Consciousness and Cognition 41 (2016) 139–149

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Preferential processing of self-relevant stimuli occurs mainly at the perceptual and conscious stages of information processing

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ARTICLE INFO

Article history:
Received 24 September 2015
Revised 22 February 2016
Accepted 23 February 2016

Keywords:
Self-concept
Self-related stimuli
Consciousness
Awareness
Priming
Masking

ABSTRACT

Self-related stimuli, such as one's own name or face, are processed faster and more accurately than other types of stimuli. However, what remains unknown is at which stage of the information processing hierarchy this preferential processing occurs. Our first aim was to determine whether preferential self-processing involves mainly perceptual stages or also post-perceptual stages. We found that self-related priming was stronger than other-related priming only because of perceptual prime-target congruency. Our second aim was to dissociate the role of conscious and unconscious factors in preferential self-processing. To this end, we compared the "self" and "other" conditions in trials where primes were masked or unmasked. In two separate experiments, we found that self-related priming was stronger than other-related priming but only in the unmasked trials. Together, our results suggest that preferential access to the self-concept occurs mainly at the perceptual and conscious stages of the stimulus processing hierarchy.

1. Introduction

The sound of our name usually signals some potentially important events, for example, that someone wants to warn us, praise us, or to start a conversation with us. Thus, it is likely that through mechanisms of associative learning people start to react to their name preferentially. That is, they react more quickly and accurately to their own name than to other people's names. Crucially, because one's own name is heard countless times in everyday life, and because automaticity develops as a function of repetition, this stimulus becomes processed in an unintentional, involuntary, and cognitively effortless manner. Indeed, many studies support that the processing of self-relevant stimuli is preferential and largely automatic (Arnell, Shapiro, & Sorensen, 1999; Bargh, 1982; Brédart, Delchambre, & Laureys, 2006; Gray, Ambady, Lowenthal, & Deldin, 2004; Moray, 1959; Shapiro, Caldwell, & Sorensen, 1997; Wolford & Morrison, 1980; but see Breska, Israel, Maoz, Cohen, & Ben-Shakhar, 2011; Devue, Van der Stigchel, Brédart, & Theeuwes, 2009; Gronau, Cohen, & Ben-Shakhar, 2003; Kawahara & Yamada, 2004). Over the years, this automaticity of self-processing has been used as an argument that self-related factors are influencing information processing at a very early level of the cognitive hierarchy and therefore shape perceptions of the world and other people in a very profound way. Such early self-biases have important implications for basic mechanisms of cognitive functioning, as well as for theories of implicit social cognition (e.g., Greenwald et al., 2002). However, to the best of our knowledge, no existing studies have tracked the processing of self-relevant information

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http://dx.doi.org/10.1016/j.concog.2016.02.013
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all the way from the unconscious and perceptual levels to the conscious and conceptual levels. As a result, the stage of the cognitive hierarchy at which the self-prioritization actually occurs remains unknown.

The mental self-representation likely consists of stimulus-specific perceptual components, as well as more abstract modality-independent components (e.g., Morin, 2006; Newen & Vogeley, 2003). Self-preferential processing at the perceptual level is a well-established phenomenon (Pannese & Hirsch, 2010; Tong & Nakayama, 1999), which also likely takes place in some animals, e.g., dogs preferentially react to their own name. What is unclear, however, is whether preferential access to self also occurs at the conceptual level. It has been shown that being exposed to one's own odor and hearing or seeing one's own name facilitates the subsequent recognition of one's own face. In contrast, these cross-modal priming effects were absent for familiar and unknown faces (Platek, Thomson, & Gallup, 2004). This result suggests that preferential conceptual processing is specific to self; however, other studies have shown that conceptual priming facilitates the recognition of any familiar person, which undermines the specificity of preferential conceptual self-access (e.g., Boehm & Sommer, 2012; Brédart, 2004). As a consequence, the precise role of post-perceptual factors in self-preferential processing is unknown.

Another issue that remains unknown is how conscious and unconscious factors contribute to the "self-prioritization effect." The majority of previous studies used only supraliminal presentations of stimuli. As a result, these studies could not dissociate between aware and unaware aspects of self-preferential processing (e.g., Arnell et al., 1999; Brédart et al., 2006; Tacikowski, Cygan, & Nowicka, 2014; Turk, Cunningham, & Macrae, 2008). Several studies used subliminal presentations of stimuli and showed that the self-preferential processing occurs even if conscious access is largely reduced or eliminated (Alexopoulos, Muller, Ric, & Marendaz, 2012; Pannese & Hirsch, 2010; Pfister, Pohl, Kiesel, & Kunde, 2012; Wentura, Kulfanek, & Greve, 2005). However, the above studies did not compare aware and unaware self-effects directly; thus, it is unclear whether (i) self-prioritization occurs mainly at the unconscious level, without additional self-prioritization at the conscious level, or (ii) whether self-preference occurs independently at both levels of information processing.

The present study had two aims: (i) to determine whether preferential access to self-representation occurs only at the perceptual level or also at the semantic stages of information processing; and (ii) to determine how conscious and unconscious factors contribute to preferential self-processing. We used a $2 \times 2 \times 2$ factorial design, with "person" (self vs. other), "type of priming" (perceptual vs. semantic), and "masking" (masked vs. unmasked) as the factors. The experimental task required participants to decide whether stimuli (e.g., names, surnames, dates of birth, or nationality codes) shown on a computer screen at the end of each trial (targets) were related to themselves or to another person (Fig. 1A and B). Before each target, a prime was briefly presented that was either congruent (i.e., self–self or other–other) or incongruent (i.e., self–other or other–self) with the following target. The prime-target congruency was based either on perceptual features (e.g., own-name–own-name) or on semantic features (e.g., own-name–own-surname). Conscious processing of primes was manipulated using a visual masking method. In half of the trials, the primes were immediately preceded and followed by visual masks ("XYXYX" strings), making the aware processing of these primes difficult. In the other half of the trials, no mask was used, making the aware processing of these primes easy compared with the masked primes. All other aspects of the stimuli presentation (e.g., location, duration, task-demands, etc.) were identical between the masked and unmasked trials, as well as between perceptual and semantic trials. Our dependent variable was the degree of different types of priming, which was calculated as the difference between RTs from respective incongruent and congruent trials.

