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Testing the Implicit Processing Hypothesis of Precognitive Dream Experience

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Abstract

Seemingly precognitive (prophetic) dreams may be a result of one's unconscious processing of environmental cues and having an implicit inference based on these cues manifest itself in one's dreams. We present two studies exploring this implicit processing hypothesis of precognitive dream experience. Study 1 investigated the relationship between implicit learning, transliminality, and precognitive dream belief and experience. Participants completed the Serial Reaction Time task and several questionnaires. We predicted a positive relationship between the variables. This prediction was not supported. Study 2 tested the hypothesis that differences in the ability to notice subtle cues explicitly might account for precognitive dream beliefs and experiences. Participants completed a modified version of the flicker paradigm. We predicted a negative relationship between the ability to explicitly detect changes and precognitive dream variables. This relationship was not found. There was also no relationship between precognitive dream belief and experience and implicit change detection.

Keywords: precognitive dream; implicit learning; change blindness; individual differences; paranormal belief; transliminality.

1. Introduction

Precognition, the putative reception of future-related information that could not have possibly been obtained by any known means (e.g., rational inference, coincidence), is one of the most widely believed paranormal phenomena. Surveys of large samples of individuals show that around one third of the population believe in the ability to foretell the future (Moore, 2005) or have experienced at least one precognitive dream (Haraldsson, 1985; Palmer, 1979). This paper explores potential psychological factors contributing to precognitive dream belief and experience.

Beside the hypothesis that precognitive dreams are a genuine phenomenon amenable to scientific testing (Krippner, Ullman, & Honorton, 1971; Sherwood & Roe, 2003), there have also been proposed several alternative hypotheses to explain this and similar experiences, such as individual differences in probabilistic reasoning and affirmative bias (Blagrove, French, & Jones, 2006), false memories (Wilson & French, 2006), or attribution of meaning to coincidence (Houran & Lange, 1998). One such, as of yet unexplored, hypothesis proposes that precognitive dreams might be a result of inferences during sleep based on subtle cues from the environment perceived outside of awareness. This hypothesis was first proposed by Aristotle over 2000 years ago in his treatise *On Prophesying by Dreams*, and was more recently voiced by James Alcock (1981). To illustrate, a fulfilled nightmare about the death of an elderly relative might be caused by perceiving, without awareness, a slight change in their appearance, behaviour or physiology (e.g., heavier breathing, paler complexion) during a previous encounter. These subtle, yet disconcerting indications of ill health might create a seemingly precognitive dream about the death of the person in question. If this person then passes away, the dream is recalled and the attribution of precognition is made.

The plausibility of the implicit processing hypothesis (IPH) of precognitive dream experiences appears to be supported by research into sleep and dreaming. There exists extensive literature supporting the notion that dreams reflect, to some extent, waking life experiences (e.g., Schredl & Hofmann, 2003; Fosse, Fosse, Hobson, Stickgold, 2003; Pesant & Zadra, 2006; Hobson, & Schredl, 2011, for discussion). In light of this research, there appears to be no reason why information acquired in waking life could not, in principle, manifest itself in dream imagery.

Moreover, the prevailing expert opinion seems to agree with the claim that sleep and dreaming can facilitate processes such as memory consolidation or learning and inspire insight (Walker & Stickgold, 2006), although there are also opposing views on the matter (Vertes, Eastman, 2000; Frank & Benington, 2006). Previous research in this area has found support for the role of REM sleep in consolidation of memory and learning (Ellenbogen, Payne, & Stickgold, 2006; Stickgold & Walker, 2007; Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010), including probabilistic and procedural learning (Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002; Djonlagic, *et al.*, 2009). There is also some evidence that sleep causes improved performance on tasks requiring insight into hidden rules (Wagner, Gais, Haider, Verleger, & Born, 2004) and primes associative networks (Cai, Mednick, Harrison, Kanady, & Mednick, 2009).

Here we present two studies testing the IPH. Study 1 explores the relationship between implicit learning and precognitive dream experiences while Study 2 focuses on perception without awareness and its relationship to these experiences. Both studies were approved by the Psychology Department's ethics panel.

2. Study 1

One prediction of the implicit processing hypothesis is that people who tend to have these experiences are better able to pick up on such subtle cues and process them without being aware of it. This can be tested in the frame of the implicit learning paradigm. Implicit learning occurs when people acquire new information without intending it or being consciously aware of having done so (Cleeremans, Destrebecqz, & Boyer, 1998; Kaufman, *et al.* 2010). Several methods for exploring implicit learning have been developed but one in particular, the Serial Reaction Time task, seems to be the most appropriate and most widely used (Jiménez & Vázquez, 2005). Moreover, this method has recently been used in individual differences research, where implicit learning significantly correlated with the personality factors of intuition, Openness to Experience, and impulsivity, as well as with cognitive variables including verbal analogical reasoning, processing speed, and academic performance (Kaufman, *et al.*, 2010). This individual differences approach regards implicit learning as an ability and is in line with our hypothesis.

