The predictive coding model asserts that perceived encounters with supernatural agents (i.e., false agency detections) rely on prior expectations of their presence coupled with the quality of sensory information in a given environment. Accordingly, belief in supernatural agents is thought to provide individuals with expectations of their presence, and low sensory reliability facilitates perceptual errors (Andersen, 2017). Although previous research has provided support for this theoretical model (Andersen et al., 2017), the current study cannot be evaluated using this model because it included only one experimental condition that instructed participants to expect the presence of agents, and a single outdoor VR environment that did not vary in its sensory stimuli (e.g., low vs. high sensory reliability). Another theoretical model, the IREM (Van Leeuwen & van Elk, 2018), proposes that individuals who believe in supernatural agents may actively seek environments that activate agency detection mechanisms, thereby reinforcing their supernatural agent beliefs. The current study, however, subjected all participants (e.g., supernatural believers and non-believers) to the same VR environment, which precludes this study from providing support for this model.

6.2. Limitations and future directions

This study has some additional limitations. First, and most importantly, this research employed a correlational design, which prevents us from drawing causal conclusions. Secondly, we used a convenience sampling method (undergraduates enrolled in psychology courses) to recruit participants, and the results may reflect the psychological characteristics of this demographic (WEIRD people; Henrich, Heine, & Norenzayan, 2010). Participants were mostly Caucasian, Christian, and psychology majors. These participants may have had fewer supernatural beliefs than the general population, as well as fewer supernatural beliefs than students in different fields of study (e.g., social science vs. humanities majors; Aarnio & Lindeman, 2005). Although it improved on other studies (Andersen

et al., 2017; Maij et al., 2017), the present sample was still relatively small (final sample of 107 participants), which may have inflated the chance of a Type I error (Tabachnick & Fidell, 2013), perhaps producing, as a consequence, our unexpected finding linking agency detection and belief in Feng Shui. Future research should address these limitations, and would benefit from replication with a larger, more representative sample (e.g., equal number of males and females).

Another important issue pertains to the VR video game paradigm. Participants' expectations of the task, as well as the task's dark, foreboding outdoor setting may have affected participants' responses (i.e., agency detection) to the presented VR environmental stimuli. Recent research suggests that agency detection is facilitated, in part, by one's expectations (i.e., expectations of the presence or absence of agents) as well as the reliability of sensory information in a given environment (Andersen et al., 2017). Because participants were explicitly told to watch out for potential agents, they may have become more vigilant to potential agents in the VR environment than they would have without any prompting. This, coupled with prior exposure to other horror-themed games and media, may have produced perceptual biases when responding to the VR environment. Without such instructions, participants may not have indicated the presence of agents as frequently, if at all. In addition, the dark, forested environment of our VR video game task may have presented participants with sufficiently low sensory reliability and "noisy" visual stimuli to elicit false agency detection. Thus, it may be important for researchers to consider individual differences in video game experiences when investigating agency detection, as prior experience with video games might alter individuals' expectations of potential encounters with agents. Furthermore, without the inclusion of other VR outdoor environments (e.g., a desert; Maij et al., 2017), we cannot determine whether participants' agency detection would differ in environments that afford greater perceptual clarity and contain fewer ambiguous visual stimuli.

There are other limitations related to the VR task used in this study. The VR video game task did not include true positives; that is, agency detection was measured using only false positives (false perception of agency). Although this is a useful way of assessing false agency detection, the inclusion of true positives (e.g., actual agents) would have provided a more nuanced picture of whether agency detection also entails heightened perception of actual agents, similar to the findings of other studies (e.g., Riekkki et al., 2013). Therefore, future research can improve on this line of inquiry by implementing a VR task that includes true positives and false positives when assessing agency detection.

The current study extends the literature regarding the association between agency detection and supernatural belief. Although we did not find evidence in support of our main hypothesis, the findings of this study are consistent with those of other related research, contributing to the weight of evidence of previous research, and calling into question the relationship between individual differences in agency detection and supernatural belief.