We hypothesized that if preferential access to the self-representation occurs at the conceptual level, then we should find a significantly stronger semantic priming in the "self" than in the "other" condition. Furthermore, we reasoned that if self-preference occurs both at the unconscious and conscious levels, then we should find a significant interaction between "person" and "masking" factors, where self-specific priming ("self" > "other") is present in the masked trials but is even stronger in the unmasked trials. In contrast, finding the main effect of "person" ("self" > "other") without an interaction effect would suggest that preferential processing of self-relevant information occurs mainly at the unconscious level and that this effect is only "carried over" to the conscious level.

2. Experiment I

2.1. Materials and methods

2.1.1. Participants

Twenty-four naïve, right-handed subjects (mean age: 27 ± 5, nine females) participated in this study. All participants were healthy, reported no history of psychiatric illness or neurologic disorder, and had normal or corrected-to-normal vision. All participants gave their written informed consent before the start of the experiment. The Regional Ethical Review Board of Stockholm approved the study.

2.1.2. Stimuli and procedure

As experimental stimuli, we used first names, surnames, dates of birth, and nationality codes that referred either to a participant (self-related) or to an unknown person (other-related). Before the study each participant was asked whether he or she knows anyone with the same name and surname as the "other" in their stimulus set; none of the participants did. Nationality was indicated by a three-letter code (e.g., "FRA" for France) according to the ISO 3166 norm. Dates were given in the "YYYY/ MM/DD" format. All words were written in white capital letters (Arial font; size ranging from 3×1 to

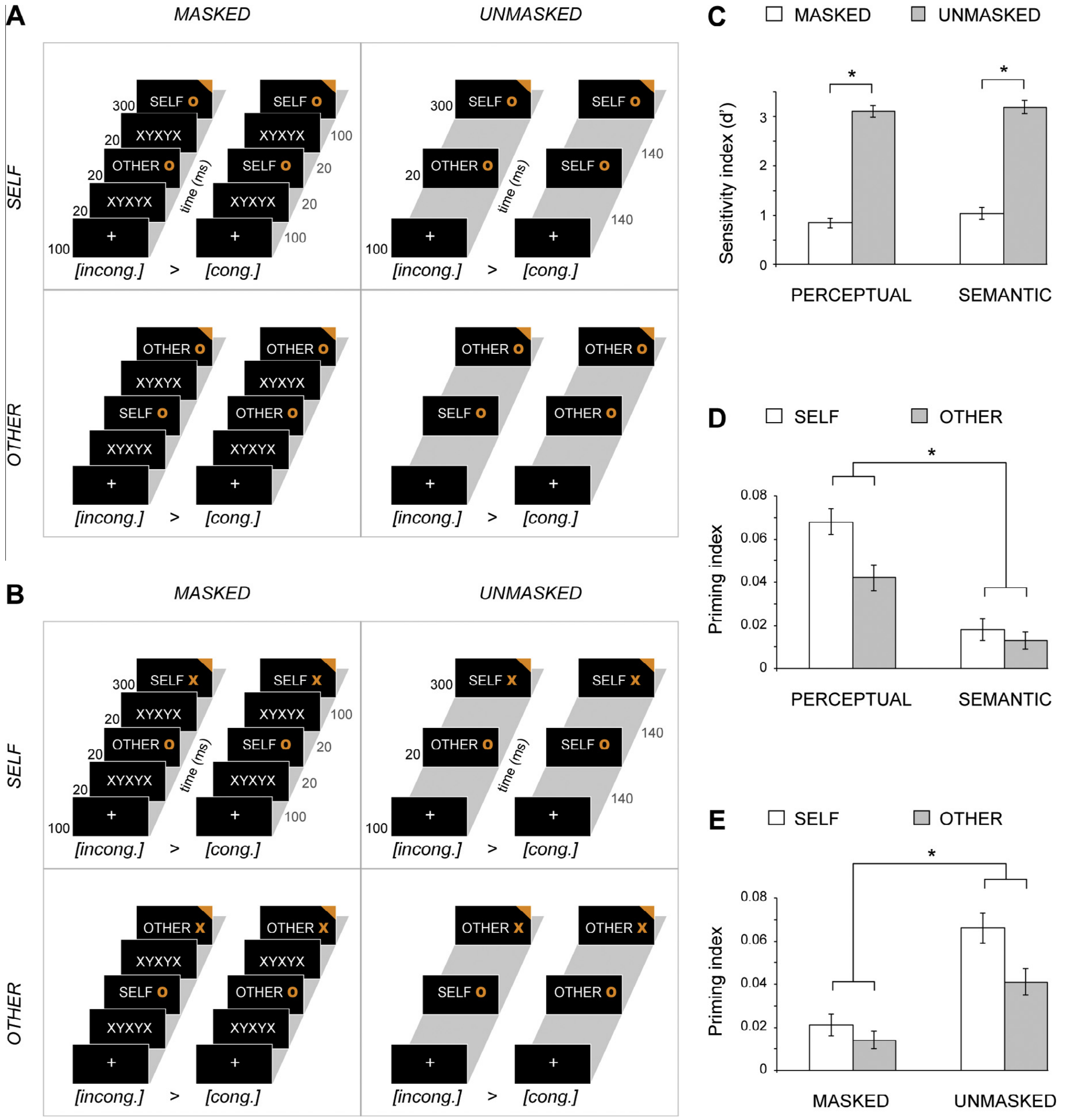

Fig. 1. The paradigm and the results of Experiment I. (A) In perceptual priming trials, primes and targets belonged to the same stimulus category, e.g., name–name, surname–surname, as indicated by orange circles. Orange triangles in the corners indicate the targets. The subject's task was to decide whether these stimuli were self- or other-related. (B) The semantic priming trials were analogous to perceptual ones, but primes and targets never belonged to the same stimulus category, as indicated by orange circles and crosses, e.g., name–surname, date–name. (C) As expected, our masking procedure significantly hindered the correct discrimination of primes. (D) We found that perceptual priming, but not semantic priming, was stronger in the "self" than in the "other" condition, which suggests that low-level (physical) features contribute to preferential processing of self-related information. (E) We also found that priming was significantly stronger for self- than for other-related stimuli but only in the unmasked trials (significant interaction). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

8 × 1 degrees of visual angle; luminance: ~246 cd/m^2) and were presented on a black background (luminance: ~2 cd/m^2; Weber contrast: 120). Primes and targets were presented in the same spatial location, which was the center of the screen. The size of self- and other-related stimuli was very closely matched (names and surnames had the same number of letters, as did the dates and nationality codes). In addition, the subject's own name and the other person's name were matched in terms of gender.