Of potential interest in exploring the relationship between implicit processing and precognitive dream experience is the concept of transliminality, developed by Thalbourne and Delin (1994) and defined as “a largely involuntary susceptibility to, and awareness of, large volumes of inwardly generated psychological phenomena of an ideational and affective kind” (Thalbourne & Delin, 1994, p25). Crawley, French, and Yesson (2001) found a link between transliminality and susceptibility to subliminal priming. Participants in this study were led to believe they were taking part in an extra-sensory perception card-guessing task. Unbeknownst to them, half of the trials were preceded by a subliminal prime showing the correct response. The results showed that transliminality was positively related to number of correct responses only on the primed trials. Furthermore, in a subsequent task, high transliminality subjects were more successful at detecting which trials had been primed, even though they reported no conscious awareness of the priming in the card-guessing task. These findings suggest that transliminality might play a role in the kind of implicit processing required by the IPH. If high levels of transliminality are conducive to being able to detect subtle environmental cues (e.g., subliminal primes used in the above-mentioned study) without being aware of them, then people who experience precognitive dreams should, under the IPH, score high on transliminality. Similarly people who possess higher levels of this trait should show superior implicit learning ability compared to low transliminality individuals.

Study 1 therefore predicts that precognitive dream experience will positively correlate with transliminality and implicit learning.

2.1. Method

2.1.1. Participants

A planned number of participants ($N = 50$, 31 females), mostly undergraduate students, were recruited and paid for their participation. Data from one participant were excluded due to incompleteness and another participant was recruited in order to preserve the planned number of participants. Participants' ages ranged from 17 to 53 years (mean = 21.98, $SD = 17.49$).

2.1.2. Materials and apparatus

Serial Reaction Time. To assess individual differences in implicit learning, we used a modified version of the widely-used Serial Reaction Time (SRT) task (Nissen & Bullemer, 1987) used by Kaufman, *et al.* (2010). During a trial, an 'X' appeared in one of four possible locations represented by underscores and arranged horizontally in the centre of the screen. The keys 'z', 'x', 'n', and 'm' were assigned one to each location ('z' to the leftmost, 'm' to the rightmost). The task was to press the appropriate key as quickly and accurately as possible. The next stimulus appeared on one of the positions 500 ms after a key was pressed. Reaction time was measured from the onset of the stimulus. If no response was recorded, the next stimulus appeared after five seconds. The sequence of locations was governed by two second order conditional (SOC) sequences, where an element is determined by a combination of two previous elements; the Probable sequence (1-2-1-4-3-2-4-1-3-4-2-3) occurred on 85% of the trials, and the Improbable sequence (3-2-3-4-1-2-4-3-1-4-2-1) occurred on 15%. Note that no individual triplet appears in both sequences. The task consisted of seven blocks of trials with 102 trials per block. Because SOC requires two pre-existing trials, the first two trials were selected at random and excluded from the analysis. The first block served as a practice block and was not analysed either. The occurrence of Probable and Improbable trials was randomised. The task was designed using E-prime version 2.0 software (Psychology Software Tools, Pittsburgh, PA) in white on black background. The design of the SRT task is summarised in Fig. 1.

[INSERT FIG. 1 ABOUT HERE]

Precognitive Dream Belief and experience. Belief in precognitive dreams was assessed using a 6-item scale created for the present study. Response options on the 5-point Likert scale ranged from 1 ('Completely disagree') to 5 ('Completely agree'). The overall reliability¹ of this scale reached the acceptable level ($\omega_t = .75$; 95% CI [.58, .86]) but the analysis revealed one very weakly and one negatively correlated item, which we omitted from further analysis, raising the reliability index of the scale to $\omega_t = .88$; 95% CI [.79, .93].

One further question that related to precognitive dream frequency ("Approximately how often you have had a precognitive dream over the last few years?") was included in the battery with response options: "Never", "Less than once a year", "About once a year",

¹ We chose McDonald's ω_t over the traditionally used Cronbach's α as an index of psychometric reliability because of the many problems associated with the latter (see e.g., Dunn, Baguley, & Brundsen, 2013). McDonald's ω_t provides a superior measure of reliability and, unlike α , does not rely on the often broken assumption of essential tau-equivalence (Dunn, Baguley, & Brundsen, 2013; Zinbarg, Revelle, Yovel, & Li, 2005).

