**The Relationship Between Anomalistic Belief, Misperception of Chance, and the Base Rate Fallacy**

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Abstract

A poor understanding of probability may lead people to misinterpret every day coincidences and form anomalistic (e.g., paranormal) beliefs. We investigated the relationship between anomalistic belief (including type of belief) and misperception of chance and the base rate fallacy across both anomalistic and control (i.e., neutral) contexts. Greater anomalistic belief was associated with poorer performance for both types of items; however there were no significant interactions between belief and context. For misperception of chance items, only experiential (vs. theoretical) anomalistic beliefs predicted more errors. In contrast, overall anomalistic belief was positively related to the base rate fallacy but no specific subtype of anomalistic belief was a significant predictor. The results indicate misperception of chance may lead people to interpret coincidental events as having an anomalistic cause, and a poor understanding of base rates may make people more prone to forming anomalistic beliefs.

*Keywords*: Anomalistic belief; paranormal belief; probabilistic reasoning; misperception of chance; base rate fallacy

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 Anomalistic beliefs relate to non-evidence based phenomena that contradict our current scientific understanding of reality, such as telekinesis, extra-terrestrial visitation, some conspiracy theory beliefs, and some alternative medicine beliefs (Brotherton & French, 2014; Drinkwater, Dagnall, & Parker, 2012; French, 2001; French & Stone, 2014). These beliefs tend to be widely held, with the majority of the population believing in at least one type of anomalistic phenomenon (Chapman University, 2017; Moore, 2005; Shannon-Missal, 2013). One growing field of research centres around understanding the link between anomalistic belief and probabilistic reasoning errors, with much of the work showing that stronger belief in anomalistic phenomena is related to more reasoning errors (e.g., Dagnall, Drinkwater, Denovan, Parker, & Rowley, 2016; Rogers, Fisk, & Lowrie, 2016; Van Prooijen, Douglas, & De Inocencio, 2018; Wiseman & Watt, 2006). The current study focused on the relationship between anomalistic belief and two different types of probabilistic reasoning tasks; misperception of chance and the base rate fallacy. We investigated whether these two reasoning errors were related to anomalistic belief, and whether they were related to general anomalistic belief or only to a particular type of belief.

 Misperception of chance may be an important contributor to the formation of anomalistic beliefs because we are prone to finding patterns and are quick to notice coincidences that seem unlikely (Alloy & Tabachnik, 1984; Griffiths & Tenenbaum, 2007; 2009). This process of finding patterns is crucial because it allows us to gain insights into the world around us (Griffiths & Tenenbaum, 2009), however, there also is potential for this process to lead to the attribution of meaningful (or paranormal) interpretations to random patterns or coincidences (Blackmore & Tro**ś**cianko, 1985; Brugger, Landis, & Regard, 1990; Kareev, 1995). Specifically, several studies have established that higher anomalistic belief is associated with poorer probabilistic reasoning in areas such as judging and producing randomness, and responding to changes in sample size (Blackmore & Tro**ś**cianko, 1985; Brugger et al., 1990; Dagnall, Parker, & Munley, 2007). Although these studies are not able to pinpoint the direction of the relationship, one proposed explanation for the formation of anomalistic beliefs is that people attribute anomalistic explanations to chance occurrences and this leads them to develop anomalistic beliefs. For example, if people have a poor understanding of how likely two events are to occur by coincidence they may assume that a purely coincidental occurrence has an anomalistic cause. However, a solid understanding of probabilistic reasoning would allow them to realise that coincidences, even if unlikely, can occur purely by chance and do not require an anomalistic explanation.

 One common way that people misperceive chance is by expecting something that is random overall (e.g., flipping an unbiased coin) to also show random patterns when a small sequence is selected (Kahneman & Tversky, 1972; Tversky & Kahneman, 1974). For example, even though an unbiased coin has a 50/50 chance of coming up heads or tails when flipped, a small sequence of flips will not necessarily have an equal number of heads and tails. Also, when tasked with generating or identifying random sequences of coin flips, people produce and/or select sequences that alternate more frequently than would be statistically expected (Lopes & Oden, 1987; Wagenaar, 1970). Oskarsson, Van Boven, McClelland, and Hastie (2009) argued that the cumulative findings from this research suggest that people have imperfect internal cognitive representations of chance, randomness, and probability, and that these representations may lead to making inaccurate judgements and decisions when assessing phenomena in the external world.

The base rate fallacy is another well-established judgement and decision-making error (Fischoff & Bar-Hillel, 1984; Kahneman & Tversky, 1973) that may contribute to anomalistic beliefs. People demonstrate the base rate fallacy when they do not consider background information that is important and relevant to a task, and instead focus on the available descriptive information. A common example of the base rate fallacy is the cabs problem, where people are told that 85% of the cabs in a city are blue and 15% are green. They also are told that there was a hit and run accident at night and that a witness, who has been shown to be able to correctly identify the colour of the cab at night 80% of the time, identified the cab as being green. People are then asked how likely it is that the cab is green, and many report an 80% likelihood. However, this conclusion does not consider the base rate of the two colours of cabs within the city (Bar-Hillel, 1980; Kahneman & Tversky, 1973). Specifically, it is important to consider both the individual descriptive information about the witness’s accuracy and the base rate of green cabs. Based on both, the correct probability of the cab being green is 41% because, even though the witness is 80% accurate and identified the cab as green, the witness is still wrong 20% of the time; thus, due to the low base rate of green cabs (15%), it is more likely that the cab was blue than green.

Calculating the correct probability in the above example relies on the normative assumption that participants should adopt the base rate as their prior and then update according to Bayes theorem. Several researchers have challenged this assumption, arguing that participants’ priors may deviate from the base rate and still be rational (Gigerenzer, 1991; Koehler, 1996). Additionally, the base rate fallacy may not be as common as initially thought, with several studies finding that participants do not always ignore base rates (for a review see Koehler, 1996). These findings suggest that the tendency to use base rates can vary considerably depending on a variety of factors; for example participants are more likely to use base rate information if they have direct experience of the base rate (e.g., through feedback after trials; Medin & Edelson, 1988) or if the problem is presented in terms of frequencies rather than probabilities (Barbey & Sloman, 2007; Gigerenzer, 1991). However, in the current study all participants were given the same stimuli, and thus specific stimuli characteristics that influence the likelihood of making base rate fallacy errors are not relevant. We are also primarily interested in examining whether greater anomalistic belief is related to an increased propensity to commit the base rate fallacy, rather than in making normative claims about the use of base rates.

Similar to what has been noted above, Blackmore and Trościanko (1985) and Brugger et al. (1990) proposed that a poor understanding of probability may contribute to anomalistic belief (see Appendix A for a summary of previous findings on the relationship between anomalistic belief and misperception of chance). Blackmore and Trościanko found that people who were higher in anomalistic belief performed worse when responding to changes in sample size, were less accurate when answering questions about sampling, were less accurate in their estimate of chance performance, and were more likely to believe they exerted control when performing a random task. On the basis of these findings, they argued that a poor understanding of probability and chance (as well as illusions of control) may lead to the formation or strengthening of anomalistic beliefs. Further, Brugger et al. (1990) found that higher levels of anomalistic belief were consistently associated with greater repetition avoidance when both generating sequences and when assessing the randomness of a sequence. Thus, they proposed that this poorer understanding of randomness and probability may lead people to assume that everyday coincidences must have a causal explanation rather than being the result of chance.

Dagnall and colleagues also have investigated the relationship between anomalistic belief and a variety of probabilistic reasoning measures, including the misperception of chance and base rate fallacy (Dagnall, Drinkwater, Parker, & Rowley, 2014; Dagnall et al., 2016; Dagnall et al., 2007). Across these studies, statistically significant relationships between higher anomalistic belief and higher misperception of chance have consistently been found; however, the findings for other forms of probabilistic reasoning, such as the base rate fallacy, have been mixed (see Appendix B for a summary of previous findings on the relationship between anomalistic belief and the base rate fallacy). For example, Dagnall et al. (2007) found no statistically significant relationship between anomalistic belief and the base rate fallacy, however in a subsequent study Dagnall et al. (2014) showed that anomalistic belief was statistically significantly negatively correlated with performance on a base rate task. In both studies, though, the strength of the correlations were similar (*r* = -.16 in the earlier study; *r* = -.12 in the later study). However, there was a much smaller sample size in the earlier study (*n* = 96 in Dagnall et al., 2007 vs. *n* = 305 in Dagnall et al., 2014), and thus the later study had greater power to detect small effects. Thus, overall there is at least some evidence that both misperception of chance and the base rate fallacy are associated with higher anomalistic belief.