Each trial began with a fixation point (i.e., a white "+") that was followed by a prime and then a target (Fig. 1A and B). In half of the trials, primes were immediately preceded by forward masks and immediately followed by backward masks. The masks were "XYXYXY" strings consisting of 13 letters. In all trials, subjects had 1500 ms to respond (i.e., the time from a target onset to the end of each trial). Fig. 1A and B provide specific information about the onsets, durations, and intervals between stimuli. Recordings performed with a high-speed camera (1000 Hz, model Exilim EX-ZR100, Casio Computer Ltd., Shibuya, Japan) confirmed that forward masks, primes, and backward masks were displayed for 20 ± 1 ms and that the intervals between them were also 20 ± 1 ms long.

We used perceptual and semantic priming procedures (Fig. 1A and B, respectively). In perceptual priming, primes and targets belonged to the same stimulus category (e.g., name–name, surname–surname), whereas in semantic priming they belonged to different categories (e.g., name–surname, date–name). This manipulation allowed us to test whether preferential access to the self-concept occurs at the semantic or only at the perceptual stages of information processing (Schacter & Buckner, 1998). Including semantic trials also helped us to accurately assess the visibility of masked primes. That is, if all trials were perceptual trials, subjects could have guessed the identity of primes based on the identity of the targets, independently from conscious awareness (e.g., "I did not see the prime, but because the target was A and because I saw that the prime and the target differed, the prime had to be B"). Crucially, being aware of a physical difference between two stimuli is not the same as being aware of what these stimuli actually are. Intermixing semantic and perceptual trials prevented such a response bias (i.e., physical difference between primes and targets was no longer informative about the identity of the primes). Notably, in perceptual trials, each stimulus pair (name–name; surname–surname; date–date; nationality–nationality) was used the same number of times (6 repetitions within each trial type). Similarly, in semantic trials, each category combination was equiprobable (12 possible combinations, each repeated twice within each trial type).

In sum, we used a $2 \times 2 \times 2 \times 2$ design with "person" (self vs. other), "type of priming" (perceptual vs. semantic), "masking" (masked vs. unmasked), and "congruency" (congruent vs. incongruent) as the factors. Thus, there were 16 trial types, and each trial type was repeated 24 times. A total of 384 trials were presented in two separate sessions in pseudo-random order (not more than three consecutive repetitions of a self- or other-related targets). In one session, we presented only masked trials, whereas in the other session, we presented only unmasked trials. The point of separating these trials was to prevent subjects from paying too much attention to masked stimuli because top-down attention has been shown to facilitate conscious access (Naccache, Blandin, & Dehaene, 2002). The order of "masked" and "unmasked" sessions was counterbalanced across participants. Each session lasted approximately 10 min, and there was a short break in the middle of each session ($\sim$1 min). There was also a break between two sessions ($\sim$2 min).

During the priming sessions, subjects were told to ignore prime stimuli and respond only to targets. The task was to discriminate whether the target in each trial was self- or other-related. The "LEFT-CTRL" and the "NUM-ENTER" buttons on a standard keyboard were used to indicate responses with button presses made with the left and the right index fingers, respectively. The key assignment was counterbalanced across participants. The instructions emphasized that responses should be as fast and as accurate as possible. After reading the instructions, the subjects underwent a practice session (a series of 16 trials, two repetitions of each trial type). Practice trials were identical to actual trials for the upcoming session but included additional feedback (i.e., "CORRECT," "INCORRECT," or "TOO LATE!") presented at the end of each trial. None of the subjects reported problems complying with the task.

During the actual study, the inter-trial intervals were 0.5, 1, or 1.5 s. The aim for using this "temporal jitter" was to reduce the effects of habituation possibly caused by a monotonous pace of stimuli presentation. Intervals of different lengths were equally distributed across 384 trials. All stimuli were displayed on an LCD computer screen (DELL S2409 W; Dell Inc., Round Rock, Texas, USA) with a 50-Hz refresh rate and a 1920×1080 resolution. The viewing distance was similar for all participants (chin rest placed $\sim$70 cm away from the screen). Presentation software (version 16.2, Neurobehavioral Systems, Inc., Albany, CA) was used to control stimuli display and to record each participant's responses.

After completing both priming sessions, the participants underwent forced-choice visibility tests. These tests were designed to assess the subjects' ability to recognize masked and unmasked primes. Compared to priming sessions, the visibility tests differed in only two ways. (i) The participants were asked to decide whether primes, not targets, were self- or other-related, and (ii) each trial type was repeated 12 instead of 24 times, so the total of 192 trials was presented in two five-minute sessions (1-min break in between). As in the priming session, masked and unmasked trials were presented separately. Each session started with an instruction and a practice session (a series of 16 trials, 2 repetitions of each trial type). The instructions emphasized that the participant was unsure, he or she should try to guess the correct response. The instructions also emphasized that the speed of responding is not crucial in visibility tests. The key assignment in the visibility tests was always the same as in the priming sessions.

2.1.3. Data analysis

First, we sought to determine whether masked primes were indeed consciously perceived with more difficulty than unmasked primes. Consistent with a long tradition of psychophysical studies, processing of a stimulus is regarded as unaware if subjects are not able to report this stimulus with accuracy greater than chance. To test this criterion, we calculated the so-called sensitivity indexes (d') based on the visibility test data (Wickens, 2002). These d' were calculated separately for masked and unmasked primes and were contrasted (i) against "0" (chance level) and (ii) against each other (to determine whether masking made aware access *more* difficult).