6.3. Conclusion

We investigated whether belief in supernatural agents is related to agency detection using a VR video game paradigm. The results indicated that agency detection is not related to belief in supernatural agents. However, agency detection was related to belief in Feng Shui. In light of these unexpected findings, future research must expand the scope of this study and address several methodological limitations. With regard to the use of VR, we encourage researchers to consider using this promising tool for research in the social and cognitive sciences.

Notes

1. In addition to the study's main hypotheses, we investigated whether trait neuroticism was associated with supernatural belief, because previous research documented this relationship (Miklousic, Mlacic, & Milas, 2012; Wiseman & Watt, 2004; Wolfradt, 1997). The results indicated that trait neuroticism was not significantly related to any variable of interest in any further analyses, and was therefore excluded.

2. Because agency detection was operationalized as the number of mouse clicks in-game, and the video game task consisted of a limited number of repetitive button controls (keyboard movement arrows, mouse clicks), we anticipated that some individuals might rapidly and excessively press the button controls during the task (i.e., “button mashing”; Shinkle, 2008; Volda, & Greenberg, 2009), which could potentially lead to skew in the data. Therefore, the decision to screen and subsequently clean the agency detection scores was made a priori.

Acknowledgments

We give special thanks to the reviewers, whose constructive advice afforded significant improvements to this manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendices

Appendix A

Table A1. Intercorrelations and descriptive statistics for agency detection (log transformed), all 7 extended RPBS subscales, and overall supernatural belief (averaged score across 7 extended RPBS subscales).

	1	2	3	4	5	6	7	8	9
1. Agency detection	—								
2. Supernatural agents	0.17	—							
3. Paranormal abilities	0.18	0.67**	—						
4. Astrology	0.18	0.46**	0.64**	—					
5. Religious beliefs	0.09	0.24*	0.31**	0.17	—				
6. Feng Shui	0.35**	0.44**	0.55**	0.63**	0.18	—			
7. Lunar effects	0.08	0.41*	0.41**	0.42**	0.21*	0.52**	—		
8. Luck beliefs	0.25*	0.43**	0.66**	0.65**	0.22*	0.60**	0.49**	—	
9. Overall supernatural belief	0.25*	0.69**	0.82**	0.79**	0.51**	0.76**	0.67**	0.80**	—
Mean	0.87	3.40	3.31	2.69	5.39	3.01	3.56	3.16	3.50
Standard deviation	0.49	1.02	1.13	1.57	1.77	1.20	1.20	1.35	0.94

Note: * $p < .05$, ** $p < .001$.

Table A2. Results of three two-step moderated multiple regressions.

	Overall supernatural belief			Supernatural agents			Feng Shui		
	R^2	ΔR^2	β	R^2	ΔR^2	β	R^2	ΔR^2	β
Step 1	0.11**	0.11**		0.01	0.01		0.13***	0.13***	
AD			0.18			0.11			0.31***
S			-0.28**			0.00			-0.19
Step 2	0.11**	0.00		0.14	0.03		0.13**	0.00	
AD \times S			0.02			-0.05			-0.02

Note: For each regression, agency detection (AD) and sex (S) were entered as predictor variables in step 1. The two-way interactions of agency detection and sex were entered into step 2. The outcome variables for each regression were as follows: overall supernatural belief (averaged score across 7 extended RPBS subscales), belief in supernatural agents (paranormal agents subscale), and belief in Feng Shui (Feng Shui subscale).

** $p < .01$, *** $p < .001$.

Appendix B. Virtual reality video game task instructions/transcript

First, experimenters provide participants with preliminary information about the study's rationale before any tasks are assigned. This information is meant to inform participants of the virtual reality task component, and also help conceal participants from the true nature of the study.

"This is a brief summary of what the study is all about: we are interested in understanding why certain people are drawn to some video game experiences over others. The development of user-friendly virtual reality has opened up new avenues for video game experiences. But what is it that draws some people to play certain games over others? What personality characteristics, beliefs, and perceptual differences influence these preferences? To test this, we will have you fill out a survey and also participate in a virtual reality-based video game task using this Oculus Rift."

