NEUROSCIENCE of Consciousness

Neuroscience of Consciousness, 2025, **2025(1)**, niaf044

DOI: https://doi.org/10.1093/nc/niaf044

Registered Report

Does transliminality predict subperceptual information processing?

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Abstract

Anomalous experiences, such as hallucinations and mystical experiences, are positively related to delusional ideation, religiosity, and paranormal beliefs. Some researchers argue that these relationships are explained by 'transliminality'—a trait describing sensitivity to stimuli crossing the threshold into consciousness. This claim suggests such beliefs may be attempts to interpret barely perceptible stimuli. The strongest evidence for this comes from Crawley et al. (2002), who found transliminality was associated with responses to subperceptual primes. In the current study, we attempted a high-powered replication of Crawley et al.'s findings that: (i) transliminality predicts identification of subperceptual visual primes, and (ii) this relationship is explained by stimulus sensitivity rather than response bias. Participants completed a transliminality measure and an online card guessing task in two parts. In part one, participants were shown 100 images of playing cards and asked to guess which of five shapes was on the other side of the card. A total of 50 trials contained a subperceptual prime in the form of a target shape, and 50 trials were unprimed. In part two, participants were shown 20 primed and 20 unprimed trials. They were told a prime was sometimes present and asked to report whether they noticed this on each trial. We found strong evidence against an association between transliminality and prime perception in both tasks. These results do not support conceptualizing transliminality as a measure of subperceptual processing capabilities. This study did demonstrate the feasibility of conducting research involving rapidly presented visual stimuli in an online setting.

Keywords: subliminal; perceptual threshold; transliminality; belief; priming; consciousness

Does transliminality predict subperceptual information processing?

This article tests a remarkable but understudied claim that scores on a psychometric measure of anomalous experiences and paranormal beliefs can predict performance on behavioural tasks involving subperceptual primes. Specifically, Crawley et al. (2002) reported that individuals who scored high on a measure of 'transliminality' were influenced by, and more able to detect, rapidly presented visual primes, compared to those who scored low on this measure. This claim is surprising as the mechanisms that govern perceptual sensitivity to rapid visual stimuli appear, at face value, disconnected from retrospective reports of the type measured by the transliminality scale (i.e. hallucinations, near death experiences, lucid dreaming, and mystical experiences; see below). Leading theories of subperceptual information processing frame perceptual sensitivity in terms of interactions between low-level physiological functions and attention allocation that appear unrelated to personality traits or anomalous experiences (Wiggs and Martin 1998, Forster et al. 2003, Kouider and Dehaene 2007, Elgendi et al. 2018). Although there are some reports of personality traits moderating perceptual processes (e.g. Shaw and Conway 1990, Bustin et al. 2012), when individual differences in subliminal processing have been identified, these have typically been related to neurophysiological characteristics rather than psychological constructs (Boy et al. 2010).

The implication of Crawley et al.'s (2002) finding is striking: if their account is valid, then individuals who hold paranormal beliefs or report anomalous experiences may simply be trying to explain vague perceptual anomalies, unnoticed by others. Despite this intriguing possibility, this finding has not gained traction beyond the specialist literature on transliminality. This seems surprising: if a psychometric individual difference measure can reliably predict low-level perceptual performance, this could be a valuable tool in studies of perception and conscious awareness. On the other hand, if Crawley et al.'s finding is not valid, then the transliminality literature may need to be revised. In this study, we attempt to determine which of these is the case. We provide a brief overview of transliminality and summarize Crawley's evidence for a link between transliminality and perceptual gating. Next, we report a high-powered replication of Crawley et al.'s task aimed at providing definitive evidence regarding the relationship between transliminality and subliminal perception.

Background to the transliminality construct

The term 'transliminality' was first proposed by Thalbourne and Delin (1994), and was derived from the Latin words 'trans',

Received 23 March 2023; **revised** 4 September 2025; **accepted** 18 September 2025

meaning 'across' and 'limin', meaning 'threshold' (i.e. transliminality refers to 'the degree to which the threshold can be crossed'). More specifically, transliminality was described as 'the selectiveness with which the barrier or gating mechanism between subliminal and supraliminal is operating' (p. 22). In other words, according to these researchers, individuals differ in their susceptibility to inwardly generated ideational and affective psychological content. In the original study, transliminality was operationalized as the single factor that emerged from a principal components analysis of measures of creative personality, mystical experience, manic experience, depressive experience, magical ideation, and paranormal belief. Accordingly, Thalbourne and Delin argued that transliminality may be a unifying characteristic that links these seemingly disparate forms of psychological experience.

Throughout the 1990s, the early research on transliminality continued this focus on psychological correlates and found that transliminality was associated with a wide range of additional variables including: unusual experiences, schizotypy, dissociation, hallucination, psychoticism, frequency of dream interpretation, hyperesthesia, and religiosity (Thalbourne et al. 1997). Transliminality was presented as a potential mechanism by which this broad range of anomalous experiences could be understood. For example, Lange et al. (2000) suggested that all these phenomena involved the processing of ambiguous content at the border between conscious and unconscious awareness.