In the analysis of the priming sessions, we first sorted RTs from all correct trials according to trial type. Second, we excluded plausible outliers. That is, we excluded trials in which RTs were 1.5 of the inter-quartile range above or below the third and the first quartiles, respectively (NB. Only 4 ± 4% of trials were removed in this procedure). Outlier-free RTs were then averaged within each trial type and used to calculate priming indexes (PI) for each subject and for each condition. PIs were calculated as the difference between RTs in incongruent and congruent trials divided by the summed RTs from these trials: $PI = (RT_{incong.} - RT_{cong.})/(RT_{incong.} + RT_{cong.})$. Unlike the classical priming coefficient (i.e., a simple difference between $RT_{incong.} > RT_{cong.}$), PI ratio accounts for the fact that priming depends on the overall RTs (Ewbank et al., 2014). For instance, the same priming value of 20 ms indicates a different effect size if the overall RT is 1300 ms than when the overall RT is 900 ms. In the former case, 20 ms corresponds to a weaker priming than in the latter case. This additional control provided by PIs is particularly important in our study, as we wanted to directly compare conscious and unconscious effects without biases related to, for example, the presence of masks that likely delay the overall RTs. Importantly, the sign of PI values is informative, with positive values indicating behavioral facilitation, zero indicating no priming, and negative values indicating negative priming. Notably, we analyzed our data also using simple priming coefficients, but this control analysis showed the exact same pattern of statistical results as the analysis on PIs.

In general, reducing the "congruency factor" simplified our analysis (interpreting a four-way interaction could be challenging) and excluded possible confounds (as congruent and incongruent trials were closely matched within each condition, contrasting them in the first step of analysis eliminated any between-condition nuisance differences, for example, due to the presence or absence of masks or due to different motor requirements). Thus, we had eight experimental conditions: self_perceptual_masked; other_perceptual_masked; self_perceptual_unmasked; other_perceptual_unmasked; self_semantic_masked; other_semantic_masked; self_semantic_unmasked; and other_semantic_unmasked. In our main analysis, we used a three-way repeated-measures ANOVA to compare the degree of priming for different conditions. This ANOVA had the following factors: "person" (self vs. other), "type of priming" (perceptual vs. semantic), and "masking" (masked vs. unmasked). We used IBM SPSS software (version 22, Armonk, NY: IBM Corp.) to perform all statistical analyses.

2.2. Results

Fig. 1C shows the sensitivity indexes (d') for masked and unmasked primes in both types of priming. Kolmogorov–Smirnov tests revealed that the distributions of d' for masked-perceptual and unmasked-semantic primes were non-Gaussian ($p = 0.037$ and $p = 0.005$, respectively), whereas d' for unmasked-perceptual and masked-semantic primes did not deviate from the normal distribution ($p = 0.133$ and $p > 0.2$, respectively). We found that d' for all types of primes were significantly higher than chance: masked-perceptual ($p < 0.0005$, one-sample Wilcoxon signed rank test), unmasked-perceptual ($p < 0.0005$, one-sample t-test), masked-semantic ($p < 0.0005$, one-sample t-test), and unmasked-semantic ($p < 0.0005$, one-sample Wilcoxon signed rank test). The related-samples Wilcoxon signed rank tests showed that d' for masked primes were significantly lower than d' for unmasked primes (perceptual: $p < 0.0005$; semantic: $p < 0.0005$). Together, these results indicate that, even if we did not create a completely unaware context of information processing, our masking procedure was highly efficient in manipulating the *level* of aware processing, which is sufficient for the purpose of our study (see Section 4).

Next, we checked whether the masking procedure was equally effective for self- and other-related primes. One might suspect, for example, that due to its high familiarity and behavioral relevance, the subject's own name could "pop up" and be consciously perceived despite the masking procedure. To test this possibility, we analyzed accuracy rates from the visibility tests. Surprisingly, we found that participants were actually worse at correctly recognizing self-related than other-related masked primes (mean accuracy: 62 ± 2% and 72 ± 1%, respectively; $p < 0.0005$; Wilcoxon signed rank test). Future studies are needed to validate this unexpected finding; however, it clearly indicates that, in the present study, self-related primes did not overcome the masking procedure to a greater extent than other-related primes.

As for our main research questions, we compared the degree of priming between experimental conditions using ANOVA. However, we first assessed the accuracy rates and normality of priming indexes. Accuracy rates for all trial types were very high (between 87% and 98%), which shows that subjects had no problem complying with the task. Priming indexes did not deviate from the normal distribution for any of the conditions (Kolmogorov–Smirnov tests). The ANOVA showed a main effect for the "type of priming," ($F_{1,\ 23} = 70.16$; $p < 0.0005$; $\eta^2 = 0.75$), "masking," ($F_{1,\ 23} = 34.68$; $p < 0.0005$; $\eta^2 = 0.6$), and "person," ($F_{1,\ 23} = 21.11$; $p < 0.0005$; $\eta^2 = 0.48$). In addition, the ANOVA showed interactions for "type of priming" × "masking," ($F_{1,\ 23} = 16.13$; $p = 0.001$; $\eta^2 = 0.41$), "type of priming" × "person," ($F_{1,\ 23} = 8.07$; $p = 0.009$; $\eta^2 = 0.26$), and "masking" × "person" ($F_{1,\ 23} = 6.25$; $p = 0.02$; $\eta^2 = 0.21$). The three-way interaction was not significant ($F_{1,23} = 0.53$; $p = 0.48$; $\eta^2 = 0.022$). Next, we performed post hoc tests (paired t-tests, two-tailed) for the interactions including the factor "person" (our main interest in this study).

Decomposition of the "type of priming" × "person" interaction (Fig. 1D) showed that the "self" > "other" difference was significant in the perceptual trials ($t_{23} = 4.91$; $p < 0.0005$) but not significant in the semantic trials ($t_{23} = 1.17$; $p = 0.26$). Therefore, the perceptual factors were likely the main contributor to the preferential processing of self-related stimuli (see Section 4). In turn, decomposition of the "masking" × "person" interaction (Fig. 1E) showed that the difference between the "self-masked" and "other-masked" conditions was non-significant ($t_{23} = 1.41$; $p = 0.17$), whereas the difference between the "self-unmasked" and "other-unmasked" conditions was highly significant ($t_{23} = 4.75$; $p < 0.0005$). This finding suggests that conscious factors significantly contributed to the preferential processing of self-related information and these factors played a more important role than the unconscious ones.