“About once in six months”, “About once a month”, and “About once a week”. This item was used to divide participants into those with and without experience of precognitive dreams.

Transliminality. In order to measure participants’ transliminality, we used the Revised Transliminality Scale (RTS; Lange, Thalbourne, Houran, & Storm, 2000), a 17-item forced choice scale. The scale is presented in an earlier 29-item form (Thalbourne, 1998) in order to preserve the context but only the 17 items of interest are scored. Houran, Thalbourne, and Lange (2003) report the scale’s high internal consistency (KR-20 $r = .85$) and test-retest reliability over an average of fifty days, $r = .82$, $p < .001$, $N = 51$. In the present sample, the reliability of the full scale was comparably high ($\omega_t = .85$; 95% CI [.75, .9]), while the reliability of the 17 items was moderate to high ($\omega_t = .77$; 95% CI [.64, .85]). This, however, is not necessarily a problem given that the RTS was validated using Rasch model and therefore its reliability should be independent of the sample (Hambleton, 1991).

2.1.3. Procedure

The study took place in the Psychology Department of the University of Edinburgh. Participants were shown individually into an experimental cubicle where they were seated in front of a computer with standard 16-inch CRT monitor with 75 Hz refresh rate. They were given an information sheet and a consent form. Next, demographic data were collected and participants were asked to complete the SRT task which was described as a reaction time task without a mention of implicit learning or the probabilistic SOC nature of the stimuli. Participants were encouraged to get comfortable pressing the assigned keys and then asked to proceed when they were ready by pressing the space bar. Once participants completed 102 trials, the block ended and they were asked to take a break. After a minute they were asked to continue, when ready, by pressing the space bar again and the next block of trials ensued in the same fashion. Once the SRT task was over, subjects were asked to complete the questionnaire part of the study. The battery of items was presented in electronic form using the Google forms service. Upon completion, subjects were thanked for their participation, debriefed about the actual nature of the SRT task, paid, and dismissed.

2.1.4. Hypotheses and analysis

Based on the implicit processing hypothesis of precognitive dream experience, we predicted the following:

H1: There is a positive relationship between the performance on the SRT task and precognitive dream belief.

H2: Performance on the SRT task is positively related to transliminality score.

H3: Transliminality is positively related to precognitive dream belief.

H4: Participants with prior precognitive dream experience will perform better at the SRT task than those who have not had such experience.

H5: Participants with prior precognitive dream experience will score higher on transliminality than participants without such experience.

To assess the individual differences in implicit learning, the SRT task was analysed using a mean difference score. To arrive at this score, we first deleted all error responses (5.08% of all trials). Next, we calculated a 20% trimmed mean reaction time (RT) for each block (2-7) per participant, separately for Probable and Improbable trials. Subsequently, we calculated the difference between the trimmed mean RT of Improbable trials and the trimmed mean RT of Probable trials in each block for each participant. The mean of the resulting six numbers was the participant’s mean difference score (MDS). For readers who may prefer a more formal notation,

$$MDS_i = \frac{\sum_{j=2}^7 (\bar{X}_{20\%RTimprob_{ij}} - \bar{X}_{20\%RTprob_{ij}})}{6},$$

where i is any given participant and j represents block. We chose the 20% trimmed mean over mean because it provides a more reliable estimator of location for non-normally distributed data (Wilcox, 2010). Higher MDS represents greater implicit learning on the SRT task.

The Revised Transliminality Scale was analysed using the Rasch score derived according to Lange, *et al.* (2000).

Unless stated otherwise, all reported p -values are two-tailed and all confidence intervals (CIs) were computed based on a bootstrap sample of $N = 2000$.

2.2. Results

2.2.1. SRT task validation

First, we analysed the overall data from the SRT task in order to validate the implicit learning effect. Fig. 2 shows the pooled performance by trial type across blocks.

A repeated measures factorial analysis of variance (ANOVA) was conducted with block (6 levels) and sequence (2 levels; probable v improbable) as within-subjects factors and 20% trimmed mean RT calculated per block per trial type for each participant as dependent variable. The results showed a significant effect of type of trial, $F(1,49) = 37.95, p < .001, \eta_p^2 = .45$, and block, $F(3.51,172.1)^2 = 2.54, p = .049, \eta_p^2 = .05$. There was also a significant interaction between trial type and block, $F(5,245) = 3.78, p = .003, \eta_p^2 = .07$. These results, combined with examination of Fig. 2, indicate that learning did indeed take place and that the greatest differences appeared later in the task.

[INSERT FIG. 2 ABOUT HERE]

Table 1 summarises the descriptive statistics for the analysed variables for the overall data as well as separately for the two compared groups.