Although there is support for an overall relationship between anomalistic belief and probabilistic reasoning, a growing area of research focuses on whether this relationship varies depending on the *type* of anomalistic belief held (Dagnall et al., 2016; Prike, Arnold, & Williamson, 2017; Prike, Arnold, & Williamson, 2018; Rogers et al., 2016). For example, Dagnall et al. (2016) used the Revised-Paranormal Belief Scale (Tobacyk, 2004) to show that, although both traditional paranormal beliefs and new age philosophy beliefs were related to poorer perception of chance, the relationship was stronger for traditional paranormal beliefs. One limitation of this finding, though, is that the scale contains items that only relate to theoretical anomalistic belief; that is, no items ask people about their experiences of anomalistic phenomena. Thus, one goal of the current study was to examine whether the relationships between anomalistic belief, misperception of chance, and base rates were stronger for experiential (vs. theoretical) anomalistic beliefs. We used the Anomalistic Belief Scale (ABS; Prike et al. 2017) because it contains items that cover both experiential (e.g., “I believe that I have had direct contact with an extra-terrestrial here on earth”) and theoretical (e.g., “I believe extra-terrestrials have visited earth”) beliefs, and factor analysis has revealed a separate factor for experiential anomalistic beliefs. Because one argument is that poorer probabilistic reasoning may lead people to assign an anomalistic cause to coincidences or chance events that they (or others) experience, the relationship between anomalistic belief and probabilistic reasoning should be strongest for anomalistic beliefs that relate to experiences.

 We also investigated the role of context in the relationship between anomalistic belief and performance. That is, context was included as a within-subjects variable to explore whether people higher in anomalistic belief are even more prone to misperception of chance and the base rate fallacy when making judgements about anomalistic phenomena compared to the “non-anomalistic” phenomena that are usually used in probabilistic reasoning tasks. Context is important to consider because previous research has shown that reasoning is influenced by beliefs and motivations (Dawson, Gilovich, & Regan, 2002; Kahan, Peters, Dawson, & Slovic, 2017; Kunda, 1990; Stanovich, West, & Toplak, 2013). For example, Dawson et al. (2002) used a Wason selection task to show that people who were presented with a threatening proposition were much more likely to attempt to disconfirm the proposition than those who were presented with non-threatening propositions. This finding suggests that when motivated (i.e., by a threatening scenario) people applied higher levels of scrutiny and attempted to discredit the proposition, whereas when the proposition was not threatening they instead only looked for confirming evidence that supported the proposition.

Evidence for a positive relationship between anomalistic belief and motivated reasoning comes from recent research showing that higher anomalistic belief is related to several evidence integration biases (Prike et al., 2018). Specifically, people higher in anomalistic belief demonstrated a liberal acceptance bias, which occurs when someone is more willing to accept unlikely conclusions based on little evidence. Prike et al. also found that higher levels of anomalistic belief were associated with a decreased willingness either to adjust a position when presented with counter evidence or to accept an alternative conclusion that was supported by new evidence. Therefore, higher anomalistic belief may be related to reduced reasoning performance in general, but this reduction may be especially pronounced for reasoning tasks that are related to the anomalistic beliefs.

There is mixed evidence, though, regarding whether people higher in anomalistic beliefs are more prone to probabilistic reasoning errors for an anomalistic context (see Appendix C for a summary of previous findings for the interaction between anomalistic belief and context; Dagnall et al., 2014; Dagnall et al. 2016; Rogers, Davis, & Fisk, 2009; Rogers et al., 2016; Rogers, Fisk, & Lowrie, 2018; Rogers, Fisk, & Wiltshire, 2011). Rogers et al. (2009) found that higher anomalistic belief was associated with making more conjunction fallacy errors (*η*2 = .22)but that both anomalistic believers and non-believers made significantly fewer conjunction fallacy errors when scenarios were presented in an anomalistic context (*η*2 = .22). However, in follow up studies Rogers et al. (2011; 2016) did not find this main effect of context. Similar to Rogers et al. (2009), Dagnall et al. (2014; 2016) and Denovan, Dagnall, Drinkwater, and Parker (2018) found fewer conjunction fallacy errors on problems framed in an anomalistic context. Dagnall et al. (2014; 2016) and Denovan et al. also found that the size of the correlation between anomalistic belief and the conjunction fallacy was statistically significantly larger for problems presented in an anomalistic (vs. general) context.1 Of particular relevance for the current study, Dagnall et al. (2016) investigated the role of context in the relationship between anomalistic belief and misperception of chance by framing half of the trials in an anomalistic context and half in a control context. For both the overall scale of the Revised-Paranormal Belief measure and its Traditional Paranormal Belief and New Age Philosophy factors, participants higher in anomalistic belief were more prone to misperception of chance. However, correlations between belief and misperception of chance were statistically significantly stronger in the anomalistic context for the overall scale and the New Age Philosophy factor.2 Thus, with all of the results taken together, it is important to investigate whether this impact of context on the relationship between misperception of chance and anomalistic belief replicates and extends to the base rate fallacy.

Beyond context, we also investigated the potential relationship between gambling attitudes, anomalistic belief, and probabilistic reasoning. Because gambling involves games of chance it is possible that people who hold positive views of gambling are more prone to misconceptions about probabilistic reasoning. A number of studies have shown that gamblers are prone to several probabilistic reasoning errors and fallacies, such as the aptly named gamblers fallacy, hot hand, and finding illusory patterns (Croson & Sundali, 2005; Xu & Harvey, 2014). Further, researchers have shown that gamblers are more prone to these reasoning errors and fallacies than non-gamblers (Fortune & Goodie, 2012; Gaissmaier, Wilke, Scheibehenne, McCanney, & Barrett, 2016; Goodie & Fortune, 2013; Wilke, Scheibehenne, Gaissmaier, McCanney, & Barrett, 2014; Yakovenko et al. 2016). Therefore, a more positive attitude towards gambling also may be associated with the misperception of chance and base rate fallacy tasks used in the current study.

We also were interested in gambling because several beliefs held by gamblers are superstitious (or otherwise non-evidence based) and thus gambling attitudes may have some overlap with anomalistic beliefs (Joukhador, Blaszczynski, & Maccallum, 2004; McInnes, Hodges, & Holub, 2014; Passanisi, Craparo, & Pace, 2017). For example, many gamblers hold beliefs about luck, the superstitious nature of certain items, or the ability of their gut/intuition to make correct predictions. These gambling beliefs could be considered anomalistic in nature, particularly gambling beliefs that are related to predicting or influencing outcomes. Morris and Griffiths (2013) tested a convenience sample of gamblers and found that attitude towards gambling was positively correlated with anomalistic belief. Further, Leonard and Williams (2019) measured anomalistic belief and susceptibility to gambling fallacies (included understanding of chance, randomness, and statistical principles) and found that greater anomalistic belief was associated with greater susceptibility to these gambling fallacies.

**Overview of the Study**

Anomalistic belief was measured with both the Australian Sheep-Goat Scale (ASGS: Thalbourne & Delin, 1993) and the recently developed ABS (Prike et al., 2017). The ASGS is widely used within the literature, which allows the findings of the current study to be easily compared with previous research. The ABS also was used because it covers a wider range of anomalistic beliefs than the ASGS, and because the factors of the ABS enable us to investigate whether the relationships between belief and the other variables depends on whether the anomalistic belief is experiential or theoretical. Attitudes toward gambling were collected using the Gambling Attitudes Scale (GAS; Kassinove, 1998), which provides both an overall measure of gambling attitudes and specific attitudes toward casino, horse race, and lottery gambling. Participants also completed two types of probabilistic reasoning problems: misperception of chance and base rate fallacy. The reasoning problems were manipulated within-subject so that all participants received trials in both anomalistic and control contexts to test whether the relationship between higher anomalistic beliefs and poorer reasoning performance was stronger for the anomalistic context.