In sum, Experiment I suggests that the preferential processing of self-relevant information occurs mainly because of perceptual and conscious factors. It is noteworthy that we did not find evidence for the "unconscious self-preferential effect," even though previous studies have supported it (Alexopoulos et al., 2012; Geng, Zhang, Li, Tao, & Xu, 2012; Pfister et al., 2012; Wentura et al., 2005). Thus, in Experiment II we asked whether we could "boost" the unconscious self-preference by using a more familiar and more automatically processed set of stimuli. We assumed that if any self-related stimulus is processed in a truly unaware way, then this stimulus would probably be the subject's own name, which appears countless times in everyday life. Because in Experiment I we analyzed pooled responses to different kinds of biographical material, the automaticity of processing one's own-name could have been "diluted" and therefore failed to produce a significant effect. Thus, in Experiment II, responses to names and to different kinds of biographic stimuli were separated. Similar to Experiment I, we hypothesized that if preferential processing of one's own name occurs mainly at the unconscious level, then we should find only a main effect of "person" in our factorial design but no interaction. In contrast, a greater difference in "self" > "other" in the unmasked trials compared to the masked trials (the same interaction as in Experiment I) would suggest that both unconscious and conscious factors contribute to the preferential processing of one's own name. In Experiment II we also decreased the duration that primes were presented to further hinder aware processing of masked stimuli.

3. Experiment II

3.1. Materials and methods

3.1.1. Participants

Twenty-four naïve, right-handed subjects (mean age: 27 ± 5, ten females) participated in this study. All participants were healthy, reported no history of psychiatric illness or neurological disorder, and had normal or corrected-to-normal vision. One participant was excluded because of an excessively low accuracy rate in one session (approximately 50%). The mean age of the remaining 23 participants (10 females) was 27 ± 5. All participants gave their written informed consent before the start of the experiment. The Regional Ethical Review Board of Stockholm approved the study.

3.1.2. Stimuli and procedure

As experimental stimuli we used first names, initials, dates of birth, years of birth, and age, that were either self- or other-related (again, the "other" was a person who the participants had no pre-existing knowledge about). We did not use nationality codes in this experiment because they might be seen as part of the "collective self" ("me" as a group member) rather than as part of the "individual self" like the rest of our stimuli. Dates of birth were presented as "MM/DD," whereas birth years were presented as "YYYY". All stimuli were written in white capital letters (Arial font; size ranging from 2×1 to 8×1 degrees of visual angle) and were presented centrally on a black background (the same luminance and contrast as in Experiment I). The subject's own name and the other's name were matched in terms of gender and number of letters. The structure of a single trial was the same as in Experiment I (Fig. 1A); however, in this experiment, forward masks, primes, and backward masks were presented only for 12 ± 2 ms with 15 ± 2 ms intervals (these exact durations were confirmed by measurements with the same high-speed camera used in Experiment I).

Our main aim in Experiment II was to test the effect of awareness on name processing vs. biographic material. Therefore, we did not include perceptual vs. semantic priming manipulation, and all trials were perceptual priming trials. Thus, we used a $2 \times 2 \times 2 \times 2$ design with the following factors: "type of stimuli" (name vs. biographic), "masking" (masked vs. unmasked), "person" (self vs. other), and "congruency" (congruent vs. incongruent). A total of 384 trials (i.e., 16 trial types, each trial type repeated 24 times) were presented in a pseudo-random order in four separate sessions (i.e., names-masked, names-unmasked, biographic-masked, and biographic-unmasked). The order of these sessions was fully counterbalanced across the participants (each of the four possible sequences of sessions applied to 6 participants). Each session lasted approximately 4 min, and there were short breaks between the sessions (~1 min). In the "biographic session," each stimulus category (date, initials, year, and age) was repeated exactly six times, whereas in the "names session" each name was repeated 24 times.

Subjects were seated in front of a computer screen (chin rest placed ~70 cm away from the computer screen) and were instructed to discriminate whether the target stimuli were related to themselves or to another person. The instructions always informed the subjects what kind of stimuli would be used in the subsequent session (names or biographic). Button presses of the "LEFT-CTRL" and "NUM-ENTER" buttons with the left and the right index fingers were used to indicate responses. The key assignment was counterbalanced across participants. The task instructions emphasized both the accuracy and speed of responses. Because the subjects in Experiment I had no problem complying with the task, we did not include practice sessions in Experiment II.

The inter-trial intervals were 1, 1.5, or 2 s and were evenly distributed across 384 trials. The stimuli were displayed on the same computer monitor that was used in Experiment I. However, to allow briefer stimuli presentations, we changed the refresh rate to 75-Hz and the resolution to 1280×1024. The fact that our high-speed camera measurements showed 12 ± 2 ms for the stimuli durations and 15 ± 2 ms for the intervals (see the text above), instead of 13.3 ± 2 for both, as expected from using a 75-Hz refresh rate, is probably because of the loss of luminance for the camera at the onset and offset of the stimuli presentation. The stimuli durations were matched across experimental conditions.

After completing all four priming sessions, participants performed four visibility tests (24 trials in each trial type). The visibility tests were the same as the priming sessions, but subjects responded to primes rather than to targets. Presentation software (version 16.2, Neurobehavioral Systems, Inc., Albany, CA) was used to present stimuli and to record responses.

3.1.3. Data analysis

Analyses of d' and RTs were the same as those performed in Experiment I. The priming data analysis included the following eight conditions: self_names_masked; other_names_masked; self_names_unmasked; other_names_unmasked; self_biographic_masked; other_biographic_masked; self_biographic_unmasked; and other_biographic_unmasked. After sorting single-trial RTs from correct trials, we excluded outliers using the same method as in Experiment I (only 6 ± 6% of trials were removed in this procedure). Then, we tested the normality of distributions and calculated subject-specific priming indexes for each condition. Finally, we ran a three-way ANOVA with the factors "type of stimuli" (names vs. biographic), "masking" (masked vs. unmasked), and "person" (self vs. other). All analyses were conducted using IBM SPSS software (version 22, Armonk, NY: IBM Corp.).

3.2. Results

Fig. 2A shows the data from the visibility tests. Kolmogorov–Smirnov tests indicated that d' for masked-names and masked-biographic primes deviated from normality ($p < 0.0005$ and $p = 0.003$, respectively), whereas d' for unmasked-names and unmasked-biographic primes did not ($p > 0.2$ in both tests). The one-sample Wilcoxon signed rank tests showed that d' for masked-names and masked-biographic primes did not differ from chance level ($p = 0.26$ and $p = 0.05$, respectively). In turn, correct recognition of unmasked-names and unmasked-biographic primes was above chance ($p < 0.0005$ in both one-sample t-tests). In both sessions, d' for masked primes were significantly lower than d' for unmasked primes ($p < 0.0005$ in both related-samples Wilcoxon signed rank tests). In general, these results indicate that masking was highly effective in hindering conscious access.