[INSERT TABLE 1 ABOUT HERE]

2.2.2. Hypothesis testing

In order to assess the relationships predicted by H1 and H2, we conducted a series of simple regression analyses with MDS as outcome variable and precognitive dream belief and transliminality respectively as predictors. Precognitive dream belief was not a significant predictor of performance on the SRT task ($\beta = 0.14, t(48) = 1.00, p = .322, R^2 = .02, F(1,48) = 1.00, p = .322$). Transliminality scores also did not significantly predict participants' performance on the implicit learning task ($\beta = -0.21, t(48) = -1.48, p = .146, R^2 = .04, F(1,48) = 2.18, p = .146$). These results did not support hypothesis H1 about positive relationship

² Greenhouse-Geisser ($\hat{\Gamma} = .702$) corrected degrees of freedom due to significant Mauchly's test of sphericity ($W = 0.357, \chi^2(14) = 48.502$).

between performance on the SRT task and precognitive dream belief, or hypothesis H2 about the relationship between SRT performance and transliminality.

We also conducted a simple regression to explore the role of transliminality in precognitive dream belief (H3). Translinality was a significant predictor of precognitive dream belief, $b = 0.51$, 95% CI [0.15, 0.83], $p = .002$. Translinality accounted for a significant proportion of variance in precognitive dream belief, $R^2 = .19$, $F(1,48) = 10.95$, $p = .002$, thus supporting the hypothesis H3 of a positive relationship between translinality and precognitive dream belief.

Given this relationship between precognitive dream belief and translinality, we investigated the unique contribution of translinality to SRT performance. In order to do this, we conducted a simultaneous multiple regression analysis with MDS as outcome variable and precognitive dream belief and translinality as predictors, thus controlling for precognitive dream belief. As shown in Table 2, translinality was a significant predictor of performance on the SRT task, $p = .035$. However, the direction of the relationship was opposite to the one predicted by H2. We also included an interaction term in the model which was also not significant ($b = 0.24$, 95% CI [-0.03, 0.51], $p = .080$). This hypothesis therefore remains unsupported by the data.

[INSERT TABLE 2 ABOUT HERE]

Finally, we compared the participants with and without a reported precognitive dream experience. This binary variable was derived from the precognitive dream frequency item. Those who selected the option 'Never' ($N=33$) were designated as 'non-precognitive dreamers' while the rest were considered 'precognitive dreamers' ($N=17$). An independent t -test revealed no significant difference in the performance on the SRT task between non-precognitive dreamers and precognitive dreamers, $t(48) = 1.13$, $p = .265$, $r^2 = .03$. Hence, the hypothesis H4 about differences in SRT task performance was not supported. There was, however a significant difference between these groups in translinality scores (mean difference = -3.19, 95% CI [-5.20, -1.18], $t(48) = -3.19$, $p = .003$, $r^2 = .17$). This finding lends support to the hypothesis H5 about differences in translinality between people with and without precognitive dream experience.

2.3. Discussion

Study 1 tested the hypothesis that people with precognitive dream belief and experience exhibit greater implicit learning than those without these beliefs and experiences. This hypothesis was not supported by the data. There was no statistically significant relationship between the performance on the SRT task and belief in precognitive dreams, nor a significant difference in the SRT task performance between participants who have had this kind of experience and those who have not. Moreover, this difference was in the opposite direction from the one predicted by the hypothesis. Our findings specifically concerning precognitive dream belief and experience and implicit learning are in line with an earlier study that found no relationship between general paranormal belief and performance on a different implicit sequence learning task (Palmer, Mohr, Krummenacher, & Brugger, 2007).

Potential criticism of our findings could concern whether the learning exhibited by participants was really implicit. Previous research employing modifications of the SRT task in combination with the process dissociation procedure has shown that under some circumstances participants are able to discriminate between the test sequence used and random sequences at an above-chance level, although there was nevertheless evidence of implicit learning (Destrebecqz & Cleeremans, 2001; Fu, Bin, Dienes, Fu, & Gao, 2011). Therefore, there is a possibility of explicit learning contamination in the study. However, we

echo Kaufman *et al.*'s (2010) argument that the probabilistic second order conditional version of the task employed in the present study makes explicit learning difficult, thus lowering this probability.

It could also be argued in defence of the IPH that, although not better at implicit learning *per se*, precognitive dreamers are more sensitive to implicit pattern violation than those people who have not had precognitive dream experience. While we agree that this is indeed a possibility, we would posit that the above-reported analysis already tests this hypothesis by using the mean difference score as a measure of implicit learning. This index takes into account the difference between RT on improbable and probable trials and therefore the response latency on improbable trials compared to probable ones.³

Finally, it is important to emphasise that this study tested merely one possible prediction of the IPH. It may be the case that the difference between precognitive and non-precognitive dreamers lies in the better ability of the latter group to notice subtle cues consciously. This would imply that although their implicit processing ability is not better, precognitive dreamers' failure to notice these subtle cues explicitly might leave more opportunities for them to process them outside of awareness. To explore this a measure of implicit processing is required that would provide a means to clearly differentiate processing accompanied by awareness from processing in its absence.

