



Self-specific priming effect

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ABSTRACT

Priority of the “self” is thought to be evolutionarily advantageous. However, evidence for this priority has been sparse. In this study, subjects performed a gender categorization task on self- and non-self target faces preceded by either congruent (same gender as target) or incongruent (different gender) perliminal (33 ms) or subliminal (17 ms) primes. We found that subliminal primes induced a priming effect only on self target faces. This discovery of a self-specific priming effect suggests that functional specificity for faces may include timing as well as spatial adaptations.

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1. Introduction

The ability to distinguish between “self” and “other” is one of the most fundamental and evolutionarily advantageous functions of cognition in both humans and animals. Among the visual cues available for a self/other judgment, the face is arguably one of the strongest identity indicators. The ability to recognise one’s own face is evolutionarily a recent acquisition. Studies have shown that, while humans are normally able to recognise themselves in a mirror by age 18–24 months (Amsterdam, 1972; Lewis, Sullivan, Stanger, & Weiss, 1989), most other animals, with the exception of chimpanzees (Gallup, 1970) and orang-utans (Suarez & Gallup, 1981), lack this ability (although see Plotnik, de Waal, & Reiss, 2006; Reiss & Marino, 2001).

1.1. Self face recognition and self-consciousness

Some authors have argued that self face recognition implies self-consciousness (Gallup, 1977) and Theory of Mind (ToM) (Gallup, 1982; Keenan, Gallup, & Falk, 2003). Evidence in this direction comes from the observation that, in humans, the mirror self-recognition timeline correlates with that of the usage of the pronoun “I”, the emergence of autoethic awareness and deceptive ability, as well as the experience of emotions requiring self-monitoring from a third person perspective, such as pride, hubris, shame, guilt (Howe & Courage, 1993; Lewis et al., 1989). However, the idea that self-awareness can be inferred from mirror self-recognition is still controversial, and has been challenged both on theoretical (DeGrazia, 1996; Schilhab, 2004) and methodological (Heyes, 1998; Kennedy, 1992; Mitchell, 1993; Morin, 2002) grounds. Specifically, it has been argued that mirror self-recognition involves matching motor cues to mirror feedback, and does not require, *per se*, a global sense of self (Mitchell, 1993; Morin, 2002). This argument has recently been challenged by Platek, Thomson, and Gallup (2004), who reported self-specific cross-modal priming. In their study (Platek et al., 2004), the authors found that being exposed to one’s own body odour, and seeing or hearing one’s own name facilitated the recognition of one’s own face, whereas no cross-modal facilitation was found for the recognition of other familiar or unfamiliar faces after exposure to their

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respective odour, spoken name or written name. The authors interpreted this finding as evidence that cross-modal facilitation of face recognition is exclusive to the self face, indicating that the sense of self is a multi-modal phenomenon. Although Platek, Thomson, and Gallup's interpretation is consistent with their own results (showing no cross-modal priming for non-self individuals), it contrasts with previously reported evidence of cross-modal priming for non-self faces (Calder & Young, 1996). An alternative account, proposed by Brédart (2004), reconciles these seemingly discrepant findings by introducing the notion of cross-modal priming as a graded phenomenon, whose existence is not exclusive to self face recognition, but whose magnitude is greater for self face recognition (compared to other faces'). In Brédart's view, Platek's et al. (2004) failure to detect cross-modal facilitation for non-self faces, in conditions that yielded cross-modal facilitation for self faces, reflects this difference in priming strength, rather than self-specificity. Critically, both Platek's et al. (2004) qualitative interpretation (cross-modal priming only occurs for self faces), and Brédart's quantitative account (cross-modal priming occurs for both self and non-self faces, but is greater for self faces) point to a processing advantage for cross-modal information related to the self face, suggesting the existence of an integrated, underlying, multi-modal self-processing system of which self-recognition would appear to be a byproduct/expression.

1.2. Self face processing advantage

Converging evidence points to the fact that the self face is an especially salient stimulus. As Brédart, Delchambre, and Laureys (2006) pointed out, the self face possesses two especially attention grabbing properties: being a face (Lavie, Ro, & Russell, 2003), and being self-referential (Gray, Ambady, Lowenthal, & Deldin, 2004). This combination of attributes may explain why self faces, compared to other faces, are identified faster (Tong & Nakayama, 1999), are primed by other self-related cues (Platek et al., 2004), and interfere more with ongoing tasks (Brédart et al., 2006). The findings by Platek et al. (2004), and Brédart et al. (2006) raise the possibility that self faces, in virtue of their unique saliency, benefit from prioritised processing.