We also checked whether self-related primes were masked equally well as other-related primes. The accuracy rates from visibility tests were as follows (mean accuracy in % ± SEM): self-name-masked (50 ± 3); other-name-masked (55 ± 4); self-biographic-masked (48 ± 4); and other-biographic-masked (54 ± 4). Wilcoxon signed rank tests did not show significant differences (self- vs. other-name: $p = 0.89$; self- vs. other-biographic: $p = 0.44$). These results suggest that masking was similarly effective for self- and other-related primes.

Our main analysis, the three-way ANOVA, compared the degree of priming between experimental conditions. Accuracy rates for all trial types were very high (between 94% and 98%). Priming indexes did not deviate from the normal distribution for most of the conditions ($p > 0.2$ in all Kolmogorov–Smirnov tests). The only exception was the SHN condition ($p = 0.016$); however, because ANOVA is robust against the violation of normality assumption (Khan & Rayner, 2003), we still used this parametric test, as it closely matches our parametric design. The ANOVA showed the main effect of "masking," ($F_{1, 22} = 42.62$;

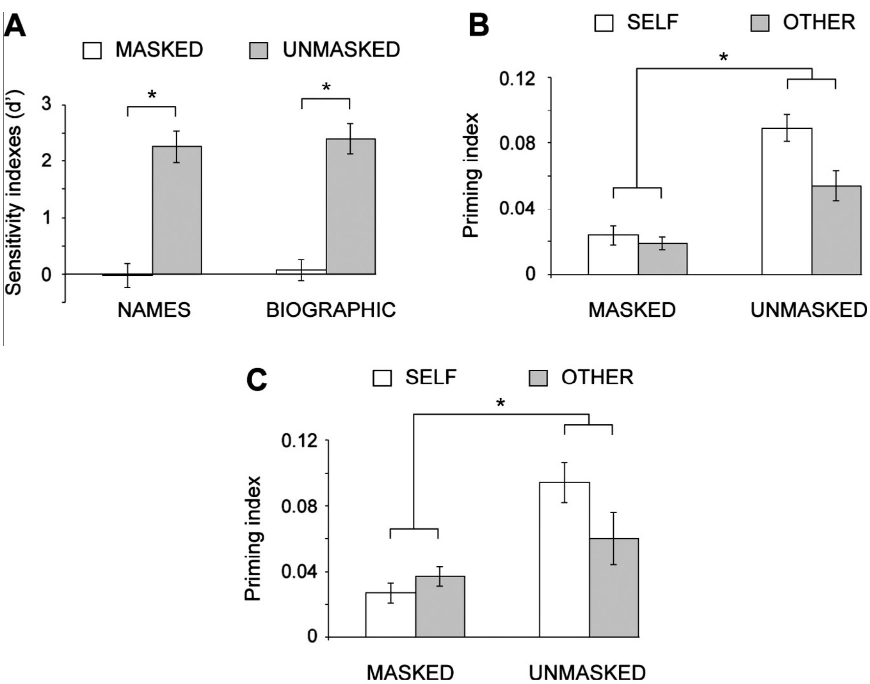

Fig. 2. Results of Experiment II. (A) Masking procedure was highly effective both for names and for biographic stimuli. (B) Priming data showed the same pattern of results as in Experiment I (compare with Fig. 1E) suggesting that preferential access to the self-concept is mainly due to conscious processes. (C) Results of only the "names" session showed that even the subject's name (i.e., probably the most automatically processed self-related stimulus) did not trigger significant subliminal self-specific effects.

$p < 0.0005$; $\eta^2 = 0.66$), and "person," ($F_{1,\ 22} = 7.49$; $p = 0.012$; $\eta^2 = 0.25$), as well as a "masking" × "person" interaction, ($F_{1,\ 22} = 6.85$; $p = 0.016$; $\eta^2 = 0.24$). The main effect of "type of stimuli," ($F_{1,\ 22} = 2.4$; $p = 0.14$; $\eta^2 = 0.01$), "masking" × "type of stimuli" interaction, ($F_{1,\ 22} = 0.38$; $p = 0.54$; $\eta^2 = 0.017$), "person" × "type of stimuli" interaction, ($F_{1,\ 22} = 1.4$; $p = 0.25$; $\eta^2 = 0.06$), and the three-way interaction, ($F_{1,\ 22} = 1.51$; $p = 0.23$; $\eta^2 = 0.064$) were non-significant.

Post hoc analysis (paired *t*-tests, two-tailed) for the "masking" × "person" interaction (our main focus in this study) showed that in the masked trials, the self- and other-related priming did not differ significantly ($t_{22} = 0.65$; $p = 0.52$), whereas in the unmasked trials, the self-related priming was stronger than the other-related priming ($t_{22} = 3.28$; $p = 0.003$). These results closely resemble those obtained in Experiment I (compare Figs. 1E and 2B) and suggest that (i) preferential access to the self-concept is related mainly to aware factors and (ii) that one's own name is not an exception to this rule.

Finally, to further confirm the role of conscious factors in the processing of one's own name, we ran a two-way ANOVA only for the "names" session. This analysis showed a main effect of "masking" ($F_{1,\ 22} = 21.17$; $p < 0.0005$; $\eta^2 = 0.49$) and the "masking" × "person" interaction ($F_{1,\ 22} = 5.3$; $p = 0.031$; $\eta^2 = 0.19$). Post hoc *t*-tests showed that there was no significant difference between the "self" and "other" conditions in the masked trials ($t_{22} = -1.49$; $p = 0.15$), but the self-related priming was stronger than the other-related priming in the unmasked trials ($t_{22} = 1.98$; $p = 0.06$; a statistical trend) (Fig. 2C). These results are analogous to the ones from a three-way ANOVA and suggest that the preferential processing of one's own name is mainly due to aware factors.

4. Discussion

The first aim of this study was to determine whether semantic factors contribute significantly to the preferential processing of self-related stimuli. We did not find evidence to support this claim. Even though we found a robust self-prioritization at the perceptual level, the semantic self-prioritization was non-significant. The second aim was to determine whether preferential access to the self-concept occurs both at the conscious and unconscious levels of information processing or whether this preference is mainly an unconscious phenomenon. In two separate experiments, we found that the self-specific effects ("self" > "other") were stronger in the unmasked than in the masked trials, which indicates that awareness significantly contributes to the preferential processing of self-related stimuli.