In the 2000s, the focus of transliminality research shifted more explicitly towards attempting to quantify variations in perceptual gating, with the core assumption that individuals higher in transliminality are more able to perceive fleeting or subliminal perceptual stimuli. Thalbourne and Houran (2000) updated the definition of transliminality to 'a hypothesised tendency for psychological material to cross thresholds into or out of consciousness'. Crawley et al.'s (2002) subliminal card sorting task (which is the primary focus of this study) is a paradigmatic example of this phase of transliminality research.

Most recently, transliminality has been recast as a measure of neuroplasticity (Lange et al. 2019) and some transliminality researchers have shifted to discussing transliminality in terms of neural gating rather than perceptual gating (Evans et al. 2019). The neuroplasticity perspective is largely based on theoretical interpretations of behavioural data, with limited direct evidence, although there is one study showing neurophysiological differences associated with transliminality (Fleck et al. 2008).

Transliminality and subliminal perception

It is well established that individual differences in transliminality are associated with a range of psychological variables (e.g. Lange et al. 2000, Evans et al. 2018). However, it is less clear whether this construct is specifically associated with differences in perceptual processing. Direct evidence for this claim comes from only two experiments. In one study, Houran et al. (2006) reported that transliminality scores were associated with vibrotactile (vibration/touch) thresholds, such that high transliminality scores corresponded to higher vibrotactile sensitivity (lower threshold). They argued that those who score high on the transliminality scale have a weaker ability to ignore irrelevant information due to 'enhanced hyperconnectivity among frontal-subcortical loops and primary or secondary sensory areas and/or sensory association cortices, which is expressed behaviourally as a weaker ability to gate or ignore irrelevant stimuli' (p. 68).

In another study, Crawley et al. (2002) showed that individuals high in transliminality were more likely to respond to a subperceptual prime compared to individuals low in transliminality. Specifically, in their task, on each trial participants were shown a digital image of the back of a playing card. A computer program had randomly assigned one of five shapes to each card, and participants were asked to guess which of these five different shapes was 'on the other side' of the card that was currently displayed. In half of the trials, presentation of the card back image was preceded by a rapidly presented (14.3 ms) and masked prime, which revealed the correct answer. A weak-to-moderate positive association was found between transliminality scores and accuracy on primed trials.

In a subsequent phase of Crawley et al.'s (2002) experiment, participants were informed that half of the trials would contain a rapidly presented prime. In this phase, participants simply reported whether or not they perceived the prime on each trial. Although participants reported no conscious awareness of the primes, Crawley et al. found a positive association between transliminality scores and correct identification of primed trials. This suggests that participants higher in transliminality were influenced by stimuli that they were not consciously aware of. Importantly, Crawley et al. also conducted a signal detection analysis and found a positive relationship between transliminality scores and *d'* (a measure of stimulus sensitivity), showing that their findings were not due to a general 'yes-bias' in the responses of highly transliminal individuals.

Given the importance of a link between transliminality and subliminal processing for later theoretical transliminality research, establishing the robustness of this finding is critical. Accordingly, we aimed to replicate this finding in the current experiment.

The impact of perceptual gating claims in the literature

Crawley et al. (2002) found a significant positive correlation between correct identification of subliminal primes and transliminality scores, suggesting that those higher in transliminality may benefit from subliminal priming as they have greater access to unconscious or preconscious material. In this section, we review some of the literature that has cited Crawley's work based on the claim that the scale predicts altered perceptual processing.

Olson et al.'s (2015) research into forcing (i.e. the factors that can influence people's choices without awareness), used a similar procedure to that of Crawley et al. (2002). Olsen et al. wanted to determine which personality factors would lead to individuals making decisions compatible with the experimenters' manipulations (forced choices). Based on Crawley et al.'s findings, they predicted that those higher in transliminality would be more sensitive and thus more easily influenced by the target cards they presented. They found that transliminality scores positively predicted the degree of forcing, but only for those participants who were unaware of the influence on their choice. In other words, in this study, transliminality was associated with greater response to unconscious stimuli.

In another study from the same lab, Olson et al. (2017) investigated ideomotor actions, using a pendulum as an implicit response to a visual detection task. In one study condition, they instructed participants to search for a target letter amongst rapidly presented characters and mentally 'ask' the pendulum whether the target was present or not. In the other condition, they instructed participants to verbally state whether the target was

present or not. They found that transliminality was associated with accuracy in the pendulum condition, but only when stimuli were presented for supraliminal durations (i.e. there was an association when targets were presented for 33 ms but not when they were presented for 17 ms). So, in this study, individuals higher in transliminality were not better at responding to rapid visual stimuli, but they did appear to be more able to accurately interpret ideomotor signals.

As mentioned previously, the transliminality scale has been conceptualized as indexing the level of transference from unconscious to conscious thought. This framing has informed various avenues of research, examining many of the scale's correlates. These include physiological functioning such as positive schizotypy Dagnall et al. (2010); ungated processing related to temporal lobe functioning (Thalbourne et al. 2003); resting brain activity (Fleck et al. 2008); and neuroplasticity (Evans et al. 2019). Further research has also been carried out on correlates of particular experiences such as self-reported happiness and illicit drug use (Thalbourne and Houran 2005); creativity (Feldges et al. 2018); paranormal events/experiences and belief in psi (Thalbourne and Houran 2000); and intuitive decision making (Lange and Houran 2010). The scale also has established psychosocial correlates such as childhood trauma (Thalbourne et al. 2003; for a review of the scale and its correlates see Lange et al. 2019).