**Method**

**Participants**

One hundred and ninety-nine participants (60.1% female; 76.4% Caucasian) completed the study via the crowdsourcing website CrowdFlower and were reimbursed $1.75 for their participation. The sample size was chosen based on effect and sample sizes reported in previous studies. Participants were eligible to complete the study if they lived in the United States of America, Canada, or Australia. Twenty-one participants were removed prior to analyses because they had not completed the study properly and/or failed to follow all instructions (e.g., did not complete the study in a reasonable time frame by taking less than 10 minutes or longer than 60 minutes).3

## Design

The study had a within-subjects factor of context of the problem (control, anomalistic). The key predictors of interest were: (1) overall anomalistic belief, measured using the ASGS and ABS, (2) level of belief in the factors of the ABS, and (3) gambling attitudes, measured using the GAS. The key dependent variables in the study were proportion correct for misperception of chance problems and proportion correct for base rate fallacy problems. Level of education (general, psychology, mathematics, and statistics) was included to control for the potential effect of education.

## Materials

Anomalistic belief was measured using three measures; the ABS, ASGS, and two overall questions. The ABS is a 40-item scale that measures a variety of anomalistic beliefs (Prike et al., 2017; see supplementary material for example items). Factor analysis of the ABS has revealed four factors; an experiential factor (14 items), a theoretical paranormal belief factor (PSI factor; 13 items), a theoretical extra-terrestrial belief factor (ET factor; 8 items), and a factor that covers both theoretical and experiential life after death beliefs (LAD factor; 5 items). The experiential factor is related to the experience of anomalistic phenomena and contains items related to belief in both PSI and extra-terrestrial experiences. The other three factors are composed of items related to theoretical belief in three distinct areas, paranormal belief, extra-terrestrial belief, and belief in life after death. The ASGS is a psychometrically valid 18-item scale that measures paranormal belief across the content areas of extra-sensory perception, psychokinesis, and life after death (Thalbourne & Delin, 1993; see supplementary material for example items). Although the ASGS covers these three different content areas, they are not considered to be distinct factors (Drinkwater, Denovan, Dagnall, & Parker, 2018). Both the ASGS and the ABS are measured on a 7-point scale (from 1 = “strongly disagree” to 7 = “strongly agree”), and scores were computed by averaging the items that make up that scale (or factor). Anomalistic belief also was measured using the two overall questions of “Overall, how would you rate your level of belief in what is commonly referred to as the "paranormal" or "psi" (e.g., psychics, spirits, telekinesis, crystals, etc.)?” and “Overall, how would you rate your level of belief in extra-terrestrials (e.g., that extra-terrestrials have visited earth, UFOs have been seen in the sky, etc.).” These two general questions were included to test whether using full scales (i.e., the ASGS and ABS) provided additional useful information above what could be gained by using simple questions about overall levels of belief. Participants responded to the overall questions on a scale from 1 to 100.4

Gambling attitudes were measured using a modified version of the GAS (Kassinove, 1998; see supplementary materials for example items). The original GAS includes 59 items, with some items also measuring risk-taking and liberal-conservative leaning. However, for the purposes of our study we only included the 36 items that related to gambling. The GAS has four gambling related subscales; general gambling, casino gambling, horse race gambling, and lottery gambling, and these subscales can be combined to compute an overall gambling attitudes score. Participants respond to the GAS using a 6-point scale (from 1 = “strongly agree” to 6 = “strongly disagree”).

Misperception of chance and propensity to commit the base rate fallacy were each measured with 10 control (i.e., neutral) and 10 anomalistic items, for a total of 40 trials (see Figure 1 for example items; supplementary materials for all items). For ease of interpretation, scores for the probabilistic reasoning items were converted to proportion correct. The misperception of chance problems required participants either to estimate the likelihood of the next item in a pattern occurring (e.g., the chance that the toss of an unbiased coin will result in heads if it has come up heads 5 times in a row) or to assess how likely several patterns were (e.g., 5 cards are drawn from a deck of playing cards, which combination of cards is most likely). The base rate fallacy problems required participants to read representative descriptions of an outcome that had a low base rate (either explicitly stated or implied) and they were required to choose between a representative statement that ignored the base rate information and a statement that accurately represented the base rate but was less representative. The misperception of chance and base rate fallacy problems were presented in two randomised orders, with the restriction that no more than two of the same problem type (misperception of chance or base rate fallacy) and no more than two of the same context (anomalistic or control) were presented in a row. Participants were randomly assigned to one of these two orders.

Several additional measures were also collected, including basic demographic information about age, ethnicity, and gender. Previous research has suggested that education may be negatively related to anomalistic belief (Aarnio & Lindeman, 2005; Schulter & Papousek, 2008) and positively related to probabilistic reasoning (Hertwig, Zangerl, Biedert, & Margraf, 2008; Siegrist & Keller, 2011). Therefore, to control for potential effects of education participants were asked about their overall level of education, as well as their level of education in the specific domains of psychology, mathematics, and statistics. For each education question they chose from 6 options; less than high school, high school, some education above high school, undergraduate degree, professional/postgraduate degree, or other (Brotherton & French, 2014; Rogers et al., 2011). When participants selected ‘other’ they were able to type in a response and these responses were then re-categorised under one of the other five options (from 1 = “less than high school” to 5 = “professional/postgraduate degree”).

## Procedure

The experiment was conducted online using Qualtrics software (Qualtrics, Provo, UT). Participants first read through an introduction, information sheet, and consent form. They then completed the misperception of chance and base rate fallacy problems in one of two randomised orders. Participants were instructed to read each scenario and its answer options, and then choose the answer they thought was correct. After completing the reasoning problems participants then completed the anomalistic belief measures and the GAS. For these measures participants were told that there were no right or wrong answers and to select the option that best represented what they think. Participants completed one of the two anomalistic belief measures first (either the ASGS or the ABS), then the GAS, and then they answered whichever anomalistic measure they had not yet completed (e.g., if they completed the ABS first they then completed the ASGS). Finally, participants answered the two overall anomalistic belief questions before completing the demographic and education questions.

**Results**

Traditional multiple regression analyses for the misperception of chance and the base rate fallacy problems were not possible because context of the problems (i.e., control vs. anomalistic) is a within-subjects variable. However, Ruscher (n.d.) outlined a suitable repeated-measures multiple regression that can be run using a repeated-measures ANCOVA and accommodates the continuous predictor variables by entering them as covariates to retrieve the multiple regression parameter estimates. Therefore, the probabilistic reasoning tasks were analysed using a repeated-measures ANCOVA, with context as the within-subjects variable and anomalistic belief and gambling attitudes entered as covariates. In situations where there were no statistically significant interactions between context and any of the key predictors, multiple regression analysis was used to obtain parameter estimates for probabilistic reasoning averaged across context. Neither overall gambling nor attitude towards specific types of gambling were statistically significantly correlated with performance on either of the probabilistic reasoning tasks. However, because we made specific predictions about the relationship between gambling attitudes, anomalistic belief, and probabilistic reasoning, overall gambling was entered as a predictor in all regressions. Additionally, to control for potential effects of education and/or order (survey or counterbalance) these variables were entered into the regression whenever they were statistically significantly related to performance on the probabilistic reasoning task.

Traditional null hypotheses significance tests are reported here, however, Bayes factors were also calculated (as recommended by Wagenmakers, 2007) using JASP with default priors (JASP Team, 2017, Version 0.8.1.1)5 and are reported for all main analyses. All Bayes factors are reported using the form *BF*10, which provides the odds ratio of the alternative/null hypotheses given the data (i.e., a value of 1 indicates the data support the alternative and null equally, values larger than 1 indicate support for the alternative, and values smaller than 1 indicate support for the null). All anomalistic belief scales, the GAS, and the education measures were coded so that larger values indicate a higher level of belief, attitude, or education, respectively. Further, misperception of chance and base rate fallacy items were analysed using the proportion correct and therefore higher values indicate better performance. Descriptive statistics for all scales are reported in Table 1.

Strong positive correlations were found between all of the anomalistic belief measures (see Table 2). Also, participants who were higher in anomalistic belief were also more likely to have more positive attitudes toward gambling. Further, significant (positive) correlations were found between most of the subtypes of gambling attitude and anomalistic belief except for between the experiential factor and attitudes towards casino and lottery gambling, or between the ET factor and lottery gambling. There also were several positive correlations between anomalistic belief and education: (1) general education was correlated with the experiential factor, (2) psychology education correlated with the overall ABS and the experiential factor, (3) mathematics education was correlated with the overall ASGS, overall ABS, the experiential factor, and the PSI factor, and (4) statistics education was correlated with the overall ASGS, overall ABS, and the experiential factor. Neither the ET factor nor the life after death factor were correlated with any of the education measures. There also were statistically significant negative correlations between attitudes towards lottery gambling and both general and mathematics education.