Our first main result suggests that preferential access to self-representation occurs mainly at the perceptual stages of information processing. Notably, in congruent perceptual trials, primes and targets were physically identical and referred to the same person (e.g., own-name–own-name), whereas in congruent semantic trials, primes and targets were physically different even though they referred to the same person (e.g., own-name–own-surname). Thus, in perceptual trials, self-related priming could have resulted from perceptual and/or semantic congruency, whereas in semantic trials, self-related priming could have resulted only from semantic congruency. We found that the self-preferential effect ("self" > "other") was stronger in perceptual trials than in semantic trials (see Fig. 1D). Because semantic congruency was present in both contexts (see the above explanation), this interaction effect had to be driven specifically by perceptual priming. This finding suggests that preferential processing of self-relevant information is mainly due to low-level features (e.g., high stimulus-familiarity, emotional salience, etc.).

This perceptual self-preference might seem inconsistent with the commonly accepted semantic interpretation of the "self-reference effect" (SRE). SRE is a well-established finding that information encoded in relation to oneself is remembered better than information encoded in other semantic contexts (e.g., Rogers, Kuiper, & Kirker, 1977; Symons & Johnson, 1997; Turk et al., 2008; see also Bergouignan, Nyberg, & Ehrsson, 2014). A common explanation of SRE is that the mental representation of the self is richer and has a more structured organization than mental representations of other objects; thus, a new piece of information is more easily incorporated into the self-concept than into other concepts (Greenwald & Banaji, 1989; Symons & Johnson, 1997). However, the ease by which information is semantically incorporated into the self-concept does not mean the self-concept has to be accessed preferentially at the semantic level, which is what our results suggest. More research is needed to shed light on this issue; however, our study clearly indicates that perceptual factors play a more important role in the self-preferential processing than do semantic factors.

Notably, the "other" condition in our study referred to an unknown person who was not associated with any pre-existing conceptual knowledge. Thus, the degree of semantic processing in this condition was initially very limited or even non-existent. Nevertheless, we observed a very significant priming effect in this condition (see Fig. 1D; priming well above zero). One possibility is that in the context of the ongoing experiment, the participants formed a task-specific semantic category about the other-related stimuli, i.e., "someone whose name I see during this experiment". Another possibility is that the priming effect in the "other" condition corresponds to the so-called "response-priming effect" (e.g., Schmidt & Seydell, 2008). We cannot distinguish between these two interpretations, and it is also possible that they co-occurred. We can say with certainty though that this effect was independent from the physical similarity of primes and targets; thus, it had to be driven by post-perceptual factors. Importantly, none of these considerations has a consequence for the main conclusion of the study, because increased pre-experimental semantic familiarity of the "other" condition (e.g., using celebrities' names) would only enhance priming in this condition and thus strengthen the interaction effect that we found.

Our second main finding is that conscious factors significantly contribute to the self-prioritization effect. This result has interesting implications for the "Global Neuronal Workspace" (GNW) model of conscious access (Baars, 2002; Dehaene & Changeux, 2011). According to GNW, there are two main computational spaces in the brain. One space is composed of a set of parallel, distributed, and functionally specialized processors that typically operate non-consciously and in a bottom-up manner. The other space is a "global neuronal workspace," consisting of a distributed set of cortical neurons receiving and sending information to many cortical areas through long-range axons (Dehaene, Changeux, & Naccache, 2011). Conscious access is said to proceed in two successive phases. In the first phase, lasting from approximately 100 to 300 ms, the stimulus climbs up the cortical hierarchy of processors in a primarily bottom-up and non-conscious manner. In the second phase, if the stimulus is selected for its adequacy to current goals and attention state, it is amplified in a top-down manner and becomes maintained by sustained activity of a fraction of GNW neurons, i.e., a "broadcasting" mechanism (Dehaene et al., 2011). We found that the behavioral facilitation related to awareness of self-processing was "above-and-beyond" the general facilitation related to aware processing of other types of stimuli. This finding suggests that information relevant to the self triggers some specific type of "broadcasting" that is more efficient than that for aware processing of different types of information. Perhaps, because of a high familiarity and high behavioral relevance, self-related information evokes a faster, more coherent, and more widespread pattern of neural connectivity, which increases the computational capacity of the "global workspace" and leads to additional behavioral facilitation. Alternatively, aware access to self-concept (i.e., self-awareness) could actually engage an additional computational workspace that is unavailable to general awareness. Such an additional workspace would also increase the efficacy of conscious self-related processing. Future neuroimaging studies are needed to shed more light on these fascinating questions.

We did not find any statistical support for unconscious self-preferential processing, even though such effects were suggested by previous studies (Alexopoulos et al., 2012; Bastuji, Perrin, & Garcia-Larrea, 2002; Geng et al., 2012; Pfister et al., 2012; Wentura et al., 2005). In fact, it is generally difficult to provide any conclusive evidence on these unaware effects. That is, a failure to detect them is statistically inconclusive, as it is only a negative finding. In turn, detecting such effects is inconclusive too because, consistent with a long tradition of psychophysical studies, the processing of a stimulus is regarded as unaware if subjects are not able to report this stimulus with accuracy greater than chance. From a statistical point of view, this reportability criterion in based on accepting a null hypothesis, which is clearly problematic. Thus, it could not be ruled out that previous studies that demonstrated the "unconscious self-preference," in fact, failed to create a completely unaware context of information processing and their results were driven by a minimal, but sufficient, effect of awareness. This impasse calls for a change in operationalization of unconscious processing where, unlike using absolute criteria, unconsciousness is treated in relative terms ("process A is more unconscious than process B," rather than "process A is unconscious"; Lau & Passingham, 2006; Overgaard, Rote, Mouridsen, & Ramsøy, 2006; Samaha, 2015). Consistent with this view, even if the present study did not render masked stimuli completely unconscious, we were able to drastically reduce the degree of conscious access and provide conclusive evidence that (i) aware factors contribute to preferential access to the self-concept and (ii) that the "fully-aware self-preference" is stronger than the "partially-aware self-preference." Thus, what logically follows, the "fully-aware self-preference" has to be stronger than the "fully-unaware self-preference."