Our focus in this article concerns the claim that transliminality is a predictor of subliminal perception. Our objective is to corroborate this claim, thereby verifying or refuting Crawley's findings.

The current study

In the current study, we attempted a high-powered, pre-registered replication of Crawley et al. (2002). Two key factors justify the need for replication. First, as detailed above, much of the existing transliminality literature has stemmed from Crawley et al.'s claim that scores on a self-report measure of anomalous experiences can predict performance on behavioural tasks in response to subperceptual primes. However, except for Crawley et al.'s original study and Houran et al. (2006), there is little direct evidence to support this claim. Given how influential Crawley et al.'s findings have been in the field, and given that Crawley et al.'s hypotheses were not pre-registered, this warrants replication.

Second, it is important to replicate Crawley et al.'s claim as this line of research potentially provides a compelling account of why some individuals report anomalous events and develop paranormal beliefs. If transliminality is truly associated with increased access to fleeting perceptual stimuli, it may be that individuals misinterpret these vague sensory events as anomalous phenomena, and these may then reinforce beliefs compatible with such bizarre occurrences. This possibility has been acknowledged in previous work (e.g. Lange et al. 2019) but has not been strongly developed. We suggest that the relationship between transliminality and paranormal beliefs may be understood through a prediction error framework (e.g. Friston 2010), whereby such beliefs develop in high transliminal individuals in order to minimize uncertainty associated with frequent fleeting perceptual stimuli. Such an approach may make a useful contribution to the science of belief formation and consciousness, but crucially depends on verification of the supposed link between transliminality and awareness of threshold stimuli.

To evaluate the link between transliminality and perceptual capacities, we replicated Crawley et al.'s (2002) study. We employed a Bayesian approach to find conclusive evidence for or against each of Crawley's reported results. Specifically, if transliminality does involve enhanced perception of threshold stimuli, we expected to find:

H1. A positive correlation between transliminality scores and correct responses on primed trials in part one of the card guessing task.

H2. A positive correlation between transliminality scores and the correct identification of primes on presence trials in part two of the card guessing task.

H3. A positive correlation between transliminality scores and stimulus sensitivity (*d'*) in part two of the card guessing task. This would indicate that participants higher in transliminality were specifically responding to primes, rather than just responding 'yes' more frequently in the card guessing task.

Methods

Approach

Although we set out to replicate Crawley et al. (2002), there were some minor methodological differences between our study and the original paper. Crawley et al. conducted their study in a lab using a 70 Hz monitor, with primes presented for 14.3 ms. In contrast, we conducted our study online using the Gorilla platform, meaning we did not have control over the monitors that participants were using. To ensure that all participants received primes of the same duration, we used a function in Gorilla to record the refresh rate for every participant. Because some monitors do not support 70 Hz, we instructed participants to standardize their refresh rate to 60 Hz. This meant that rather than primes being presented for 14.3 ms, they were presented for 16.7 ms. Participants completing the task with a refresh rate other than 60 Hz were excluded. Due to the slightly longer stimulus duration, we anticipated that more participants would be aware of the primes compared to the original study. As such, we excluded all participants who indicated that they were clearly aware of the primes. Specifically, after the card sorting task participants were asked to rate their awareness of primes on an ordinal scale (see below). Participants indicating the highest category of prime awareness ('I clearly saw shapes on multiple trials') were excluded. We also had two additional exclusion criteria. First, although all questions were forced choice (thereby reducing the possibility of missing data), we excluded participants who did not fully complete the study. Second, we used completion time as a proxy for attention. As response latencies in the card sorting task are expected to be small (thereby minimizing potential differences in completion time across the entire study), we instead calculated a mean completion time for the transliminality scale itself and excluded any participant who finished the scale faster than 3 SDs below this mean.

Participants

In total, 277 participants were recruited from the Prolific recruitment service, and received £2.70 for participating in an 18-minute study. A total of 83 participants were excluded according to our pre-registered criteria. Specifically, all of these 83 participants were excluded for reporting awareness of the primes in the card sorting task. No participants were excluded due to incomplete responses or fast responding, and no participants reported technical difficulties. This resulted in a final sample of 194. We recruited participants until reaching the Bayes stopping rule criterion described below. Specifically, we stopped when the Bayes factor (BF) calculation for the association between transliminality and accuracy on primed trials in the card selection task was B_{HN} (0, 0.25) = 0.157, which was lower than our cutoff of

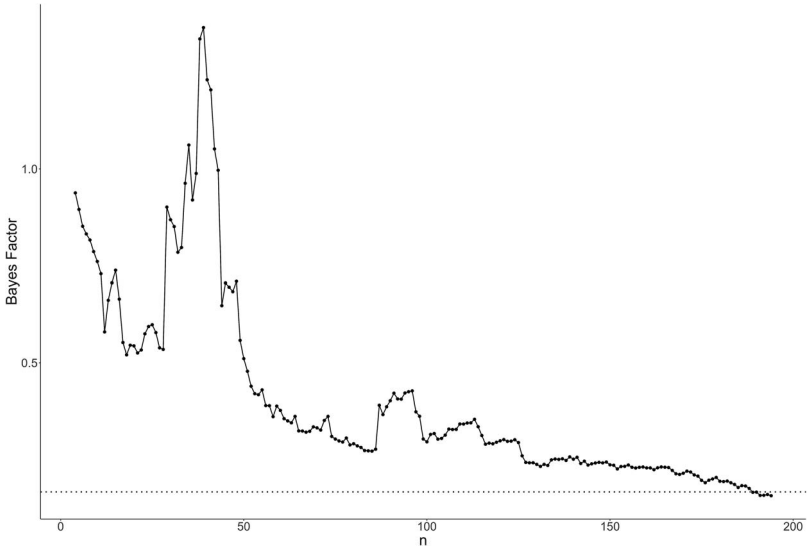

Figure 1. Bayes factor stopping rule calculations. Dotted line represents the lower cutoff of 0.167.