In this study we tested this self face advantage hypothesis by exploiting the phenomenon of unconscious (masked) priming. In masked priming, a stimulus (such as a face) flashed for a few tens of milliseconds becomes unreportable (masked) when presented in close spatial and temporal proximity with other stimuli (mask) (Dehaene et al., 2001). Although the mask can abolish the subjective perception of the stimulus, autonomic and motor responses to aspects of the stimulus may still be elicited (Esteves & Öhman, 1993) and can be inferred by their consequences on observable behavioral measures, such as reaction times in task performance. In our study, subjects performed a gender categorization task on self- and non-self targets, which, unbeknownst to them, were preceded by congruent (same gender as target) or incongruent (different gender) primes (Fig. 1a and b). Previous studies have shown that the earlier the target appears on the screen (relative to the prime), the stronger the impact of the prime on task performance (priming effect) (Eimer & Schlaghecken, 2003), suggesting that targets that start being processed early after the prime are more exposed to the prime's lingering effect than targets that start being processed later on. Based on this notion, we predicted that if the self face initiates processing earlier compared to non-self faces (despite physically appearing on the screen at the same relative point in time), then it will be more affected than non-self faces by the immediately preceding prime.

2. Methods

2.1. Subjects

Twelve healthy volunteers participated in the study (7 males, mean age 30, age range 20–49) according to IRB approved procedures. Each volunteer brought one close friend or domestic partner, one friend of medium familiarity, and one acquaintance, who were photographed by the experimenter.

2.2. Stimuli

Prior to the experiment, photographs were taken of each participant and each of their three friends, in order to create stimuli for the "self" and for three (high-, middle-, and low-) familiar conditions. Photographs of celebrities drawn from the internet served as stimuli for the "famous" condition. Anonymous photographs drawn from publicly available face databases served as stimuli for the "unknown" condition. All images were cropped into a 500 by 500 pixel square and converted into black and white format using Adobe Photoshop (San Jose, CA). Self face photographs were mirror-reversed. Two hundred and eight photographs were selected for each condition, totalling 1248 photographs (208 × 6 conditions, 50% males) for each subject's session. Each photograph was only shown once. In the "self" and in each of the "familiar" conditions, the same individuals were shown in 208 different poses. In both "famous" and "unknown" conditions 208 different individuals were portrayed. Upon completion of the experiment subjects were asked to identify each of the 208 celebrities. Unrecognised celebrities were subsequently treated as "unknown" in the data analysis.

2.3. Experimental design and task

Self-, familiar-, famous-, and unknown target faces were presented either in isolation (unprimed), or preceded by either perliminal (33 ms) or subliminal (17 ms) primes. Subjects were instructed to identify the gender of the target face