The order in which participants complete the survey and participate in the VR task is counterbalanced. The following script is initiated when it is determined that the VR task is next.

"This part of the study will involve playing a virtual reality video game, which includes a perceptual task. Basically, I am going to randomly assign you to play one game out of a list of games. All of these possible games are easy to play, because we want to make the video game task accessible for everyone. The game will simply involve using the keyboard and mouse while wearing the Oculus Rift headset. As far as the keyboard is concerned, you will simply use the movement keys, W A S D, which are labeled for your convenience, to move around in the game. You will also use the mouse to orient your direction; the mouse controls where you are looking or facing. All of this will make more sense once you have a chance to practice with the controls. That being said, let's figure out which game you are playing so I can better explain the rules.

The experimenter turns participants away from the computer activates the computer program with the pre-selected video game.

"You've been randomly selected to play the exploration game, where you will be going on a virtual reality hike. Recent advances in virtual reality graphics have inspired the creation of many exploration-style games, which have

started to become popular. In this game, you'll be walking around and exploring a virtual reality outdoor environment while engaging in a perceptual task. First, there will be a few things to set up before I have you play the game."

Participants are prevented from seeing the title/opening credits of the video game. The experimenter loads the game, selects the appropriate level, and activates the environment. The experimenter then sets up the equipment for the participant's use, followed by a practice demonstration of the Oculus Rift apparatus while using the keyboard and mouse to ensure that participants are acquainted with the controls.

"You are now ready to participate in the exploration video game task. Throughout the duration of this task, you must simply walk around and explore the outdoor virtual reality environment that is right before your eyes. In addition, while you explore the map, you will participate in a perceptual task. For this perceptual task, you must click the right-click button of your mouse every time you think you see someone, or something else in your environment. That is, I want you to indicate, using the right click-button on your mouse, if you think you see a living, moving, form in your environment. I am being intentionally vague about what it is that you are looking out for, but I want you to attend to any sights or sounds that seem unusual. For example, if you think you perceive the form of someone or something in your surroundings, or out of the corner of your eye, we want you to right-click the mouse button. If you do not see anything out of the ordinary in this outdoor environment, then do not click the mouse button. Do not press the right-click button if nothing appears out of the ordinary, and do not click when you see trees, rocks, or any other ordinary or inanimate objects that are in the natural setting.

This outdoor map is rather large, with much explore. You may walk around in any direction at your own pace and discretion. I encourage you to walk off of the beaten path, back track, and explore as much of the outdoor map as you can. There are hills, woods, and dense foliage for you to traverse. There are also some man-made structures that you may enter and explore; however, exploring these landmarks is not a requirement for completing the game. Simply walk around and observe the map, while looking out for other agents in the environment for a duration of 15 minutes. The task officially begins as soon as I leave the room, I will also keep track of how long you've been playing, and after 15 minutes of you playing the game by yourself I will come back to the room, help take off your headset, and prepare you for the next part of the study. Any questions?"

After leaving participants alone to play the game for 15 minutes, the researcher enters the laboratory room, states that the video task is over, and exits the video game while assisting the participant in removing the Oculus Rift equipment.

Appendix C. Revised paranormal belief scale with additional items

Please select the number next to each item that indicates the extent to which you agree or disagree with each statement. There are no right or wrong answers. This is an assessment of your own beliefs and attitudes. Use the numbers as indicated below.