0.167 (see Fig. 1). Ages ranged from 18 to 65 (M = 31.70, SD = 9.82), with 102 males, 88 females, and 4 non-binary participants.

Materials

Transliminality Scale

Transliminality was assessed using the Transliminality Scale (Thalbourne 1998). This is a unidimensional scale, which contains 29 items about experience with hallucinations (e.g. '*when listening to organ music or other powerful music, I sometimes feel as if I am being lifted up into the air*'), mystical experiences (e.g. '*it is sometimes possible for me to be completely immersed in nature or in art and to feel as if my whole state of consciousness has somehow been temporarily altered*'), and paranormal beliefs (e.g. '*now that I am grown up, I still in some ways believe in such beings as elves, witches, leprechauns, fairies, etc.*'). All items are scored either true (1) or false (0), and a total score is obtained by summing all 29 items. The Transliminality Scale showed excellent internal consistency $\alpha = 0.92$, which was slightly higher than previously reported norms ($\alpha = 0.87$; Crawley et al. 2002).

Card priming paradigm

To measure the extent to which transliminality scores predicted the detection of subperceptual primes, we presented participants with an online version of Crawley et al.'s (2002) card priming paradigm. The experiment was divided into two parts.

Card guessing task

In part one, participants were presented with 10 practice trials, followed by four blocks of 25 trials. The structure of each trial is shown in Fig. 2. Each trial began with a blank screen (500 ms), followed by a fixation cross (1000 ms) and another blank screen (500 ms). Then, either a prime or an image of an empty card was presented (16.7 ms). Specifically, half the trials contained one of five Zener card symbols (cross, circle, waves, star, and square) as a subperceptual prime (with each shape presented an equal number of times). On these primed trials, the prime matched the correct target for the trial. The other half of the trials contained an image of an empty card (i.e. no prime). The prime or empty card screen was followed by a blank screen (16.7 ms), and then a persisting image of the back of a playing card. The card back was accompanied by pictures of the five Zener symbols. Participants had to guess which of the symbols was 'on the other side' of the displayed playing card image. In reality, the correct target was pre-assigned randomly by the computer prior to the trial beginning. The card back and response options remained on screen until the participant responded. The order of trials within blocks, and the position of response options on the final screen were fully randomized.

Presence-or-absence detection task

In part two of the card priming paradigm, participants had to indicate whether a prime was present or absent. Participants were told that part 1 had contained primes on some of the trials and were asked to report their overall level of awareness of these primes (see 'Procedure' section). They then completed an additional 40 trials with identical timing to the first part of the task. Again, half the trials contained a Zener symbol as a prime, and half contained an image of an empty card. In this part of the study, rather than selecting from the five response options, participants simply selected whether a prime was 'present' or 'absent' after each trial.

Equipment

We used a function in Gorilla to detect and record monitor refresh rates for each participant and instructed participants to adjust their monitor to 60 Hz. This should result in prime durations of 16.7 ms (1000 ms/60 Hz). However, as there have not been many precedents for running online experiments that involve rapidly presented stimuli, we conducted a series of benchmarks, across different computers and operating systems, to ensure that our experiment could successfully present stimuli at consistent rapid durations in an online environment. We used a slow-motion camera to record 20 trials of our task on a series of different computer configurations, and summarized the results in Table S1. We used the Chrome browser for all tests as earlier piloting indicated potential timing inconsistencies with other browsers. Overall, our task ran successfully on all of the Windows computers that we tested, but we did detect dropped frames (up to 30%) on some Mac systems, particularly older systems. This is consistent with findings from a larger study of timing accuracy across a range of online platforms (Anwyl-Irvine et al. 2021). Accordingly, we restricted enrolment in this study to individuals using Chrome

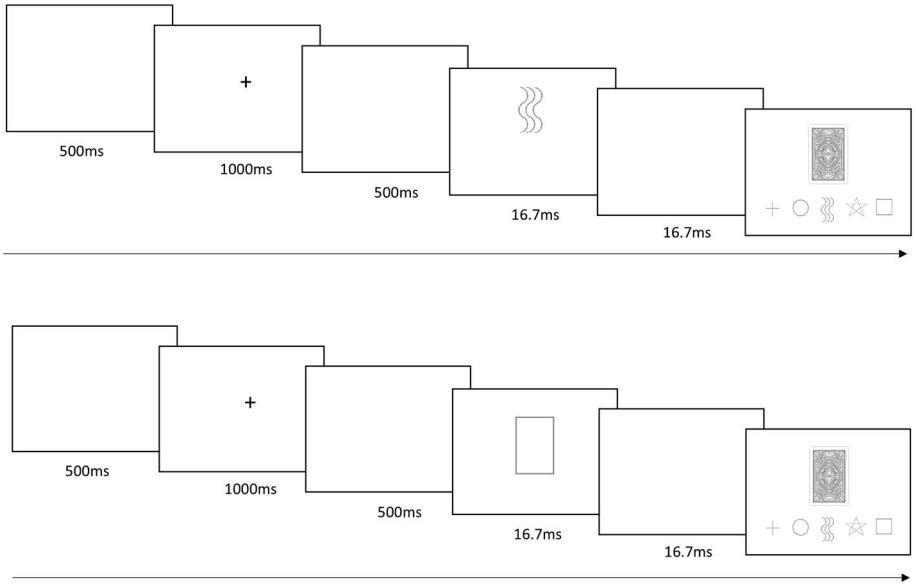

Figure 2. The sequence of screens within primed trials (top) and unprimed trials (bottom).