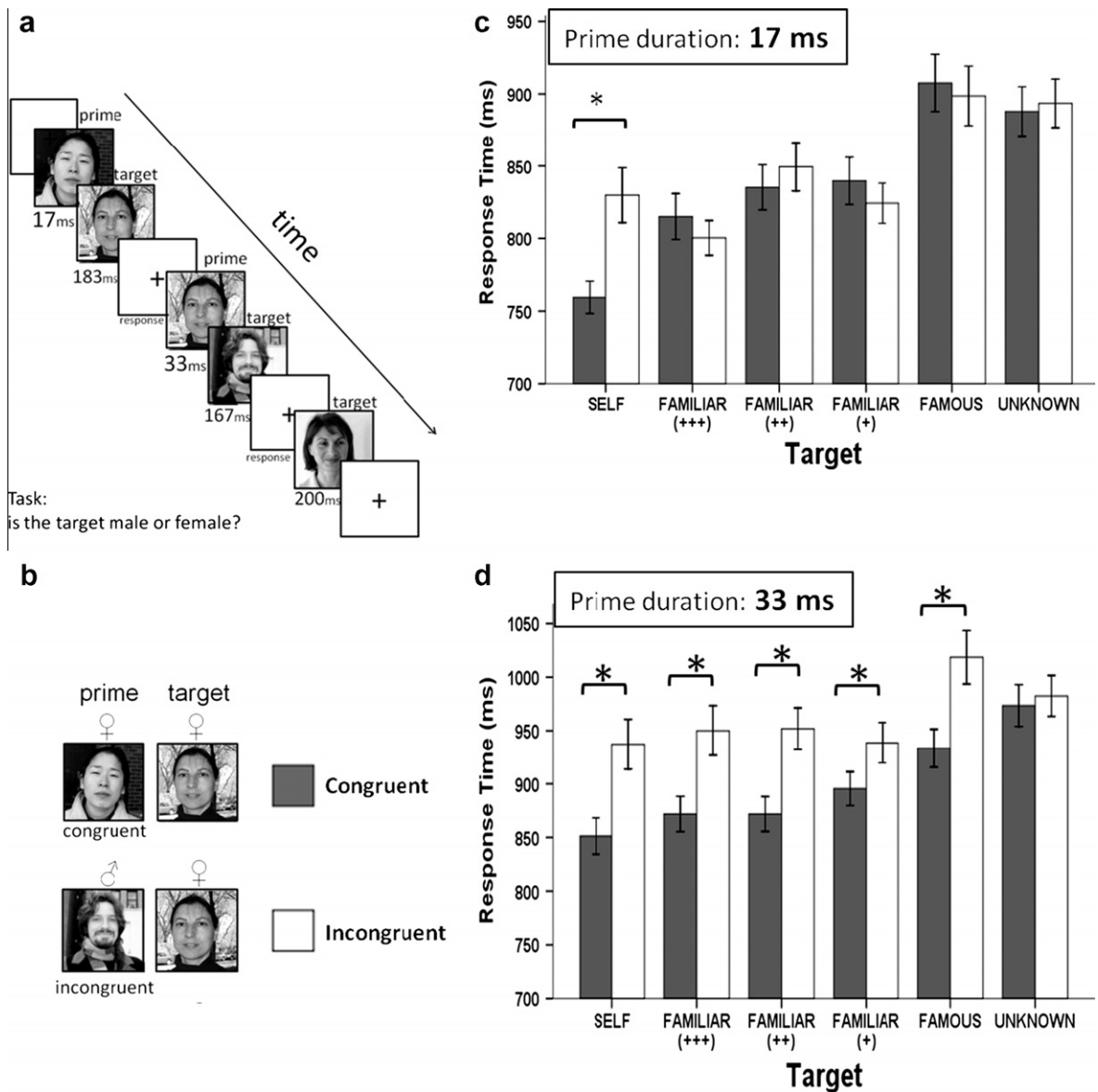


Fig. 1. (a) Experimental design. Each trial consisted in a 200 ms stimulus presentation followed by a variable delay (2.6 – 6.6 s) during which subjects responded to the gender of the target face. (b) Target faces could be preceded by either congruent (same gender) or incongruent (different gender) primes. (c) Mean reaction time for trials in which primes were subliminal (17 ms). Incongruent subliminal primes interfere with the task exclusively when followed by target self face (self-specific priming effect) ($p = .0005$, paired t -test, one-tailed). (d) Periliminal primes (33 ms) interfere with the task also when followed by non-self targets. $N = 12$, error bars represent standard error of the mean.

as “male” or “female” by pressing one of two buttons on a response pad. The existence of primes was not mentioned to the subjects until after the study was completed. Each trial consisted of a 200 ms stimulus presentation (200 ms for the unprimed; 17 + 183 ms, and 33 + 167 ms respectively for the subliminal and periliminal primed conditions), followed by a blank screen with a central crosshair, at jittered intervals spanning from 2.2–6.6 s (Fig. 1a). Four 15-min runs were carried out, in which a total of 1248 photographs were shown in 672 trials. Photographs were presented in a pseudo randomised order, counterbalanced for gender (50% males) and identity. Relative to the target face, primes could be either congruent (same gender) or incongruent (different gender) (Fig. 1b). The spatio-temporal arrangement of the stimuli was symmetrical: each and every face type (i.e.: self, familiar, famous, unknown) appeared an equal number of times in combination with each and every other face type, both as target and as prime. The experimental paradigm was developed using Matlab (Mathworks). All visual stimuli were administered to the subjects through LCD goggles while subjects were lying in a 1.5 T MRI scanner.