**Misperception of Chance**

 The relationship between anomalistic belief, overall gambling attitude, and misperception of chance was analysed first using separate analyses for the overall ASGS and ABS scales, and then using the ABS factors (see Table 3). In all analyses there was a main effect of context, range *F*s (1, 169 – 172)6 = 48.51 – 48.92, all *MSE*s = .01, all *p*s ≤ .001, all *ηp2* = .22, range *BF*10 = 78910000 – 80690000, with the proportion of correct responses higher in the control context (*M* = 0.68, *SD* = 0.25) than in the anomalistic context (*M* = 0.61, *SD* = 0.22). For the overall ASGS there also was a statistically significant main effect of anomalistic belief, *β* = -.22, 95% CI [-.37, -.07], with higher anomalistic belief leading to a lower proportion of correct responses. The same pattern was found for the overall ABS scale, with higher anomalistic belief associated with a lower proportion of correct responses, *β* = -.28, 95% CI [-.43, -.13]. However, in both the overall ASGS and ABS regressions there was no main effect of overall gambling attitude, range *β* = -.02 - .01. Further, in both regressions neither overall gambling attitude nor anomalistic belief statistically significantly interacted with context, *F*s (1, 172) ≤ 0.10, all *MSE*s = .01, all *p*s ≥ .75, all *ηp2* ≤ .001, range *BF*10 = 0.07 – 0.14.

 The relationship between anomalistic belief and misperception of chance was also analysed at a more fine-grained level by using the four ABS factors. This analysis found that only the experiential factor was a statistically significant negative predictor of the proportion of items correct, *β* = -.47, 95% CI [-.66, -.28]. Additionally, the experiential factor was a statistically significantly stronger predictor of misperception of chance than the other three factors, all *t*s (169) ≥ 2.68, all *p*s ≤ .008.7 There were no statistically significant differences in the strength of the relationships between the other factors and misperception of chance, all *t*s (169) ≤ 1.31, all *p*s ≥ .19. Again, there was no statistically significant effect of overall gambling attitude, *β* = -.02, 95% CI [-.16, .12], and no statistically significant interactions between context and overall gambling attitude or any of the factors, *F*s (1, 169) ≤ 0.83, all *MSE*s = .01, all *p*s ≥ .36, all *ηp2* ≤ .005, range *BF*10 = 0.06 – 0.15.

**Base Rate Fallacy**

The base rate fallacy also was analysed using a repeated-measures ANCOVA, with context as the within-subjects variable, and anomalistic belief and overall gambling attitude entered as the covariates (see Table 4). Separate analyses were first run for the overall ASGS and ABS scales, and then using the ABS factors. There was a main effect of context in all analyses, range *F*s (1, 171 – 174) = 43.54 – 44.17, all *MSE*s = .02, all *p*s ≤ .001, range *ηp2* = .20 – .21, range *BF*10 = 17210000 – 18530000. Unlike for misperception of chance, though, the main effect for the base rate fallacy items occurred because participants had a higher proportion of correct responses in the anomalistic context (*M* = 0.49, *SD* = 0.21) than in the control context (*M* = 0.40, *SD* = 0.19). For the ASGS there was a statistically significant main effect of anomalistic belief, *β* = -.22, 95% CI [-.37, -.07], with higher belief leading to a lower proportion of correct responses. The same pattern was found for the overall ABS, with a negative relationship between level of anomalistic belief and proportion correct for the base rate fallacy items, *β* = -.27, 95% CI [-.42, -.12]. However, in both the ASGS and ABS regressions there was no main effect of overall gambling attitude, range *β* = .06 - .08, and neither anomalistic belief nor gambling attitude statistically significantly interacted with context, *F*s (1, 174) ≤ 1.59, all *MSE*s = .02, all *p*s ≥ .21, all *ηp2* ≤ .009, range *BF*10 = 0.19 – 0.35.

The relationship between anomalistic belief and the base rate fallacy was also analysed using the ABS factors. This analysis found that, although the overall regression was statistically significant, no individual ABS factor was a statistically significant predictor of the proportion of correct responses. There were also no statistically significant differences in the strength of the relationships between the factors and the base rate fallacy, all *t*s (171) ≤ 1.16, all *p*s ≥ .25. Further, there also was no main effect of gambling attitude, and no statistically significant interactions between context and overall gambling attitude or any of the ABS factors,all *F*s (1, 171) ≤ 3.19, all *MSE*s = .02, all *p*s ≥ .08, all *ηp2* ≤ .02, range *BF*10 = 0.15 – 0.67.

**Discussion**

Overall, the results of the study support the prediction that greater anomalistic belief is related to poorer probabilistic reasoning ability: Higher levels of belief were related to lower performance for both misperception of chance and the base rate fallacy. However, there were no interactions with context. For misperception of chance, the Bayes factors for the interactions between anomalistic belief and context provided some support for the null (range *BF*10 = 0.06 – 0.15), suggesting that the relationship found between anomalistic belief and misperception of chance occurred regardless of context and was not amplified in an anomalistic context. For the base rate fallacy, some of the Bayes factors for the interactions between anomalistic belief and context provide support for the null; however, for other interactions the Bayes factors suggest there is little evidence to support either the null or the alternative hypothesis (range *BF*10 = 0.15 – 0.67). Therefore, it is inconclusive whether the relationship between anomalistic belief and the base rate fallacy differs between general and anomalistic contexts. Further, although higher overall anomalistic belief was related to more errors on the misperception of chance problems, the more fine-grained analysis showed that only higher levels of experiential anomalistic belief was related to this poorer performance. In contrast, though, no individual factor was a statistically significant predictor for the base rate fallacy. Because the ABS factors are highly correlated with one another, it appears that it is a general aspect of anomalistic belief that is shared across the factors (i.e., not unique to any individual factor) that is related to a poorer understanding of base rates.

The finding that, regardless of context, higher anomalistic belief was associated with a poorer understanding of probabilistic reasoning is consistent with the idea that differences in reasoning ability may contribute to the formation of anomalistic beliefs (Blackmore & Tro**ś**cianko, 1985; Brugger et al., 1990). For example, misperception of chance or a poor understanding of base rates may lead people to assign an anomalistic explanation to experiences that occurred due to coincidence or chance. Additionally, this finding casts some doubt on the idea that people higher in anomalistic belief have poorer reasoning abilities because they are motivated to reason in a way that supports their belief. If people higher in anomalistic belief were simply engaging in motivated reasoning or wishful thinking, then differences in probabilistic reasoning ability should have been more pronounced for items in an anomalistic context.

Our lack of context findings differs, though, from Dagnall et al. (2016) and Denovan et al. (2018) who found that anomalistic belief was more strongly related to performance on misperception of chance items presented in an anomalistic context. However, previous work on the role of context for the conjunction fallacy also has produced mixed results (Dagnall et al., 2014; 2016; Rogers et al., 2009; 2011; 2016). One potential explanation is that people may endorse only a specific subset of anomalistic beliefs and therefore may not be more prone to probabilistic reasoning errors for stimuli that relate to a different anomalistic belief (e.g., someone with greater levels of belief in ghosts may not be more likely to make errors for a reasoning item about Ouija boards). However, our probabilistic reasoning stimuli related to a wide variety of anomalistic beliefs and had considerable overlap with the item content of our anomalistic belief scales. Regardless, it may be beneficial in future work to systematically create scale questions and matching stimuli to more fully examine this hypothesis; however it would be important to avoid the increased risk that a close alignment between scale items and stimuli may produce demand effects and/or lead participants to interpret the reasoning questions as though they also are belief questions. It also is possible that item difficulty and/or the level of detail provided in the descriptions influences the strength of context effects. For example, context may only play a role if participants detect a conflict between the incorrect heuristic response and the correct systematic answer (i.e., people are aware of the two options and so choose the belief congruent option; Pennycook, Fugelsang, & Koehler, 2012). Stimulus difficulty may therefore influence the likelihood of conflict detection because people may choose either the heuristic answer (for difficult stimuli) or the systematic answer (for easy stimuli) without detecting any conflict between the response options.