1 = Strongly Disagree, 2 = Moderately Disagree, 3 = Slightly Disagree,
4 = Uncertain, 5 = Slightly Agree, 6 = Moderately Agree, 7 = Strongly Agree

PARANORMAL AGENTS

Extraterrestrial beings

1. Sightings of human-like creatures suggest that there are human-like creatures in space
2. Some UFOs (Unidentified Flying Objects) are probably alien spaceships
3. Crop circles are traces left by alien spacecrafts
4. UFO abductions, in which aliens have abducted humans, have happened
5. Some of the light phenomena in the sky cannot be explained by anything other than flight of alien spacecrafts
6. Objects made up of unknown materials found on Earth are proof of alien visits to Earth
7. There is life on other planets *

Ghosts

8. Ghosts exist
9. Some places are haunted
10. Those who have died a violent death return as ghosts to haunt the place where they died

Witchcraft

11. Black magic exists *
12. Witches exist *
13. Through the use of formulas and incantations, it is possible to cast spells on people *
14. There have been documented cases of witchcraft *

Other Extraordinary Life Forms

15. The abominable snowman of Tibet exists *
16. The Loch Ness monster of Scotland exists *

PARANORMAL ABILITIES OF HUMAN BEINGS

Extrasensory perception

- 17. Some people are capable of transferring thoughts to other people telepathically
- 18. Some people have an ability to perceive hidden objects without using their physical senses (e.g., sight, sound, touch, taste)
- 19. Some people have an unexplained ability to predict the future *
- 20. Mind reading is not possible (Reverse scored) *
- 21. Some individuals are able to levitate (lift) objects using psychic powers *
- 22. Psychokinesis, or the movement of objects using psychic powers, is possible *
- 23. Some psychics can accurately predict the future *
- 24. People can move physical objects using their thoughts *

Spiritualism

- 25. Your mind or soul can leave your body and travel (astral projection) *
- 26. During altered states, such as sleep or trances, the spirit can leave the body *
- 27. Reincarnation is possible *
- 28. It is possible to communicate with the dead *

ASTROLOGY

- 29. Astrology can predict an individual's personality characteristics
- 30. A horoscope that is devised by a professional can accurately predict a person's future
- 31. The position of the stars at the time of birth influences an individual's personality
- 32. Astrology accurately predicts the future *
- 33. Horoscopes accurately tell a person's future *

RELIGION

Religious beliefs

- 34. The soul continues to exist after the body dies *
- 35. There is a devil *
- 36. I believe in God *
- 37. There is a heaven and a hell *

FENG SHUI

Feng shui

- 38. Furnishing and arranging one's living space according to the principles of Feng shui balances your environment, and thus positively affects your health and success.
- 39. There should not be items placed in front of the outer door, because that hinders the flow of life energy inside the house.
- 40. The northern side of the house is the side corresponding to the water element; therefore, blue and black coloring, as well as the inclusion of a fountain or a fish pool, balances the energy of this area
- 41. You should not place cactuses in your home or at your office, because they may bring about an energy imbalance
- 42. You should not have a TV in the bedroom because the screen generates too much life energy, which may prevent a good night's sleep

LUNAR EFFECTS

Lunar effects

- 43. Lunar madness exists
- 44. The moon's gravitational forces cannot affect a person's mental health (Reverse scored)
- 45. The moon influences the success of crop harvests
- 46. The phase of the moon (e.g., full moon) affects fertility
- 47. The full moon negatively affects people's mental health
- 48. People are more violent than usual during the full moon
- 49. People are more active than usual during the full moon
- 50. The phase of the moon may influence people's behavior

LUCK BELIEFS

Amulets

- 51. Amulets (e.g., ornaments or small pieces of jewelry) bring good luck
- 52. Lucky charms can protect people against illnesses
- 53. It is useful to carry lucky charms in exciting situations (e.g., sporting events, competitions, contests) to guarantee success

Rituals

- 54. Going through rituals before an exciting event (e.g., sporting event, competition, contest) can bring good luck
- 55. When talking about luck, it is useful to knock on wood so that the luck doesn't go away
- 56. I don't believe that rituals have an influence on success (Reverse scored)

Omens of luck

- 57. Black cats can bring bad luck *
- 58. If you break a mirror, you will have bad luck *
- 59. The number "13" is unlucky *

* From Tobacyk's (2004) Revised Paranormal Belief Scale