browser (using the recruitment restrictions in Gorilla), and we further restricted participation to individuals using Windows operating systems (using the audience filters on Prolific). We recommend researchers attempting future online studies in Gorilla with rapidly presented visual stimuli to similarly restrict participation to those using Chrome browser on a Windows operating system.

Procedure

Participants were provided a link to the experiment, which was hosted on the Gorilla platform. Upon giving informed consent, participants provided basic demographic information of age, gender, ethnicity, and socio-economic status. Before part one of the card guessing task, participants were informed that the computer would randomly select one of five Zener cards on each trial, but that only the back of the card would be displayed. Their task was simply to guess, from the five response options displayed after each trial, which card the computer had selected.

After completing part one of the card guessing task, participants were informed that on half the trials, the card back had been accompanied by a subliminal presentation of the target card in order to prime their selection. They were asked to select one of four options:

1) *I was completely unaware of rapidly presented shapes before the card back appeared.*
2) *I had a vague impression of something flashing up, but I did not recognize any shapes.*
3) *I think I noticed shapes appear on a few trials.*
4) *I clearly saw shapes on multiple trials.*

Participants who selected option #4 ('I clearly saw shapes on multiple trials') were excluded from the main analyses.

Having been informed about the presence of primes on half the trials, participants completed part two of the card guessing task, where they had to indicate the presence or absence of a prime across 40 trials.

Following these 40 trials, participants were presented with four questions included for exploratory purposes. These questions asked whether any of the target shapes stood out more than the others, the type of computer and monitor that the participant used, whether the participant had any other comments, and whether they had experienced any internet or other technical problems during the study.[1] Following these questions, participants completed the transliminality scale.

Analysis plan

The effect of greatest interest from Crawley et al. (2002) was a significant positive correlation of $r = 0.24$ between transliminality scores and correct responses on primed trials.

An indicative *a priori* power calculation using G*Power (Faul et al. 2009) revealed that to detect an effect of this magnitude with power of 0.95 and an alpha of 0.05, a sample size of $N = 219$ would be required. However, in order to obtain strong evidence in favour of either the alternate or null hypothesis for the relationship between transliminality scores and correct responses on primed trials, we pre-registered our decision to use a Bayes stopping rule with cut-offs of 6 (in favour of H_1) and 0.167 (in favour of H_0).

For readers unfamiliar with Bayesian statistics, Bayesian analyses allow researchers to compare two contrasting hypotheses with a Bayes Factor (BF), which is the ratio of likelihoods for the competing theories. Thus, a BF of 6.43 indicates that H_1 is 6.43 times more likely than H_0 given the observed data and modelled priors. H_0 is typically represented by a point prediction of 0 (i.e. no effect; Dienes 2021). H_1 can be specified based on prior findings (Dienes 2014, 2019, 2021). As an additional comment on BF notation: B_{HN} (0, x) indicates a BF with H_1 modelled as a half-normal distribution with a mean of 0 and an SD of x, where x represents the expected effect size (Dienes 2014). We also provided robustness regions (RRs; i.e. ranges on which the evidence for H_1 or H_0 will continue to be true), as they allow readers to evaluate the robustness of our conclusions against other theoretical SDs (Dienes 2019).

Our alternative prior for our main research hypothesis was modelled as a half-normal distribution centred on 0 with an SD of 0.25. A half-normal was selected as our theory makes a directional prediction, and this distribution naturally assumes

[1] Note that we did not specify exclusion based on answers to the question about technical difficulties. As Gorilla pre-loads all stimuli at the start of the study, a temporary drop in internet speed should not affect the participant experience. This question was included for exploratory purposes only.

that smaller effects are more likely than larger ones (Dienes 2021). The SD was derived by converting Crawley et al.'s observed correlation of $r = 0.24$ to Fisher's z to ensure a normal distribution: Fisher's $z = 0.5 \times \log_e [|(1+r)/(1-r)|] = 0.5 \times \log_e (1.24/0.76) = 0.25$ (see Dienes 2011). This prior distribution was used in all analyses related to the identification of primes.

Priors were similarly calculated for our other main research hypotheses. Specifically, our prior for H2 (concerning the correlation between transliminality scores and the correct identification of primes on presence trials) was a half-normal distribution centred on 0 with an SD of 0.27 (based on Crawley's result of $r = 0.26$). This prior distribution was used for all analyses related to presence of primes. Our prior for H3 (concerning the correlation between transliminality scores and stimulus sensitivity) was a half-normal distribution centred on 0 with an SD of 0.26 (based on Crawley's result of $r = 0.25$). This prior distribution was used for all analyses related to signal detection.