The positive relationship found between misperception of chance errors and experiential belief is consistent with previous work on the conjunction fallacy and biases in evidence integration, and thus provides further evidence that there may be an important difference between experiential and theoretical anomalistic beliefs (Prike et al., 2017; 2018). One way to understand this relationship is through consideration of what differentiates experiential from theoretical anomalistic beliefs. That is, experiential beliefs involve actively interpreting experiences as having an anomalistic cause; for example, judging something you see out of the corner of your eye as a ghost (vs. as a perceptual illusion). Thus, as mentioned in the Introduction, misperception of chance may play a particularly pronounced role in relation to experiential beliefs because many experiences that are assigned an anomalistic explanation are likely to be coincidences or strange experiences (Hadlaczky & Westerlund, 2011; Ross, Hartig, & McKay, 2017). In contrast, theoretical anomalistic beliefs are less likely to involve evaluating whether a particular experience could have occurred by chance because they only need to involve the possibility that something potentially exists (or is true) in a general and/or abstract sense.

Unlike misperception of chance, the propensity to commit the base rate fallacy was not related to any individual subset of anomalistic belief, which highlights that one particular type of belief (e.g., experiential) may not be uniquely related to performance for all probabilistic reasoning tasks. However, it is important to note that the average proportions correct on the base rate fallacy task were either below chance (control context) or at chance level (anomalistic context). Thus, consistent with previous research, participants were just as likely (or more likely for the control context) to choose the answer supported by the superficial representative statement than to use the statistical base rate information to guide their decision (Pennycook et al., 2012). This combination of overall poor performance and negative relationships between anomalistic belief and base rate fallacy accuracy suggests that participants with higher levels of anomalistic belief were more likely to rely on the superficial representative statement than the base rate information, whereas participants with lower levels of anomalistic belief were approximately equally likely to rely on either the representative information or the base rate. Thus, because participants had a high likelihood overall of choosing the representative option, there may have been a limited range to find an association between a specific subtype of anomalistic belief and more reliance on the representative rather than base rate information.

Although we found a context effect for both types of probabilistic reasoning items, the pattern differed between them. One potential explanation for why base rate errors were lower in the anomalistic (vs. control) context is that, regardless of level of anomalistic belief, participants recognised that anomalistic events are rare. Therefore, when the stimuli context was anomalistic the superficial descriptive information was less likely to lead them to overlook the base rate information. In contrast, misperception of chance errors were lower for the control (vs. anomalistic) stimuli, which may be due in part to familiarity. Previous research has shown that familiarity can influence performance on probabilistic reasoning tasks; for example, people perform better on tasks that contain familiar and concrete, rather than abstract content (Markovits, 1986; Markovits & Vachon, 1990; McKenzie, 2006). Participants in our study likely were more familiar with the control misperception of chance materials (e.g., with standard coins, decks of cards) than the anomalistic items (e.g., tarot cards, Ouija board), which may have contributed to the increased probabilistic reasoning performance for the control context items. Although it could be argued that increased familiarity should also influence performance for the base rate fallacy task, the nature of the task makes it less conducive to familiarity effects. Specifically, base rate items do not require participants to engage in any calculation or consideration of probabilities that may have benefitted from increased familiarity.

Consistent with the claim that there is overlap between anomalistic beliefs and gambling attitudes (Joukhador et al., 2004; McInnes et al., 2014; Passanisi et al., 2017), we found that more positive gambling attitudes were related to higher levels of anomalistic belief for most of our measures. However, unlike previous work on gambling and reasoning, we did not find any relationship between gambling attitudes and probabilistic reasoning (Fortune & Goodie, 2012; Gaissmaier et al., 2016; Goodie & Fortune, 2013; Wilke et al., 2014; Xu & Harvey, 2014). It is possible, though, that the results would have been different if we had targeted problem or pathological gamblers. Additionally, we used a measure of gambling attitudes rather than gambling behaviour. Although previous research has shown that gambling attitudes are predictive of gambling behaviour and intentions to gamble (Dahl, Tagler, & Hohman, 2018; Moore & Ohtsuka, 1999), the relationship between probabilistic reasoning and gambling may exist for gambling behaviour rather than gambling attitudes. That is, poorer probabilistic reasoning may not be related to the attitudes that people hold towards gambling, but may be predictive of the gambling behaviour that people engage in.

Somewhat surprisingly, we found that higher levels of education in psychology, mathematics, and statistics were related to poorer performance on the misperception of chance items, which differs from previous work that generally has found positive correlations between education and reasoning ability (Hertwig et al. 2008; Siegrist & Keller, 2011). However, previous work also has found that the relationship between education and performance depends on the type of reasoning problems: Education more consistently led to better performance on reasoning problems presented using frequencies rather than probabilities (Siegrist & Keller, 2011). Additionally, Hertwig et al. (2008) found that education was associated with better performance on abstract probability problems but was not related to performance on items that approximated real-world scenarios. Although these results may explain why greater education may not have led to better performance on the misperception of chance items within this study, they do not explain the negative relationship. One possible explanation for the negative relationship is that people with greater education were overconfident in their abilities and did not take the time to slow down and consider their responses carefully. Relatedly, Sanchez and Dunning (2018) found that for probabilistic learning tasks people did not initially start out overconfident but became overconfident after a small amount of practice (i.e., “a little learning is a dangerous thing”). Because misperception of chance items often cue intuitive but incorrect responses, it is possible that participants with higher education were more likely to be overconfident and assume their initial inaccurate intuitive responses were correct, leading to a greater number of errors.

There also were several positive correlations between the education measures and anomalistic belief. These findings are somewhat counterintuitive, although other recent studies have found positive correlations between education and anomalistic belief (Prike et al. 2017; 2018). One potential explanation is that having strange experiences that seem anomalistic and/or holding some anomalistic beliefs may motivate people to pursue education in a topic like psychology. When studying psychology people also will likely complete statistics courses (as well as potentially some mathematics courses), which may help to explain the positive correlations found in this study. However, the correlations were generally quite weak, and further research is required to replicate the patterns and test the proposed explanations.

One limitation of the current study is that it used a correlational design, which means that rather than probabilistic reasoning contributing to greater anomalistic beliefs, it is possible that greater levels of anomalistic belief lead to poorer probabilistic reasoning. One explanation for why anomalistic belief might causally contribute to poorer probabilistic reasoning is that motivated reasoning may lead people to discount probabilistic information that threatens their anomalistic beliefs (Dawson et al., 2002; Kahan et al., 2017; Kunda, 1990; Stanovich et al., 2013). As noted above, though, both our findings and other previous research has shown that anomalistic belief is related to poorer probabilistic reasoning even for items where correct answers would not threaten people’s underlying beliefs (i.e., neutral contexts), which casts doubt on this explanation. Additionally, Bouvet and Bonnefon (2015) measured analytical thinking at baseline and found that it was predictive of the likelihood that people would later accept anomalistic explanations for potentially anomalous experiences. It is difficult to experimentally manipulate either anomalistic belief or reasoning ability, but there are several avenues that may more closely link probabilistic reasoning and experiential anomalistic beliefs. For example, in future work more realistic and engrossing scenarios could be developed that present ambiguous events that either can be (incorrectly) interpreted as an anomalistic experience or (correctly) explained using probabilistic reasoning. For instance, a more realistic scenario could provide a detailed description of a psychic reading, with some aspects of the description focused on a non-anomalistic explanation (e.g., the person knows a male with a name beginning with J, which may be interpreted either as evidence of psychic ability or as a highly probable statement because of the high frequency of male names beginning with J). Additionally, monetary rewards could be offered for correct responses to increase motivation to engage in effortful probabilistic reasoning. A monetary reward would help to discern whether people higher in anomalistic belief simply differ in their preference or willingness to engage in systematic and analytical thinking (i.e., are cognitive misers) or whether they are unable to accurately complete the reasoning scenarios.

A greater endorsement of anomalistic beliefs and poorer probabilistic reasoning also may be due to other variables. For example, people with greater levels of anomalistic belief also have a greater tendency to make perceptual errors. Specifically, Simmonds-Moore (2014) found that paranormal believers made more misidentifications and had greater confidence in their guesses when attempting to identify degraded visual stimuli. Similarly, Riekki, Lindeman, Aleneff, Halme, and Nuortimo (2013) found that anomalistic believers had a more liberal answering criteria when deciding that an image contained a face-like region (e.g., a tree trunk with face-like features), however, they did not differ from non-believers in their sensitivity to detect the face-like regions. Therefore, it is possible that a predisposition towards finding patterns, even when patterns are not actually present, may lead to both an increase in anomalistic beliefs and also to poorer probabilistic reasoning. However, it also may be that poorer reasoning contributes to an increased likelihood of finding patterns because reasoning plays a crucial role in discriminating between meaningful patterns and those that are meaningless and/or are simply due to chance or randomness (Griffiths & Tenenbaum, 2007; 2009). Future work needs to more thoroughly investigate the relationships between pattern finding and probabilistic reasoning, and attempt to establish whether these variables are uniquely related to anomalistic belief.