Study 1 also investigated the role of transliminality in implicit learning and precognitive dream belief and experience. Transliminality was positively related to both precognitive dream belief and experience. However, the significant relationship between transliminality and measure of implicit learning after controlling for precognitive dream belief was in the opposite direction to the one predicted. We find this result difficult to reconcile with that of Crawley *et al.* (2001) who found that high transliminality individuals performed better on a subliminal priming task than those low on transliminality as well as with our prediction which follows from the concept of transliminality itself. We can only speculate about the reasons for this contradiction. Perhaps the transliminality measure partly taps into some other variable that mediates the relationship between transliminality and susceptibility to subliminal priming. If believers in precognitive dreams happened to score higher on this unknown variable, it would explain the findings reported by Crawley *et al.* (2001), who did not control for precognitive dream/paranormal belief. If true, this would call into question the validity of transliminality as a unitary construct. Alternatively, the inconsistent nature of the findings obtained using transliminality scales could be caused by suboptimal psychometric characteristics of these measures. Although Lange, Houran, Thalbourne, and Storm (2000) claim that the revised transliminality scaled is a unidimensional measure, an additional principal component analysis of the data from the present sample revealed that the first principal component accounted merely for 26% of the total variance in the scores. Bartlett scores based on this principal component correlated with precognitive dream belief even more strongly than the Rasch scores used in the primary analysis ($r = .498$, 95% CI [.195, .745], $p < .001$). In order to account for over a half of the total variance of the RTS scores, a total of five components would need to be extracted. Furthermore, only four of the scale's 17 items had communalities over .3 (items 3, 8, 16, and 18 with $h^2 = .53$, .62, .56, and .53 respectively), while seven items had communalities below .1. It thus seems that, at least in the present sample, the Revised Transliminality Scale cannot be considered a valid measure. We encourage researchers working with this scale to pay closer attention to its psychometric characteristics in future studies.

³ This argument is supported by the corroborative nature of the result obtained from an additional analysis of covariance that explored the differences in mean RT on improbable trial between the two groups while controlling for the mean RT on probable trials, $F(1,47) = 1.27$, $p = .265$.

3. Study 2

In the previous section, we outlined an alternative prediction of the implicit processing hypothesis of precognitive dream experience. We hypothesised that if these experiences really arise through the proposed mechanism, and if people *without* these experiences are better at noticing subtle cues explicitly, then non-precognitive dreamers are less likely to be influenced by this mechanism than precognitive dreamers, because precognitive dreamers are less able to consciously notice subtle cues. In other words, non-precognitive dreamers may have fewer precognitive dream experiences because they consciously notice subtle cues.

In order to explore this prediction, Study 2 uses the flicker task, a well-established paradigm used in change blindness research. The term change blindness (Rensink, O'Regan & Clark, 1997) describes a phenomenon whereupon people fail to notice sometimes major changes in stimuli when the presentation of the stimuli is disrupted (for example by camera cuts) and the change occurs during this disruption. This phenomenon has been extensively studied and has proved to be highly robust and generalisable (c.f. Rensink, 2000; Simons, 2000; Simons & Rensink, 2005). The flicker task developed by Rensink *et al.* (1997) and used in Study 2 involves presenting participants with stimuli in quick succession interrupted by a mask, usually a monochrome empty screen. The stimuli are two photographs, sometimes identical, sometimes with a single change to one of the pair. This task is appropriate for the purposes of the present study for several reasons. Firstly, as stated above, it is a widely-used research method in the field capable of creating a robust effect. Secondly, a modification of the flicker task described in the Methods section below offers means to distinguish conscious identification from implicit change detection and thus to assess them separately. It therefore appears appropriate for our purposes. Finally, the flicker task has previously been used in studies investigating implicit detection. In his study, Rensink (2004) asked participants to press a key when they feel a change has occurred and then again once they are able to identify the change explicitly. He found that some participants were able to 'sense' the change in the stimulus several seconds before they could identify it. In light of this finding, it is possible that the individual differences in the ability to 'sense' and 'see' the change might be related to precognitive dream experience. In this study, we therefore test the discussed prediction in terms of the change blindness paradigm, using a variation on the flicker task.