2.4. Discriminability test

After the experiment was completed, the existence of primes was revealed, and their visibility to the subjects was individually assessed through a forced-choice test. A subset of non-self (familiar-, famous-, and unknown) target faces from the main experiment was presented in combination with subliminal (17 ms) or perliminal (33 ms) self- or non-self primes. The self face never appeared as target, whereas its rate of occurrence as prime was 50%. Subjects were instructed to press a key whenever they saw their own face (self). Each subject's performance was measured in terms of discriminability score (d'), representing the standardized difference between the means of the Signal Present (self) and Signal Absent (non-self) distributions. This score was calculated according to the formula: $d' = z(H) - z(FA)$, where $z(H)$ and $z(FA)$ represent the transformation of the hit and false alarm rates to z-scores. A discriminability score of "0" corresponds to 50% accuracy. In our study we found that discriminability score for 33 ms primes was significantly higher than 0 ($t_{(11)} = 4.07, p = .002$), indicating that 33 ms primes were visible, whereas discriminability scores for 17 ms primes was not significantly higher than 0 ($t_{(11)} = 2.2, p = .05$). More specifically, individual discriminability scores for 17 ms primes were below 0.77 (corresponding to approximately chance level accuracy) for 11 out of 12 subjects.

2.5. Data analysis

Response times and accuracy data were analysed with Microsoft Office Excel and the Statistical Package for the Social Sciences (SPSS 15) softwares. Responses were sorted based on the identity of the target face and on the congruency of the preceding prime relative to the target face. Mean response times were calculated for each subjects and each target face. Paired Student's t -tests were performed in order to find differences between congruent and incongruent trials.

3. Results

Consistent with our predictions, we found that, while primes displayed for 33 ms (periliminal) affected task performance across all (except the "unknown") targets ($t_{(11)} =$ between -1.96 and $-2.85, p < .038$ for all, one-tailed) (Fig. 1d), primes displayed for 17 ms (unreportable for 11 out of our 12 subjects) affected task performance exclusively in trials whose target was the self face ($t_{(11)} = -4.78, p = .0005$, one-tailed) (Fig. 1c). This effect remained significant also after we excluded from the analysis data from the only subject (ET) whose discriminability score for 17 ms exceeded our threshold for subliminality ($t_{(10)} = -4.53, p = .0005$, one-tailed). No priming effect was found in any of the non-self trials ($t_{(11)} =$ between -0.34 and $-0.9, p > .19$ for all, one-tailed). Furthermore, for all types of targets we compared congruent- and incongruent-primed trials with unprimed controls, where the target face was presented in isolation (without any preceding prime). No significant differences were found between the mean reaction times to the unprimed (control) self face and any of the other faces ($t_{(11)} =$ between -2.175 and $0.026, p > .05$ for all), ruling out an intrinsic pre-existing self-other difference in baseline, and suggesting that the interference illustrated in Fig. 1c is due to the conflict generated by the preceding incongruent prime. Additionally, while for all non-self faces, response times to both congruent- and incongruent-primed trials did not differ from the response times to the corresponding unprimed (control) condition ($t_{(11)} =$ between 0.35 and $1.87, p > .88$ for all), reaction times to incongruent trials whose target was the self face were significantly longer than those to the unprimed self condition ($t_{(11)} = 2.69, p = .021$). This allows qualifying the interference effect we found as a self-specific negative priming.

4. Discussion

Priming effect is thought to reflect an early initiation of response selection (Schlaghecken, Bowman, & Eimer, 2006). According to the reentrant theory of perception (Enns & Oriet, 2007), the prime activates its associated response, and if the following target maps to the same response, the evidence required for responding accumulates faster than if the following target maps to a different response (in which case the accumulation of evidence for the correct response must start over). Our data suggest that when primes were shown for 17 ms (subliminally) this differential accumulation of evidence occurred exclusively in self face trials. This is consistent with the existence of different temporal dynamics between the processing of self and non-self faces. At short SOAs, target response selection can overlap (in time) with the prime-related response activation phase, leading to longer reaction times for incongruent trials. Our results suggest that, for subliminal (17 ms) trials, this temporal overlap only occurred when the target was the self face, consistent with our hypothesis that self face benefits from an early processing. Importantly, our SOA was kept constant (all targets physically appeared on the screen at the same point in time relative to the preceding prime). Consequently, the presence of priming effects on self targets (and not on any of the non-self ones) cannot be explained in terms of differences in target "availability" for processing, but must reflect differences in the target actual processing.