The current study showed that higher levels of anomalistic belief were related to poorer probabilistic reasoning for both misperception of chance and the base rate fallacy. Further, finding that misperception of chance was primarily related to experiential anomalistic beliefs adds to the recent work that has highlighted the importance of investigating the relationships between specific subsets of anomalistic belief and different reasoning/cognitive biases (i.e., rather than just using broad overall measures; Dagnall et al. 2016; Prike et al. 2017; 2018; Rogers et al. 2016). Using this more fine-grained approach of focusing on specific types of belief allows for the relationships to be disentangled, leading to the development of a more nuanced understanding of these non-evidence based beliefs. The findings are also consistent with the notion that poorer probabilistic reasoning may contribute to the formation of anomalistic beliefs and suggest that misperception of chance may have an important role in whether people assign anomalistic explanations to experiences.

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# Footnotes

1 Dagnall et al. (2016) did not report whether the correlations were statistically significantly different, however, we tested if they statistically significantly differed using methods outlined in Steiger (1980).

2 The difference between correlations again was not reported in Dagnall et al. (2016), thus we tested if they statistically significantly differed using methods outlined in Steiger (1980).

3 Minimum timing was decided based on the time taken to complete the survey without reading and maximum time was decided so that participants could complete the study at a leisurely pace. Average time taken to complete the study was approximately half an hour (before participants removed, *M* = 27:51, *SD* = 15:19; after participants removed for timing, *M* = 27:55, *SD* = 11:13).

4 The overall paranormal and extra-terrestrial belief questions showed the same patterns as the ABS and ASGS belief scales and/or the relevant factors of the ABS, however, the belief scales and factors provided a better understanding of the relationship between probabilistic reasoning and anomalistic belief. Therefore, the overall questions are not discussed further (see supplementary material).

5 The default priors used in JASP for Bayesian repeated measures ANOVAs are *r* scale fixed effects = 0.5, *r* scale random effects = 1, and *r* scale covariates = 0.354. For Bayesian linear regressions JASP uses a default prior of *r* scale = 0.354. All priors use a Cauchy distribution with *r* = ${1 }/{√2}$.

6 The reported degrees of freedom vary because some of the analyses include the ABS factors, and some include only an overall anomalistic belief measure (i.e., analyses with the ABS factors include an extra 3 variables and therefore the degrees of freedom are reduced).

7Analyses to test for significant differences in the strength of the relationships between the factors and the outcome variables (misperception of chance and base rate fallacy) were conducted based on methods described in Cohen and Cohen (1983) for testing differences between regression coefficients from the same regression equation.

Table 1.

*Mean scores for all scales.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scales | Mean | SD | Min. | Max. | α |
| 1. ASGS
 | 2.70 | 1.33 | 1.00 | 6.56 | .95 |
| 1. ABS
 | 2.59 | 1.30 | 1.00 | 6.00 | .98 |
| 1. Experiential Factor
 | 1.78 | 1.17 | 1.00 | 5.93 | .96 |
| 1. PSI Factor
 | 2.82 | 1.59 | 1.00 | 6.92 | .96 |
| 1. ET Factor
 | 3.22 | 1.86 | 1.00 | 7.00 | .96 |
| 1. Life After Death Factor
 | 3.28 | 1.85 | 1.00 | 7.00 | .91 |
| 1. Gambling
 | 3.59 | 1.00 | 1.39 | 6.00 | .97 |
| 1. General Education
 | 3.60 | 0.98 | 1.00 | 5.00 | n/a |
| 1. Psychology Education
 | 2.20 | 1.12 | 1.00 | 5.00 | n/a |
| 1. Mathematics Education
 | 2.74 | 0.94 | 1.00 | 5.00 | n/a |
| 1. Statistics Education
 | 2.36 | 1.03 | 1.00 | 5.00 | n/a |

*Note*: *n* = 178

Table 2.

*Correlations for Base Rate, Misperception of Chance, and all scales*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scales | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | 17. | 18. | 19. | 20. |
| Reasoning Tasks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Base Rate – Control
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Base Rate –Anomalistic
 | .59\*\*\* |   |   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Chance – Control
 | .26\*\*\* | .30\*\*\* |   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Chance – Anomalistic
 | .26\*\*\* | .41\*\*\* | .84\*\*\* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Anomalistic Belief |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. ASGS
 | -.15 | -.20\*\*\* | -.24\*\* | -.27\*\*\* |   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. ABS
 | -.19\* | -.22\*\*\* | -.30\*\*\* | -.32\*\*\* | .91\*\*\* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ABS Factors |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Experiential
 | -.13 | -.23\*\*\* | -.41\*\*\* | -.44\*\*\* | .74\*\*\* | .83\*\*\* |   |   |   |  |  |  |  |  |  |  |  |  |  |  |
| 1. PSI
 | -.14 | -.18\* | -.20\*\* | -.22\*\* | .92\*\*\* | .93\*\*\* | .66\*\*\* |   |   |  |  |  |  |  |  |  |  |  |  |  |
| 1. ET
 | -.21\*\* | -.17\* | -.20\*\* | -.20\*\* | .60\*\*\* | .79\*\*\* | .53\*\*\* | .63\*\*\* |   |  |  |  |  |  |  |  |  |  |  |  |
| 1. LAD
 | -.17\* | -.16\* | -.21\*\* | -.20\*\* | .78\*\*\* | .81\*\*\* | .55\*\*\* | .78\*\*\* | .52\*\*\* |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |

(continued)

Table 2.

*Correlations for Base Rate, Misperception of Chance, and all scales*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scales | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | 17. | 18. | 19. | 20. |
| Gambling Attitudes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Overall Gambling
 | .04 | -.05 | -.05 | -.07 | .26\*\*\* | .28\*\*\* | .15\* | .27\*\*\* | .22\*\*\* | .33\*\*\* |  |  |  |  |  |  |  |  |  |  |
| 1. General
 | .05 | -.02 | -.11 | -.12 | .26\*\*\* | .29\*\*\* | .16\* | .27\*\*\* | .24\*\*\* | .33\*\*\* | .95\*\*\* |  |  |  |  |  |  |  |  |  |
| 1. Casino
 | .02 | -.01 | .00 | -.02 | .22\*\* | .22\*\* | .04 | .25\*\*\* | .19\* | .30\*\*\* | .94\*\*\* | .92\*\*\* |  |  |  |  |  |  |  |  |
| 1. Horses
 | .03 | -.09 | -.13 | -.12 | .23\*\* | .28\*\*\* | .31\*\*\* | .22\*\* | .20\*\*\* | .21\*\* | .78\*\*\* | .67\*\*\* | .59\*\*\* |  |  |  |  |  |  |  |
| 1. Lottery
 | .02 | -.06 | .05 | .02 | .19\*\* | .20\*\* | .03 | .23\*\* | .14 | .33\*\*\* | .87\*\*\* | .78\*\*\* | .81\*\*\* | .50\*\*\* |  |  |  |  |  |  |
| Education |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. General
 | .17\* | .06 | -.00 | -.01 | .09 | .12 | .23\*\* | .07 | .09 | -.05 | -.08 | -.06 | -.12 | .06 | -.16\* |  |  |  |  |  |
| 1. Psychology
 | .12 | -.07 | -.27\*\*\* | -.17\* | .14 | .16\* | .24\*\* | .13 | .06 | .09 | .01 | -.01 | -.04 | .09 | -.01 | .31\*\*\* |  |  |  |  |
| 1. Mathematics
 | .07 | -.05 | -.21\*\* | -.21\*\* | .16\* | .20\*\* | .28\*\*\* | .16\* | .13 | .05 | -.09 | -.08 | -.13 | .04 | -.16\* | .51\*\*\* | .42\*\*\* |  |  |  |
| 1. Statistics
 | .13 | .06 | -.22\*\* | -.17\* | .16\* | .16\* | .24\*\* | .13 | .07 | .08 | -.07 | -.05 | -.10 | .05 | -.15 | .51\*\*\* | .46\*\*\* | .67\*\*\* |  |  |
| Order |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Survey
 | .02 | .05 | .03 | -.00 | -.15\* | .02 | -.00 | -.01 | .09 | -.03 | -.03 | -.02 | -.03 | -.04 | -.03 | .17\* | .02 | .05 | .10 |  |
| 1. Counterbalance
 | -.10 | -.07 | -.00 | -.03 | -.04 | -.03 | .03 | -.08 | -.01 | -.02 | -.01 | -.05 | -.03 | .06 | -.02 | -.03 | .04 | .10 | .10 | .06 |

\*Correlation is statistically significant at the level *p* < .05, \*\*Correlation is statistically significant at the level *p* < .01, \*\*\*Correlation is statistically significant at the level *p* < .001.