3.1. Method

3.1.1. Participants

As in Study 1, a planned number of mostly undergraduate student participants (N = 50, 26 females) were recruited for the study and paid £6.20 each for their participation. Participants' ages ranged from 15 to 53 years (mean = 21.64, SD = 6.33). Data from one participant were omitted due to outlier values on the change detection measures.

3.1.2. Material and apparatus

Flicker task. In order to assess both explicit and implicit change detection, we used a modified version⁴ of the flicker paradigm used in change blindness research (Rensink, *et al.*, 1997). In this task, participants are presented with two pictures that oscillate in quick succession and asked to identify which element in the pictures undergoes change. In the present study, participants completed a total of 43 trials each, three practice trials and forty test trials. The stimuli, arranged in pairs, were all colour images with a resolution of 700x500

⁴ We are grateful to Professor Richard Wiseman for suggesting this modification.

pixels, displayed full-screen. The images used depicted everyday scenes (e.g., a picture of a train station) and were downloaded from Ronald Rensink's personal website (<http://www2.psych.ubc.ca/~rensink/>). The first image of the pair was shown for 240 ms, followed by a 120 ms mask (grey screen), after which the second image of the pair appeared for another 240 ms again followed by the mask. Each trial consisted of six such cycles, thus lasting 4.32 seconds. Fig. 3 shows a flowchart of a trial's design. The pictures were identical ('no-change trials') in half of the test trials, while in the other half ('change trials'), there was a single change, easily detectable under normal viewing conditions. The change to an object in the picture could be either in its presence (e.g., appearance and disappearance of a person) or in its location (e.g., horizon shifting up and down). The order of the trials was randomised.⁵ The task was designed using E-prime version 2.0 software (Psychology Software Tools, Pittsburgh, PA). All instructions were written in white font on black background.

[INSERT FIG. 3 ABOUT HERE]

Precognitive dream belief and experience. Participants' belief in precognitive dreams was assessed using the same scale as in Study 1. This time, the reliability of the scale was high for all six items, $\omega_t = .86$; 95% CI [.76, .91]. The scale was again followed by an item inquiring into the frequency of participants' precognitive dreams used to assess precognitive dream experience.

3.1.3. Procedure

Data were collected in the Psychology Department of the University of Edinburgh. As in Study 1, participants were seated in an experimental cubicle in front of a computer with standard 16-inch CRT monitor with 75 Hz refresh rate. Participants were given an information sheet and a consent form, after which demographic data were collected.

Next, participants completed the flicker task. They were asked to carefully read the instructions and informed that the first three trials would serve as practice trials. Subjects then proceeded, when ready, by pressing the space bar. Subsequently, a fixation cue in the form of a plus sign appeared in the centre of the screen for three seconds, after which the task began. After each trial, participants were prompted to indicate whether or not they detected a change by pressing the 'y' key for yes and the 'n' key for no. If they answered yes, they were asked to report verbally to the experimenter what the change was. If they did not see a change, they were prompted to decide based on their 'gut feeling' whether or not there was a change. The task terminated after three practice and forty test trials. Responses to the first prompt were labelled 'explicit trials' and responses to the gut feeling prompt were labelled 'implicit trials'.

Finally, they completed the precognitive dream belief and experience questionnaire presented using the Google forms service. After that, participants were debriefed, thanked for taking part in the study, paid, and dismissed.

3.1.4. Hypotheses and analysis

Study 2 explores the following hypotheses:

⁵ Due to an error in the design, one trial was presented twice, which did not influence the total number of trials but, as a result, only 39 different test stimuli were presented. Both the duplicated and the omitted stimuli were 'no-change' stimuli and therefore this error did not increase the likelihood of change detection.

H1: There is a negative relationship between explicit performance on the flicker task and precognitive belief.

H2: Participants without precognitive dream experience will perform better on the explicit flicker trials than those participants who have had such experience.

As an additional test of the hypothesis investigated in Study 1, we formulated two further hypotheses:

H3: There is a positive relationship between implicit performance on the flicker task and precognitive dream belief.

H4: Precognitive dreamers perform better on implicit trials than non-precognitive dreamers.

The flicker task was analysed using the d' and c indices as described in Stanislaw and Todorov (1999), used in signal detection analysis. The d' (d prime) index provides an estimate of sensitivity to signal versus noise, which, in the present case, translates to participants' ability to detect change. It can theoretically range from $-\infty$ to ∞ with 0 representing chance performance. The c index is a measure of bias, i.e., a tendency to indicate the presence (liberal bias, $c < 0$) or absence (conservative bias, $c > 0$) of signal in situations of uncertainty. In our analysis, we calculated one set of indices for the explicit identification and one for implicit identification, based on participants' 'gut feeling'. Extreme values of hit rate and false alarm rate (0 and 1) were adjusted using the loglinear correction also described in Stanislaw and Todorov (1999). Furthermore, in implicit hit rates, this correction was multiplied by the ratio of implicit change trials to no-change trials in order to compensate for the bias caused by their unequal numbers.