In Experiment I, we found rather high d' values for masked primes (i.e., approximately 1) and these d' were significantly higher than chance level. This result might mean that (i) over many trials some primes were processed fully consciously and some completely unconsciously and that the "gradualness" of consciousness was only due to averaging across these trials or (ii) that in each trial there was relatively "more consciousness" or "less consciousness" for a single act of perception. To address this issue, we ran an additional experiment on eight naïve participants (see Supplementary Experiment S1). This experiment was a replication of the visibility test from Experiment I, but for this experiment we used only masked trials, and each trial was followed by an objective (forced-choice: "Self or other?") and a subjective measure of consciousness ("On a scale from 1 to 5 indicate how well you saw the prime"). We found that the most common subjective ratings were "1" and "2" (25% and 43% of trials, respectively) and that the other ratings were also commonly used ("3" in 17%, "4" in 7%, and "5" in 7% of trials) (Fig. S1). This rather continuous distribution of responses suggests that the actual subjective experience was gradual. Experiment S1 also shows that the subjective visibility was very low, despite the relatively high objective performance. Finally, in Experiment II the values of d' for masked stimuli were very low, and they did not differ from the chance level, yet we still found the exact same pattern of results as in Experiment I (d' values approximately 1). Altogether, this evidence shows that our masking procedure was highly effective in manipulating the level of conscious access.

One possible concern is that if the primes and targets in our study were subject to a spatiotemporal luminance summation, then our basic findings might have been driven by higher apparent contrast of the targets in the "self–self" condition. The higher apparent contrast could lead to faster RTs, which hypothetically could replace our priming paradigm with a direct perception paradigm. This possibility seems highly unlikely for two reasons: (i) all the presentation parameters in our studies were closely matched in a factorial design, and (ii) we found significant differences between the "self–self" and "other–other" perceptual conditions (in both cases, the primes and targets were identical; thus, even if any luminance summation took place, it should have had the same impact in both these trial types). However, to be absolutely sure that not even some very subtle differences in low-level features affected our results we ran an additional control experiment, where we used unmasked perceptual trials from the four conditions: "self–self," "other–self," "other–other," and "self–ot her" (see Supplementary Experiment S2). The participants performed a simple detection task ("Respond as soon as you see a target"), which requires only the perceptual analysis of stimuli, but no categorization or memory processes. We reasoned that if an apparent contrast could explain our original results then we should find a similar pattern of results even in a detection task. In contrast, if priming explained our original findings, then all the effects should be absent in a detection task. In line with the second possibility and our initial predictions, we did not find any significant effects in Experiment S2.

The generalization of our results is naturally limited by the fact that all our stimuli were presented visually. The modality of stimulus presentation could be particularly important for the processing of a subject's own name. The auditory version of this stimulus, not the visual one, is most often used in real-life social interactions. Indeed, the sound of one's own name has quite unique properties. Even 4- and 5-month-old infants differentiate the sound of their own name from other names (Grossmann, Parise, & Friederici, 2010; Parise, Friederici, & Striano, 2010), and demented patients react to this stimulus even when their perception of time and place is greatly deteriorated (Fishback, 1977). In contrast, the visual version of one's own name, not the auditory version, is used for communication via e-mail, chat, and letters. In fact, their own name is the first lexical item that children learn to read and write (Levin, Both–De Vries, Aram, & Bus, 2005). Thus, the behavioral relevance of visual and auditory versions of one's own name might not be so different after all. Importantly, we showed common patterns of results for very different types of self-related material (name, surname, date of birth, initials, age, and nationality), which suggests that our main findings were related to general features of self-related stimuli, rather than specifically to the modality.

Importantly, our main conclusions are based on interaction effects; we showed that self-preferential processing occurs more at perceptual than semantic, and more at conscious than unconscious, stages of information processing. These conclusions would be problematic if in our study there was no semantic and/or no masked priming. For example, if there was a general "floor effect" for masked priming, then it would be incorrect to conclude that "self-preference" was weaker during unconscious than conscious processing, because there was probably no unconscious processing whatsoever (e.g., primes presented too briefly, or masked too heavily, to have any congruency effect on the following targets). However, visual inspection of Figs. 1 and 2 indicates that this "floor effect" interpretation could not explain our results; all bars for semantic and masked priming are well above zero. Statistical analyses confirmed this observation; masked and semantic priming for self- and for other-related stimuli were all above zero, and these effects were highly significant ($p < 0.0005$ in all tests, in both experiments). These results demonstrate that masked and semantic priming produced very robust effects in our study but still the magnitude of these effects was similar for the "self" and the "other" condition.

Additionally, in both of our experiments we compared highly familiar stimuli (self-related) to unfamiliar stimuli (other-related). Thus, it could be argued that our effects were driven by familiarity and had nothing to do with self-relevance *per se*. This objection relates to the very basic question about what actually constitutes self-relevance. We think that familiarity is one such constituting factor. Therefore, we do not treat familiarity as a confounding factor, but rather as an important aspect of our effect of interest. Nevertheless, it is unlikely that familiarity alone has driven our main results (i.e., the interaction effects) because (i) the degree of familiarity was perfectly matched between masked and unmasked trials, as well as between perceptual and semantic trials, and (ii) familiarity alone would conceivably strengthen the degree of automaticity and thus reduce the involvement of awareness (Bargh, 1994; Schneider & Chein, 2003), which is exactly the opposite to what we have found for aware self-processing. Future studies more interested in the dissociation between familiarity and self-relevance could compare aware vs. unaware (or perceptual vs. semantic) access to memory representations of the self and another familiar person (the latter condition would be more matched to self-stimuli in terms of familiarity).

In summary, the present study shows that self-relevant stimuli are prioritized mainly at the perceptual and conscious stages of stimulus processing hierarchy. This finding positions the "self-prioritization effect" somewhere between fully automatic and fully controlled cognitive processes. Focusing on both these aspects and treating them in relative terms seems necessary to better understand how our selves shape our perception of the world.

Acknowledgments

P.T. and H.E. designed the study and wrote the manuscript. P.T. collected and analyzed the data. The study was funded by Grants from the Swedish Research Council, the James S. McDonnell Foundation, Torsten Söderbergs Stiftelse, Riksbankens Jubileumsfond, and StratNeuro. The funding sources were not involved in the study design; in the collection, analysis, or interpretation of data; in the writing of the report; or in the decision to submit the article for publication. The authors declare no conflict of interest.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2016.02.013.

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