4.1. Self-specific priming: three possible mechanisms

Our results raise the question of whether the self-specific priming effect is accompanied by an enhanced processing of the immediately preceding subliminal primes. Three mechanisms could explain this phenomenon whereby the target self face is

a “weaker” mask (allows more prime processing) than non-self faces. One possibility is that primes undergo more processing by virtue of their being beneficiaries of globally increased perceptual resources in the presence of a visible self face. This interpretation draws from, and expands, the idea that self face recognition is connected to self consciousness. Based on its unique self-referential attributes, it is conceivable that the self face may induce a burst of awareness, which spills over to neighboring stimuli (such as the primes) amplifying their signal. Target-dependent signal amplification of unconscious primes has been described in the context of the *global neuronal workspace* (GNW) theory (Dehaene & Naccache, 2001), whereby conscious stimuli would induce a reorganization of the GNW, which, in turn, can affect the processing of unconscious information. According to this model, the (otherwise unprocessed) primes would become more visible in the presence of the self face, as a result of their being indirect beneficiaries of extra processing resources. Note that the notion of increased prime visibility occurring exclusively in presence of the target self face does not contradict the chance level score obtained for 17 ms images in the discriminability test (see Methods), as in the discriminability test the self face was never a target. If this interpretation is correct, it would be interesting to test whether the self-related boost in visual awareness also happens in the opposite direction, for example in forwardly masked primes.

A second possibility is that primes benefit from a prolonged processing when immediately followed by a self face. This would be possible if we assume that the neuronal populations preferentially activated by the self face and by non-self faces are distinct. As shown by electrophysiological data (Rolls & Tovee, 1994), face responsive neurons exhibit a prolonged firing after the offset of a masked stimulus (prime). This firing is thought to reflect a storage mechanism ensuring that information is kept available for subsequent processing (as long as its activity exceeds a given threshold). When a second stimulus (target) is presented immediately after the prime's offset, this (prime-related) firing is interrupted and replaced with a newer and more sustained (target related) one. However, the replacement of prime-related firing by target related activity is possible only in those neuronal populations responsive to both stimuli (prime and target), and not in those only responsive to the prime (which would prolong their firing irrespective of the target). If the neuronal populations preferentially activated by the target self face are distinct from those activated by non-self primes, the interruption/replacement of activity does not occur, and prime-related information is still available for some degree of processing. Imaging studies may contribute in identifying and characterizing neuronal activity in these selectively responsive regions.

A further possible explanation is that primes undergo more processing because the following self face requires fewer resources than any other face. According to this view, the self face would act as a low saliency stimulus, which would allow more attentional resources to be directed towards the processing of primes. This explanation is consistent with the perceptual load model (Lavie, 1995; Lavie et al., 2003), which predicts that increased perceptual load of the task stimulus (target) results in decreased detection of irrelevant stimuli (primes), because of fewer available processing resources. It should be noted, however, that task-irrelevant stimuli semantically related to the target have been shown to enter visual awareness independently of perceptual load, suggesting that attentional selection may be driven by purely semantic features (Koivisto & Revonsuo, 2007, 2009). It is therefore conceivable that, rather than being determined solely by the perceptual load of the target, our self-specific priming effect also involve some degree of semantic processing of the prime, especially given the fact that in our study all photographs were different throughout the experiment, and low processing demand for self or familiar faces cannot be explained merely in terms of habituation to perceptual attributes (e.g.: a given physical stimulus).

4.2. Self-specific priming and self-recognition's evolutionary advantage

The discovery of a self-specific unconscious priming effect extends previous knowledge about self face priority to the domain of unconscious processing. Specifically, it shows that self face priority is both task-irrelevant (unlike in Tong and Nakayama's study, our subjects identified faces' gender, not identity), and capable of inducing behaviorally observable consequences in absence of conscious perception (unlike Platek et al., we used unreportable primes). This automaticity fits well with the notion that self-face recognition is evolutionarily advantageous (Keenan, Rubio, Racioppi, Johnson, & Barnacz, 2005), as it enables casting oneself into the past and future, judging beforehand possible outcomes of different actions (so called 'cognitive goldilocks' by Keenan et al. (2003)). Moreover, it has been proposed that self-recognition involves the ability to model the mental state of others (Keenan et al., 2003), which allows both deceiving and detecting (and avoiding) deception, thereby increasing chances of survival.