We also specified a secondary stopping rule of a maximum of 500 participants, as this was the maximum that our budget allowed. We followed the procedure outlined by Lakens et al. (2020) to determine whether this sample size would provide 'noteworthy' evidence. This involves calculating a BF assuming evidence in support of the null (i.e. a mean of 0) and a separate BF assuming evidence in support of the alternative (i.e. a mean of 0.25). For both these distributions we used an SE of 0.045. The value of 0.045 was approximated as follows. The SE of Fisher's z is given by the formula: $1/\sqrt{(N-3)}$, where N is the sample size. Accordingly, the SE for Crawley et al.'s reported correlation is 0.10: $1/\sqrt{(100-3)} = 0.10$. As SE varies as a function of sample size, we can calculate the appropriate SE for 500 participants as: $\sqrt{(100/500)} * 0.10 = 0.045$. These values (i.e. $M = 0$ or $M = 0.25$, and $SE = 0.045$) were then used to calculate hypothetical BFs for both scenarios. The BF assuming evidence in support of the null ($M = 0$) was 0.18. The BF assuming evidence in support of the alternate ($M = 0.25$) was $= 1.10 * 10^6$. As these values approximate or exceed our specified BF cut-offs, we should obtain sufficient evidence to support the presence/absence of meaningful effects. Analyses were conducted in R using the bayesplay package (Colling 2023).

Results

All analyses were conducted using R. Raw data and code for analyses are available *via* OSF (https://osf.io/xnkm6/). Descriptive statistics are included in Table S2.

Card selection task

Our primary interest was the relationship between transliminality scores and accuracy on the primed and non-primed trials in the card selection task. In contrast to Crawley et al. (2002), bivariate correlations revealed no relationship between transliminality scores and accuracy on primed trials, $r = -0.06$, $P = .370$, CI [−0.20, 0.08], B_{HN} (0, 0.25) = 0.157, RR [0.23, 1.00] (Fig. 3). There was insensitive evidence regarding a relationship between transliminality scores and accuracy on non-primed trials, $r = 0.05$, $P = .490$, CI [−0.09, 0.19], B_{HN} (0, 0.25) = 0.517, RR [0.00, 0.83].

Prime identification task

In part two of the experiment, participants were told primes were sometimes present before each card display and asked to identify which trials contained primes. Transliminality scores were not related to the correct identification of primed trials, $r = -0.06$, $P = .382$, CI [−0.20, 0.08], B_{HN} (0, 0.27) = 0.147, RR [0.23, 1.00] (Fig. 4). There was insensitive evidence regarding a relationship between transliminality and correct identification of non-primed trials, $r = -0.01$, $P = .876$, CI [−0.15, 0.13], B_{HN} (0, 0.27) = 0.231, RR [0.00, 0.38].

Signal detection analysis

To rule out the possibility that participants scoring higher on the transliminality scale simply adopted a more lenient response pattern (i.e. a 'yes-bias'), we conducted a signal detection analysis on responses to the presence-or-absence task and investigated whether sensitivity, as measured by *d'*, was positively correlated with transliminality scores. In contrast to Crawley et al. (2002), we found no relationship between transliminality scores and *d'* values ($M = 1.49$, $SD = 1.30$, $r = -0.09$, $P = .226$, CI [−0.23, 0.05], B_{HN} (0, 0.26) = 0.129, RR [0.19, 1.00]) (Fig. 5). This result suggests that transliminality was not related to participants' sensitivity to stimuli in this study. There was insensitive evidence regarding a relationship between transliminality scores and beta values ($M = 1.85$, $SD = 1.79$, $r = -0.02$, $P = .737$, CI [−0.16, 0.12], B_{HN} (0, 0.26) = 0.211, RR [0.00, 0.34]), and insensitive evidence regarding a relationship between transliminality scores and the response threshold for detecting a prime ($M = 0.44$, $SD = 0.80$, $r = 0.03$, $P = .721$, CI [−0.12, 0.17], B_{HN} (0, 0.26) = 0.361, RR [0.00, 0.59]).

Exploratory analyses

As an exploratory test, we investigated whether participants who were excluded from the main analyses due to reporting awareness of the primes, differed in transliminality scores compared to participants included in the main analyses. Excluded participants reported 'clearly seeing shapes on multiple trials'. These excluded participants had a mean transliminality score of 10.12 ($SD = 6.13$, $n = 83$). Included participants had a mean transliminality score of 10.80 ($SD = 7.12$, $n = 194$). A Welch two sample *t*-test indicated no difference between these scores ($t(178.74) = 0.81$, $P = .419$; $d = 0.10$, CI [−0.15, 0.35]).

Amongst included participants, 115 (59.3%) reported they were 'completely unaware of rapidly presented shapes before the card back appeared'; 38 (19.6%) reported that they 'had a vague impression of something flashing up but did not recognise any shapes'; and 41 (21.1%) reported that 'they thought they noticed shapes appear on a few trials'.

Discussion

The results of this experiment do not support a connection between transliminality and subperceptual processing. Specifically, our analyses indicated evidence of no relationship between transliminality and responses to rapidly presented primes (when participants were unaware that priming was taking place), evidence of no relationship between transliminality and detection of primes (when participants were told that primes were sometimes present), and evidence of no relationship between transliminality and stimulus sensitivity.