# Table 3.

*Regressions Predicting Proportion Correct for Misperception of Chance using Anomalistic Belief (i.e., ASGS, ABS Total, or ABS Factors)*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | *β* | *β CI 95%* | *t* | *p* | *BF10* | *F* | *R2* | *Adj. R2* | *ΔF\** | *ΔR2\** | *Δp\** |
| Step 1 (All Models) |  |  |  | .004 | 4.49 | 4.56 | .07 | .06 |  |  |  |
| Psychology | -.16 | [-.32, .01] | -1.89 | .06 | 1.33 |  |  |  |  |  |  |
| Mathematics | -.11 | [-.31, .09] | -1.11 | .27 | 0.45 |  |  |  |  |  |  |
| Statistics | -.06 | [-.26, .14] | -0.59 | .56 | 0.30 |  |  |  |  |  |  |
| Step 2 ASGS Model |  |  |  | < .001 | 27.61 | 4.78 | .12 | .10 | 4.80 | .05 | .009 |
| Psychology | -.14 | [-.30, .02] | -1.73 | .09 | 1.16 |  |  |  |  |  |  |
| Mathematics | -.09 | [-.29, .10] | -0.96 | .34 | 0.46 |  |  |  |  |  |  |
| Statistics | -.04 | [-.24, .15] | -0.44 | .66 | 0.33 |  |  |  |  |  |  |
| Overall Gambling | -.02 | [-.16, .13] | -0.21 | .83 | 0.31 |  |  |  |  |  |  |
| ASGS | -.22 | [-.37, -.07] | -2.91 | .004 | 12.89 |  |  |  |  |  |  |
| Step 2 ABS Model |  |  |  | < .001 | 300.96 | 6.00 | .15 | .12 | 7.64 | .08 | <.001 |
| Psychology | -.13 | [-.29, .03] | -1.65 | .10 | 0.99 |  |  |  |  |  |  |
| Mathematics | -.07 | [-.26 .12] | -0.73 | .47 | 0.36 |  |  |  |  |  |  |

(continued)

Table 3.

*Regressions Predicting Proportion Correct for Misperception of Chance using Anomalistic Belief (i.e., ASGS, ABS Total, or ABS Factors)*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | *β* | *β CI 95%* | *t* | *P* | *BF10* | *F* | *R2* | *Adj. R2* | *ΔF\** | *ΔR2\** | *Δp\** |
| Statistics | -.05 | [-.25, .14] | -0.52 | .60 | 0.32 |  |  |  |  |  |  |
| Overall Gambling | .01 | [-.14, .16] | 0.11 | .91 | 0.29 |  |  |  |  |  |  |
| ABS | -.28 | [-.43, -.13] | -3.76 | <.001 | 140.51 |  |  |  |  |  |  |
| Step 2 ABS Factors Model |  |  |  | < .001 | 18464.60 | 6.27 | .23 | .19 | 6.84 | .16 | < .001 |
| Psychology | -.10 | [-.25, .06] | -1.25 | .21 | 0.63 |  |  |  |  |  |  |
| Mathematics | -.05 | [-.24 .14] | -0.52 | .60 | 0.36 |  |  |  |  |  |  |
| Statistics | -.03 | [-.22, .15] | -0.35 | .73 | 0.33 |  |  |  |  |  |  |
| Overall Gambling | -.02 | [-.16, .12] | -0.25 | .80 | 0.32 |  |  |  |  |  |  |
| Experiential | -.47 | [-.66, -.28] | -4.93 | <.001 | 7871.01 |  |  |  |  |  |  |
| PSI | .20 | [-.05, .45] | 1.55 | .12 | 0.93 |  |  |  |  |  |  |
| ET | -.02 | [-.20, .15] | -0.25 | .80 | 0.32 |  |  |  |  |  |  |
| LAD | -.08 | [-.30, .14] | -0.72 | .47 | 0.40 |  |  |  |  |  |  |

\*change statistics represent change from Step 1.

*Β* represents standardised regression coefficients

# Table 4.

*Regressions Predicting Proportion Correct for Base Rate Fallacy using Anomalistic Belief (i.e., ASGS, ABS Total, or ABS Factors)*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | *β* | *β CI 95%* | *t* | *p* | *BF10* | *F* | *R2* | *Adj. R2* | *ΔF\** | *ΔR2\** | *Δp\** |
| Step 1 (All Models) |  |  |  | .09 | 0.60 | 2.84 | .02 | .01 |  |  |  |
| General Education | .13 | [-.02, .27] | 1.68 | .09 | 0.60 |  |  |  |  |  |  |
| Step 2 ASGS Model |  |  |  | .01 | 1.69 | 3.80 | .06 | .05 | 4.23 | .05 | .02 |
| General Education | .15 | [.00, .30] | 2.02 | .04 | 1.72 |  |  |  |  |  |  |
| Overall Gambling | .06 | [-.09, -.21] | 0.78 | .44 | 0.35 |  |  |  |  |  |  |
| ASGS | -.22 | [-.37, -.07] | -2.91 | .004 | 11.91 |  |  |  |  |  |  |
| Step 2 ABS Model |  |  |  | .002 | 10.13 | 5.21 | .08 | .07 | 6.31 | .07 | .002 |
| General Education | .16 | [.02, .31] | 2.23 | .03 | 2.47 |  |  |  |  |  |  |
| Overall Gambling | .08 | [-.07, .23] | 1.04 | .30 | 0.42 |  |  |  |  |  |  |
| ABS | -.27 | [-.42, -.12] | -3.55 | <.001 | 71.40 |  |  |  |  |  |  |

(continued)

Table 4.

*Regressions Predicting Proportion Correct for Base Rate Fallacy using Anomalistic Belief (i.e., ASGS, ABS Total, or ABS Factors)*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | *β* | *β CI 95%* | *t* | *p* | *BF10* | *F* | *R2* | *Adj. R2* | *ΔF\** | *ΔR2\** | *Δp\** |
| Step 2 ABS Factors Model |  |  |  | .01 | 0.80 | 2.92 | .09 | .06 | 2.91 | .08 | .02 |
| General Education | .18 | [.03, .33] | 2.35 | .02 | 3.81 |  |  |  |  |  |  |
| Overall Gambling | .07 | [-.08, .22] | 0.93 | .36 | 0.51 |  |  |  |  |  |  |
| Experiential | -.18 | [-.38, .02] | -1.76 | .08 | 1.35 |  |  |  |  |  |  |
| PSI | .05 | [-.23, .32] | 0.34 | .74 | 0.36 |  |  |  |  |  |  |
| ET | -.15 | [-.33, .04] | -1.52 | .13 | 0.96 |  |  |  |  |  |  |
| LAD | -.06 | [-.30, .18] | -0.50 | .62 | 0.39 |  |  |  |  |  |  |

\*change statistics represent change from Step 1.