An interesting line of research would be to compare self-related prioritized processing across different species. Broadly speaking, the current debate about self-consciousness in non-human animals revolves around two main theories: the “discontinuity”, and the “continuity” (Velmans, 2007). Discontinuity theories claim that self-consciousness appeared suddenly at certain stage of evolution, for example after acquisition of language, development of theory of mind, or reaching a critical brain size or complexity. Along this line of thought, the presence of self-recognition in non-human primates (Gallup, 1970; Suarez & Gallup, 1981), and not in other animals, suggests the existence of a cognitive gap dividing great apes and humans from the rest of the animal kingdom (Gallup, 1970). On the other hand, the observation that language is not needed to pass the mirror test may suggest that self-consciousness is a graded phenomenon, whereby the gradations are correlated with the phylogenetic (more evolved species have higher consciousness) and ontogenetic (adults are more conscious than newborn) differentiation of the cerebral cortex (Singer, 2001). Detecting self-specific unconscious priming effects in non-human animals exhibiting – versus those not exhibiting – self-recognition based on the mirror test (Gallup, 1970) would contribute biological evidence to the debate about evolutionary discontinuity/continuity. Specifically, finding self-specific

priming effects in animals which do not pass the mirror test would provide evidence for some degree of self-recognition in (previously thought) “non-self-recognising animals”, thereby supporting the “continuity” view.

4.3. Impaired self-recognition and frontal lobe damage

Our results prompt further investigation in the localization of self-recognition and self-consciousness. The fact that species exhibiting self-recognition have highly developed frontal lobes (Semendeferi, Damasio, & Frank, 1997) suggests that frontal lobes may be a required substrate for the capacity to engage in self-processing. The temporal overlap between the acquisition of self-recognition, and the rapid frontal lobe development in children, both occurring between the ages of one and three (Amsterdam, 1972; Lewis et al., 1989), as well as the evolutionarily recent development of frontal/prefrontal cortex (PFC) (Rakic, 1995; Semendeferi et al., 1997) have led to the development of frontal lobe localization models of self-awareness and theory of mind (Keenan et al., 2003). These frontal lobe models are further supported by clinical reports of altered self-recognition occurring after brain injury involving frontal lobe damage (Weinberger, 1993), as well as in autism (Spiker & Ricks, 1984) and schizophrenia (Blakemore, Smith, Steel, Johnstone, & Frith, 2000; Harrington, Oepen, & Manfred, 1989; Kircher, Seifert, Plewnia, Baar, & Schwabe, 2007), conditions associated with frontal lobe deficits (Callicot et al., 2000; Mattay, Bachevalier, Frank, Egan, & Weinberger, 1999; Zilbovicius et al., 1995). Interestingly, in both schizophrenic patients (Corcoran, Mercer, & Frith, 1995; Frith & Corcoran, 1996) and autistic children (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997), damaged self-recognition has been found to occur in conjunction with deficit in ToM tasks, implying an overall disturbance of self-concept. These reports seem to suggest that self-processing and mental state attribution are subserved by shared behavioral and neurocognitive networks (Platek et al., 2004).

Although data from brain disease support the idea that self-recognition involves frontal lobe activity, it is becoming increasingly clear that self-processing is a highly integrated cognitive function involving multiple substrates besides the frontal lobes Platek, Wathne, Tierney, and Thomson (2008) for a meta-analysis, and integrating bilateral circuits (Kircher et al., 2001; Platek et al., 2006; Sugiura et al., 2000; Uddin, Rayman, & Zaidel, 2005). Our results provide new evidence for self face processing temporal specificity. Further work may be able to characterize the spatial networks involved in self-specific priming.

5. Conclusions

In summary, our data document a self face specific priming effect consistent with self face early processing onset, and consequent exposure to the prime's lingering effect. To our knowledge, these results provide the first psychophysical evidence supporting the notion that the self face benefits from privileged access to processing. Future work may be able to clarify whether or not the observed priming effect is accompanied by increased prime visibility.

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