As in Study 1, unless stated otherwise, all reported p -values are two-tailed and all confidence intervals are based on a bootstrap sample of $N = 2000$.

3.2. Results

Table 3 summarises the descriptive statistics for the analysed variables.

3.2.1. Flicker task item analysis

We verified explicit hits by comparing participants' verbal identifications to the stimuli. If participants scored an explicit hit but were unable to identify the element of change, the trial was relabelled a false alarm.⁶

Furthermore, we explored the flicker task at the item level (individual stimuli used in trials) to identify potential ceiling and floor effects. We analysed both explicit and implicit hit rate on change items and correct rejection rates on implicit trials only. The rationale for this being that, in case of no-change trials, explicit 'correct rejections' can be expected to be high. Two change items scored a 100% explicit hit rate and were excluded from further analyses of explicit detection due to ceiling effect. One item scored a 0% hit rate and was also excluded due to floor effect. One further change trial was eliminated from implicit detection analysis due to floor effect, having never been implicitly detected.

Finally, in order to assess possible effects of learning, we compared the hit rate on first half of the trials to that on the second half. If, during the course of the task, participants learnt what changes are most likely to occur, their explicit hit rates on the second half of the trials should be higher than their explicit hit rates on the first half. A paired sample t -test

⁶ On top of the reported analysis, we also re-analysed the data with these trials scored as implicit hits to allow for the possibility that participants did indeed notice that something changed but could not make out what it was. This additional analysis was in agreement with the main analysis and the conclusions of the study.

comparing these groups of hit rates was not significant (mean difference = -0.13, 95% CI [-0.09, 0.06], $t(49) = -0.335, p = .739$).

[INSERT TABLE 3 ABOUT HERE]

3.2.2. Hypothesis testing

First, we explored the hypothesis H1 about a negative relationship between precognitive dream belief and explicit change detection. Two simple regression analyses conducted on measures of sensitivity and bias respectively, summarised in Table 4, did not reveal a significant relationship.

Subsequently, in line with the hypothesis H2, we compared participants with ($N = 18$) and without ($N = 31$) precognitive dream experience on the explicit d' and c measures. Participants were divided into these groups by the same principle as in Study 1. Again the difference was non-significant for sensitivity, $t(47) = 1.28, p = .256, r^2 = .03$, or bias, $t(47) = .11, p = .917, r^2 = 2.57 \times 10^{-4}$. The results of this analysis do not lend support to the tested hypotheses.

[INSERT TABLE 4 ABOUT HERE]

In order to assess the hypothesised differences in implicit change detection, we first explored participants' overall performance on implicit trials. The mean sensitivity on these trials was 0.35 (SD = 0.61) which indicates an above-chance performance. This value differed significantly from zero, $t(48) = 4.00, p < .001, 95\% \text{ CI } [0.17, 0.51], r^2 = .25$, suggesting that participants were able to detect a change even when they reported not having seen it.

Another set of simple regression analyses was conducted in order to investigate the hypothesised relationship between precognitive dream belief and measures of sensitivity and bias on implicit trials (H3), however no significant relationship was discovered. The findings are summarised in Table 5. Controlling for sensitivity on explicit trials did not change the null result; the effect of implicit d' was still not significant, $b = -1.41, SE = 1.40, \beta = -0.15, p = .318, 95\% \text{ CI of } b [-4.14, 2.26]$.

Again, these findings are corroborated by comparing the implicit performance of precognitive dreamers and non-precognitive dreamers, as stated in the hypothesis H4. There was no significant difference between these groups on sensitivity, $t(47) = 0.84, p = .452, r^2 = .01$, or bias, $t(47) = 1.24, p = .237, r^2 = .03$. Thus, the hypotheses about a relationship between implicit change detection and precognitive dream belief and experience were not supported by the data.

[INSERT TABLE 5 ABOUT HERE]

3.3. Discussion

Study 2 focused on the role of explicit and implicit change detection in precognitive dream belief as well as differences in these variables between people with and without precognitive dream experience. We hypothesised a negative relationship between explicit change detection and precognitive dream belief and a positive one between implicit detection and this belief. Furthermore we predicted differences in explicit and implicit change detection between precognitive and non-precognitive dreamers. None of the hypotheses were supported by the data. In contrast to a previous study investigating paranormal belief using signal detection

methods (Krummenacher, Mohr, Haker, & Brugger, 2010), we did not find that paranormal believers exhibited a lower response criterion (i.e., favoured false alarms over misses).