Crawley et al. (2002) reported that participants were unaware of primes in the card selection task, but that individuals higher in transliminality were more likely to respond correctly on primed trials. When told that primes were sometimes present, Crawley et al. reported that individuals higher in transliminality were more likely to correctly identify primed trials. We did not replicate either of these findings, and instead showed evidence that transliminality is not a measure of individual responsiveness to rapidly presented stimuli. Crawley et al. included signal detection analyses to better understand the drivers of their findings. We also reported signal detection metrics, but as there was no relationship between

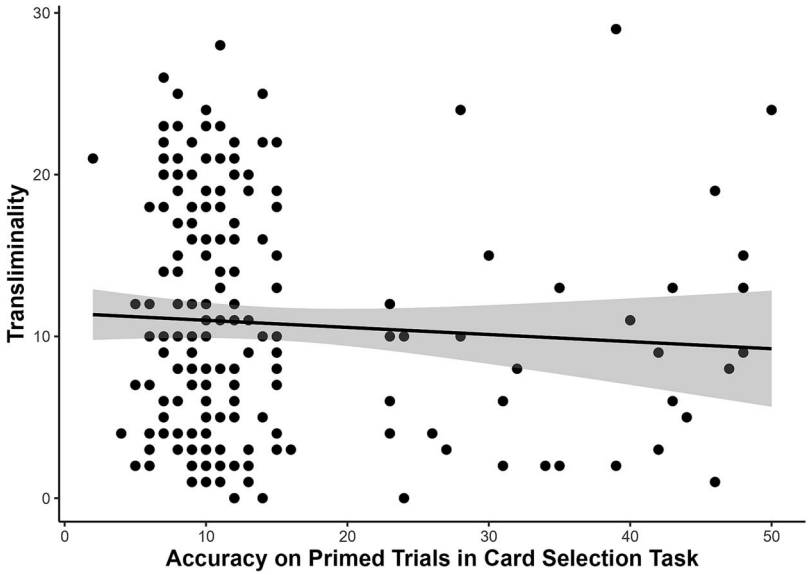

Figure 3. Transliminality scores and accuracy on primed trials in the card selection task.

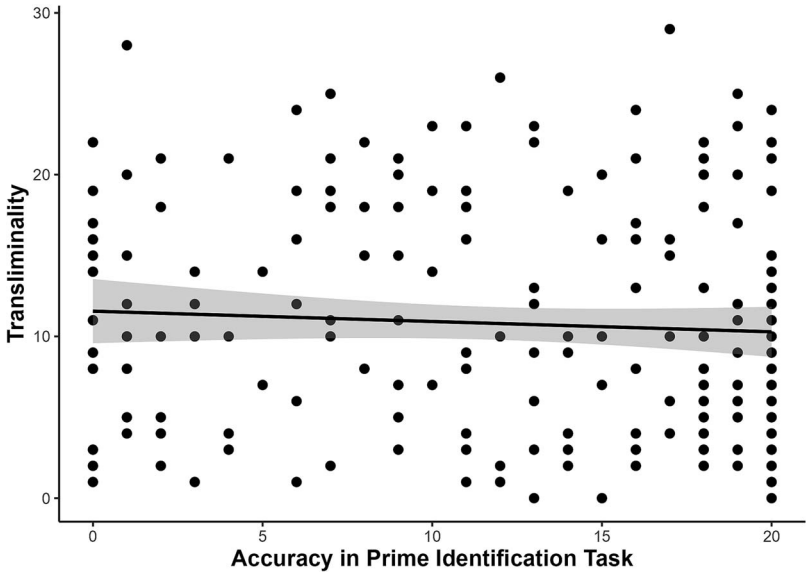

Figure 4. Transliminality scores and correct responses in the prime identification task.

transliminality and prime responsiveness or detection, it is unsurprising that there was also no relationship with signal sensitivity.

Our key concern in this article was exploring potential relationships between transliminality and performance on primed trials. However, like Crawley et al. (2002) we also reported associations between transliminality and accuracy on unprimed trials. We found insensitive evidence regarding relationships between transliminality and accuracy on unprimed trials, and between transliminality and ability to identify unprimed trials. The magnitudes of these associations were extremely small ($r = 0.05$ and $r = -0.01$) with CIs overlapping zero, and there is no known mechanism by which there could be any relationship (as unprimed trials lack the 'subliminal stimuli' that transliminality is hypothesized to influence). Accordingly, we do not view these inconclusive results as meaningful. Regarding the sensitive nature of the primed trial analyses as compared to the insensitive nature of the non-primed trials, these differences can be explained by the polarity of the data. Specifically, as we modelled our alternative hypothesis as a half-normal distribution (expecting a positive correlation in line with Crawley et al.), the negative correlations observed for the primed trials resulted in BFs below the cutoff threshold while they were insensitive for the non-primed trials.

A secondary outcome of this study was that we demonstrated the feasibility of conducting research on rapidly presented visual primes in an online setting. Although online experiment platforms do allow presentation of visual stimuli with short durations, to our knowledge this experimental approach has not been widely used in priming studies. Previous research has shown that online priming can be successfully implemented in PsychoPy (Angele et al. 2023). The current results demonstrate that online priming studies are also possible using Gorilla, although consistent with Anwyl-Irvine et al. (2021), we recommend that researchers restrict participation to users of Windows and Chrome browser (see Table S1).