*β* represents standardised regression coefficient

Appendix A

*Summary of Misperception of Chance Results from Previous Studies*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Study | *Expt.* | *n* | Belief Measurea | Reasoning Measure | Groupingb | Result | *p* |
| Blackmore & Trościanko (1985) | 1 | 50 | Custom | Randomness Judgements | Mean Split | Not reported | ns |
|  |  |  | Custom | Coin Tossing | Mean Split | *t*(48) = 2.00, *d* = 0.58 | .051 |
|  |  |  | Custom | Sampling Questions | Mean Split | Not reported | ns |
|  | 2 | 100 | Custom | Randomness Judgements | Mean Split | Not reported | ns |
|  |  |  | Custom | Coin Tossing | Mean Split | Not reported | ns |
|  |  |  | Custom | Sampling Questions | Mean Split | *t*(98) = 2.58, *d* = 0.52 | .011 |
|  | 3 | 53 | Custom | Estimate of Chance | Mean Split | *t*(98) = 2.10, *d* = 0.42 | .038 |
| Blagrove et al. (2006) |  | 385 | Dreams | Dice Rolls | Categorical | *χ*2(4) = 4.43, *V* = .05 | .35 |
| Bressan (2002) | 1 | 111 | Custom | Sampling Questions | Quartiles | *t*(54) < 1.5 | ns |
|  |  |  | Custom | Maternity Ward Problem | Quartiles | Not reported | ns |
|  | 2 | 103 | Custom | Pollster Problem | Continuous | *r* = -.07 | .48 |
|  |  |  | Custom | Coin Tossing | Continuous | *rs* = -.38 | <.001 |
|  |  |  | Custom | Birth Orders | Continuous | *r* = -.05 | .62 |
|  |  |  | Custom | Dice Sequence | Continuous | *rs* = -.27 | .006 |
| Brugger et al. (1990) |  | 48 | 2 ESP Questions | Dice Sequence | Based on Scale | *t*(37) = 3.11, *d* = 1.03 | .004 |
| Brugger et al. (1991) |  | 95 | 1 ESP Question | Dice Rolls | Based on Scale | *χ*2(1) = 3.92, φ = .20 | .046 |
| Dagnall et al. (2007) |  | 96 | R-PBS | Randomness Judgements | Continuous | *r* = -.32 | .001 |

(continued)

Appendix A

*Summary of Misperception of Chance Results from Previous Studies*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Study | *Expt.* | *n* | Belief Measurea | Reasoning Measure | Groupingb | Result | *p* |
| Dagnall et al. (2014) |  | 305 | R-PBS | Randomness Judgements | Continuous | *r* = -.17 | .003 |
|  |  |  | ASGS | Randomness Judgements | Continuous | *r* = -.18 | .002 |
|  |  |  | MMU-N | Randomness Judgements | Continuous | *r* = -.19 | .001 |
|  |  |  | R-PBS | Probability Judgements | Continuous | *r* = -.10 | .08 |
|  |  |  | ASGS | Probability Judgements | Continuous | *r* = -.14 | .014 |
|  |  |  | MMU-N | Probability Judgements | Continuous | *r* = -.14 | .014 |
| Dagnall et al. (2016) |  | 254 | R-PBS | Randomness (Control) | Continuous | *r* = -.25 | <.001 |
|  |  |  | R-PBS | Randomness (Paranormal) | Continuous | *r* = -.38 | <.001 |
| Denovan et al. (2018) |  | 725 | R-PBS | Randomness (Control) | Continuous | *r* = -.24 | <.001 |
|  |  |  | R-PBS | Randomness (Paranormal) | Continuous | *r* = -.37 | <.001 |
| Drinkwater et al. (2018) |  | 248 | R-PBS | Randomness Judgements | Continuous | *r* = -.28 | <.001 |
| Musch & Ehrenberg (2002) |  | 123 | Custom | Dice Sequence | Continuous | *r* = -.25 | .005 |
|  |  |  | Custom | Dice Rolls | Continuous | *r* = -.20 | .027 |
|  |  |  | Custom | Birthday Paradox 1 | Continuous | *r* = -.04 | .66 |
|  |  |  | Custom | Birthday Paradox 2 | Continuous | *r* = .12 | .19 |
|  |  |  | Custom | Coin Tossing | Continuous | *r* = -.21 | .020 |
| Roberts & Seager (1999) |  | 65 | BPS + PSI | Probabilistic Reasoning | Continuous | *r* = .01 | .94 |

a R-PBS, Revised-Paranormal Belief Scale; ASGS, Australian Sheep Goat Scale; MMU-N, Manchester Metropolitan University New; BPS, Belief in Paranormal Scale. b Grouping refers to how participants were categorised as anomalistic believers (vs. non-believers) or if belief was a continuous measure.

Appendix B

*Summary of Base Rate Fallacy Results from Previous Studies*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study | *n* | Belief Measurea | Reasoning Measure | Groupingb | Result | *p* |
| Dagnall et al. (2007) | 96 | R-PBS | Base Rate Fallacy | Continuous | *r* = -16 | .12 |
| Dagnall et al. (2014) | 305 | R-PBS | Base Rate Fallacy | Continuous | *r* = -.07 | .22 |
|  |  | ASGS | Base Rate Fallacy | Continuous | *r* = -.12 | .036 |
|  |  | MMU-N | Base Rate Fallacy | Continuous | *r* = -.13 | .023 |

a R-PBS, Revised-Paranormal Belief Scale; ASGS, Australian Sheep Goat Scale; MMU-N, Manchester Metropolitan University New.

b Grouping refers to how participants were categorised as anomalistic believers (vs. non-believers) or if belief was a continuous measure.

Appendix C

*Summary of Context Findings from Previous Studies*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study | *n* | Belief Measurea | Reasoning Measure | Neutral Context Result | Anomalistic Context Result | Context×Belief Resultb |
| Dagnall et al. (2014) | 305 | R-PBS | Conjunction Fallacy | *r* = -.06, *p* = .30 | *r* = -.30, *p* < .001 | *t*(302) = 3.40, *p* < .001 |
|  |  | ASGS | Conjunction Fallacy | *r* = -.03, *p* = .60 | *r* = -.32, *p* < .001 | *t*(302) = 4.06, *p* < .001 |
|  |  | MMU-N | Conjunction Fallacy | *r* = -.09, *p* = .12 | *r* = -.31, *p* < .001 | *t*(302) = 3.12, *p* = .002 |
| Dagnall et al. (2016) | 254 | R-PBS | Randomness Judgements | *r* = -.25, *p* < .001 | *r* = -.38, *p* < .001 | *t*(251) = 2.01, *p* = .045 |
|  |  | R-PBS | Conjunction Fallacy | *r* = -.17, *p* = .007 | *r* = -.49, *p* < .001 | *t*(251) = 4.71, *p* < .001 |
| Denovan et al. (2018) | 725 | R-PBS | Randomness Judgements | *r* = -.24, *p* < .001 | *r* = -.37, *p* < .001 | *t*(722) = 3.37, *p* < .001 |
|  |  | R-PBS | Conjunction Fallacy | *r* = -.14, *p* < .001 | *r* = -.45, *p* < .001 | *t*(722) = 7.58, *p* < .001 |
| Roberts & Seager (1999) | 65 | BPS + PSI | Conditional Reasoning | *r* = -.23, *p* = .065 | *r* = -.24, *p* = .054 | Not reported, ns |
| Rogers et al. (2009) | 200 | ASGS | Conjunction Fallacy | *t*(198) = -4.39, *p* < .001,*d* = -1.24 | *t*(198) = -8.79, *p* < .001,*d* = -0.62 | *F*(1,195) = 4.76, *p* = .030,η2 = .02 |
| Rogers et al. (2011) | 162 | ASGS | Conjunction Fallacy | *t*(160) = -1.87, *p* = .064,*d* = -0.29 | *t*(160) = -2.84, *p* = .005,*d* = -0.45 | Not reported, ns |
| Rogers et al. (2016) | 200 | ASGS-ESP | Conjunction Fallacy | *r* = -.17, *p* = .016 | *r* = -.09, *p* = .21 | *Z* = 0.20, *p* = .84 |
|  |  | ASGS-PK | Conjunction Fallacy | *r* = -.24, *p* < .001 | *r* = -.16, *p* = .024 | *Z* = 0.72, *p* = .47 |
|  |  | ASGS-LAD | Conjunction Fallacy | *r* = -.19, *p* = .007 | *r* = -.09, *p* = .21 | *Z* = 0.03, *p* = .98 |
| Rogers et al. (2018) | 261 | ASGS-ESP | Conjunction Fallacy | *r* = -.23, *p* < .001 | *r* = -.20, *p* < .001 | *Z* = 0.31, *p* = .75 |
|  |  | ASGS-PK | Conjunction Fallacy | *r* = -.18, *p* < .001 | *r* = -.17, *p* < .001 | *Z* = 0.12, *p* = .91 |
|  |  | ASGS-LAD | Conjunction Fallacy | *r* = -.20, *p* < .001 | *r* = -.20, *p* < .001 | *Z* = 0.14, *p* = .89 |
| Wierzbicki (1985) | 64 | BPS | Conditional Reasoning | *r* = -.14, *p* = .27 | *r* = -.39, *p* = .001 | *t*(62) = 1.75, *p* = .085 |

a R-PBS, Revised-Paranormal Belief Scale; ASGS, Australian Sheep Goat Scale; MMU-N, Manchester Metropolitan University New; BPS, Belief in Paranormal Scale; ESP, extrasensory perception subscale; PK, psychokinesis subscale; LAD, life after death subscale.

b Tests for statistically significant differences in the strength of the correlations were conducted using methods outlined in Steiger (1980).