It could be argued that the employed task did not in fact measure implicit detection. Indeed, this line of argumentation has been raised in a critique of Rensink's (2004) study by Simons, Nevarez, and Boot (2005). They argued, in terms of signal detection theory, that when participants indicate they sensed a change, they are merely expressing that they have evidence of change but that this evidence has not yet reached the decision criterion. In other words, the 'sensing' detections represented merely liberal responses waiting to be confirmed. If this criticism applies to the present study, one would expect to find the participants exhibiting liberal bias in their performance on implicit trials. However, in the present study, participants tended to adopt a somewhat conservative bias for both explicit and implicit trials. Furthermore, Simons *et al.* (2005) show that participants in the 'can-sense' category (those who 'sensed' the change substantially sooner than they 'saw' it) made more false alarms than 'only-see' participants. In our study, however, the mean sensitivity to change on implicit trials was significantly higher than chance-level, which would not occur had false alarms been proportional to hits.

Granted the argument above, one could nevertheless suggest that the hits and correct rejections on implicit trials represented situations when the phenomenon of change was detected consciously but the particular element that changed was not. This argument would imply that participants first use some kind of global perception to assess the overall state of the stimuli and only then use a more analytical approach to identify the changing element. While this idea seems plausible at least at face value, we would suggest that a potential proponent of this explanation needs to provide an explanation of what it means to notice something without knowing what it is, as well as account for why participants indicated that they had not noticed a change.

4. General discussion and conclusion

In this paper, we investigated the hypothesis that putative precognitive dream experiences are caused by implicit processing of subtle environmental cues. Study 1 explored the hypothesis of a positive relationship between transliminality, implicit learning ability, and precognitive dream belief and experience. None of the predictions were confirmed by the data analysis. Furthermore, we found a negative relationship between transliminality scores and performance on the SRT task. Study 2 focused on the relationship between implicit and explicit change detection ability on one hand and precognitive dream belief and experience on the other. We hypothesised that belief and experience of precognitive dreams would be negatively related to explicit change detection. Neither of these hypotheses was supported by the data. In light of these two studies, we conclude that precognitive dream experience is not explained by individual differences in explicit and implicit processing abilities, such as the ones assessed by the reported studies.

Some remarks on the limitations of the reported studies are in order. Firstly, there is an on-going discussion in the scientific community about whether or not the methods employed in these studies have demonstrated the existence of true implicit processing in the absence of awareness (c.f. Mitroff, Simons, & Franconeri, 2002; Destrebecqz & Cleeremans, 2001). If we adopt the negative stance on this debate, there are two possible implications; either this kind of higher processing cannot take place without being accompanied by awareness or it can take place but there are currently no good methods of assessing it. In case of the latter, further development in this field is needed before the IPH can be reliably tested. However, if there is indeed no such thing as implicit processing, the hypothesis in question becomes false by definition.

Secondly, it could be argued that more emotionally impactful stimuli than those used in the present studies are needed in order for the implicit mechanisms leading to precognitive dreams to take effect. Returning to the hypothetical example in the introduction, anxiety resulting from unrealised concern for one's relative's health certainly bears more personal relevance than a sequence of characters on a computer screen, however, the aim of this paper was to examine the variability of general implicit processing ability, not of implicit processing of emotionally upsetting stimuli. The point is nevertheless valid and we would encourage future research on this topic.

Furthermore, the sample sizes used in our studies might not have been large enough to detect the true effects. There were only 17 precognitive dreamers (34%) in Study 1 and 18 (37%) in Study 2, which might not have been sufficient numbers for the conducted comparisons. We might have obtained a higher proportion of precognitive dreamers had we used a sample with a cultural background that particularly endorsed such experiences. Our sample consisted mostly of white, UK-domiciled undergraduate psychology students, however the proportion of precognitive dreamers that we obtained with this sample is in line with that found in most representative surveys of paranormal beliefs.

Finally, there are at least two possible predictions of the IPH that were not explored by our studies. Firstly, it may be that precognitive dream experiences are not explained by individual differences in waking life implicit processing, but by differences in the extent to which this processed information manifests itself in the individual's dream imagery. A study exploring this hypothesis could, for instance, assess the relationship of precognitive dream experience and sleep-inspired insight. Secondly, it could be argued that most people have dreams that, to some extent, reflect unconscious inferences about implicitly processed information and that whether or not these are deemed precognitive depends largely on external circumstances and subjective assessment. Some people might be more inclined to attribute precognitive character to such dreams, others might look for other, less extraordinary explanations. Thus, while fully embracing any efforts to replicate our findings and to find alternative means of testing the implicit processing hypothesis, we would also like to encourage research into potential mechanisms leading to differences in precognitive dream attribution.

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