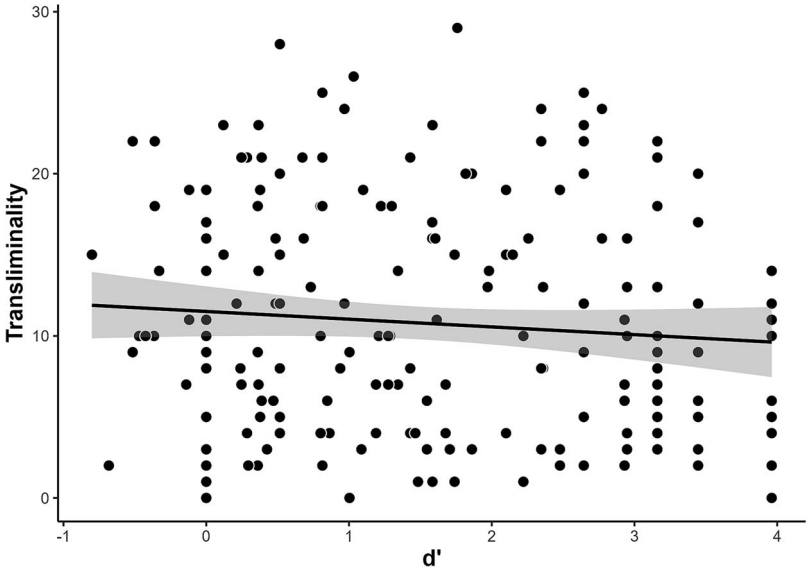

Figure 5. Transliminality scores and *d'* in the prime identification task.

Limitations

Although we aimed for a close replication of Crawley et al. (2002), there were two differences to our design that must be acknowledged. First, Crawley et al. conducted their experiment as a lab-based study with participants completing the task in a controlled university environment, whereas participants in the current study completed the task in an uncontrolled online context. In preparing this study, we carefully assessed whether an online presentation would allow for successful presentation of the online priming tasks and determined that there were no technical barriers to implementing this experiment. Despite this, it may be that participants did not attend to the online task in comparable ways to participants in the original lab-based study. However, we note that one study has shown very similar performance for online compared to in-person priming responses (Angele et al. 2023), and in general participants do tend to perform similarly in online versus offline cognitive tasks (Uittenhove et al. 2023).

Second, as a consequence of our online presentation, we used a different prime duration (16.7 ms in the current study compared to 14.3 ms in Crawley et al. 2002). This difference may have impacted results. Indeed, in our study 83 out of an initially recruited 277 participants were excluded as they reported clearly seeing the primes in part one of the study (30.0%). By contrast, only 2 out of 102 participants reported clearly seeing the primes in Crawley et al. (2002; 1.9%). This is a considerable difference, however, in both studies analyses were only conducted on those participants who reported no awareness of primes in part one. There is evidence of variation in individual sensitivity to rapidly presented visual stimuli across the population (Pessoa et al. 2005, Sklar et al. 2021), so restricting our sample in this way should allow a consistent test of the impact of transliminality. A strong proponent of the idea that transliminality measures perceptual sensitivity may be sceptical on this point, however they would then need to explain why transliminality would be related to processing of primes displayed for 14.3 ms but clearly not related to processing of primes displayed for 16.7 ms.

Conclusion

Although transliminality was originally conceptualized as sensitivity to 'inwardly generated psychological phenomena' (Thalbourne and Delin 1994, p. 25), later investigations of this construct began to suggest that individuals high in transliminality may also be sensitive to subtle external stimuli (e.g. Thalbourne and Houran 2000, Evans et al. 2018). Crawley et al. (2002) aimed to empirically test this idea and reported evidence supporting a link between transliminality and subliminal perception. The current findings strongly refute this claim. Based on these results we suggest that the original framing of the transliminality construct, which emphasized the internal generation of ideational content, is more coherent than later framings that focus on perceptual thresholds. A large portion of the transliminality literature consists of theoretical and survey-based research that leans on the assumption that transliminality is related to perceptual processing. As outlined above, there has been very limited empirical investigation of this connection. In light of this failed replication, we urge caution in the way that transliminality is conceptualized in future research.

Acknowledgements

We thank James Donohoe for assistance benchmarking our online task.

Author contributions

Vince Polito (Conceptualization [lead], Data curation, Formal analysis [equal], Funding acquisition [lead], Investigation, Methodology [equal], Project administration, Writing—original draft [lead], Writing—review & editing [equal]), Stephanie Howarth (Conceptualization, Investigation, Methodology [equal], Project administration, Writing—original draft, Writing—review & editing [equal]), Andrew Roberts (Conceptualization, Data curation [equal], Formal analysis [lead], Investigation, Methodology, Project administration, Writing—original draft, Writing—review & editing [equal]), Spencer Arbige (Formal analysis [equal], Validation, Writing—review & editing [supporting])

Supplementary data

Supplementary data is available at *Neuroscience of Consciousness* online.

Conflict of interest

We have no conflicts of interest to disclose.

Funding

None declared.

Data availability

Raw data and code for analyses are available via OSF (https://osf.io/xnkm6/).

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Neuroscience of Consciousness, 2025, **2025(1)**, **2025**, niaf044
https://doi.org/10.1093/nc/niaf044
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