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The self-face automatically captures attention without consciousness

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Abstract

It is intuitively clear and experimentally well established that stimuli representing ourselves, like our own name or face, benefit from preferential processing. However, two questions remain to be addressed. First, does the prioritization mechanism operate in an automatic manner during an early processing, or rather in a more controlled fashion at later processing stages? Second, which of the reported effects are specific to self-related stimuli, and which can also be observed for other familiar or salient stimuli? We used a dot-probe task and an N2pc ERP component analysis to investigate attentional mechanism of the self-face perception and to tackle both questions. The former, by employing a backwards masking procedure to render faces subliminal and thus isolate the early and preconscious processing stages. The latter, by investigating whether a face that is only visually familiar captures attention in a similar manner to the self-face. We demonstrate that both conscious and unconscious perception of the self-face image results in a robust attention capture, which indicates an early and automatic self-prioritization mechanism. Further, the visually familiar face did not attract attention in the conscious condition, suggesting that the attentional prioritization was specific to a self-referential stimulus. Unexpectedly, the visually familiar face did attract attention, but only in the second half of the unconscious block, after a sufficient number of presentations. Such attention shifts to an already visually familiar, but still highly degraded stimulus, might facilitate its' recognition. More generally, our study provides further evidence supporting a dissociation between attention and consciousness.

Keywords: self, face, attention, N2pc, consciousness

Significance statement

The ability to recognize ourselves lies at the heart of self-consciousness. It is well known that stimuli representing or associated with "self" are processed preferentially by our cognitive system. In the present study we show that an image of our own face indeed robustly attracts attention. Importantly, even when participants were not aware that their own face was presented - due to a very short display time and a "masking" procedure - their attention was shifted to the invisible self-face image. This indicates that the mechanism of self-prioritization is very rapid, automatic, and occurs at early stages of visual processing. More generally, our study provides evidence that attention can operate and select salient stimuli even in the absence of awareness.

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Introduction

The ability to recognize and distinguish oneself from the environment is one of the key aspects of self-consciousness. It seems intuitively clear that stimuli representing ourselves, like a self-name or a self-face, hold a special status in our mind. A classic demonstration of the phenomenon is when attention is automatically drawn to a conversation in which our own name is mentioned - a so called “cocktail party” effect (Cherry, 1953; Moray, 1959). Multiple experimental studies have subsequently confirmed preferential processing of self-related information (review: Deuve and Bredard, 2011; Sui and Humphreys, 2015; Humphreys & Sui, 2015; Sui and Gu, 2017). Specifically, a range of behavioral paradigms indicate that self-referential stimuli are detected faster and with higher accuracy (Keyes et al., 2010; Sui et al., 2012, 2014; Schafer et al., 2016; Macrae et al., 2018), and are also memorized better (Cunningham et al., 2008; Turk et al., 2008; meta-analysis: Symons and Johnson, 1997). Neurophysiological basis of these effects has been investigated by the EEG studies, which revealed greater amplitude of the P3 ERP component in response to one’s own name or face (Tacikowski and Nowicka, 2010; Ninomiya et al., 1998; Sui et al., 2006; review: Knyazev, 2013). Similarly, the fMRI studies consistently indicate stronger activations of several brain regions, particularly in the right hemisphere, in response to the self-related stimuli (review: Keenan et al., 2000; Devue and Bredart, 2011; Qin and Northoff, 2011).

One of the key mechanisms contributing to the self-preference effect might be prioritized allocation of attention (review: Humphreys and Sui, 2016; Sui and Rotshtein, 2019). Indeed, several studies found that the self-name and self-face capture attention automatically (Tong and Nakayama, 1999; Brédart et al., 2006; Alexopoulos et al., 2012; Yamada et al., 2012; Yang et al., 2013). However, others challenge this conclusion by showing that, first, the effect is not automatic but rather contingent on the task type or availability of attentional resources; and second, that it occurs also for other highly familiar stimuli and thus is not specific to self (Bundesen et al., 1997; Gronau et al., 2003; Harris and Pashler, 2004; Devue and Brédart, 2008; Devue et al., 2009a, 2009b; Keyes and Dlugokencka, 2014; Qian et al., 2015). To further investigate the role of attention in the self-preference effect we have recently conducted a series of dot-probe experiments, involving lateral presentations of the face images - subject’s own face on one side of a fixation cross, and an unfamiliar face on the other side. Analysis of the N2pc ERP component - a classic index of covert attention shifts (Eimer and Kiss, 2008; Sawaki and Luck, 2010) - revealed that the self-face automatically attracts attention even when presented as a task-irrelevant distractor (Wójcik et al., 2018). Crucially, attention was shifted towards the self-face also when faces were rendered invisible by backward masking and participants were unaware of their identity (Wójcik et al., 2019). Therefore, our results indicate that identification of the self-face might be performed pre-attentively and pre-consciously.

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To address controversies around the mechanisms of self-bias it is critical to identify whether stimuli representing self are indeed special and processed in a qualitatively different way, or rather the observed effects can be accounted for by exceptional familiarity with their low-level (physical) features. The key role of familiarity is suggested by studies showing that the pre-experimentally familiar faces (e.g. of celebrities) can cause similar attention capture (e.g. Devue and Brédart, 2008; Devue et al., 2009a, 2009b) and ERP effects as the self-face (Tacikowski et al., 2014). However, strong evidence against the familiarity hypothesis is provided by experiments revealing that even abstract stimuli arbitrarily assigned to represent a participant during the experiment benefit from a robust prioritization effect (e.g. Sui et al., 2012, 2014).

Therefore, in the present study we investigated the mechanisms of an automatic attention capture by the self-related stimuli. First, we set out to replicate and extend our previous findings of involuntary attention capture by visible (Wójcik et al., 2018) and invisible self-face (Wójcik et al., 2019). Second, we aimed to test whether a face with high *intra-experimental* familiarity will cause similar attention shifts as the self-face. To this end, subjects were familiarized with one face before the experimental procedure, and then the “familiar” face was repeatedly presented in each trial (paired with unfamiliar faces, similarly to the self-face). Additionally, we hypothesized that greater attention capture by the “familiar” face will occur in the second phase of the experiment, as it’s familiarity will increase across trials (in line with: Tanaka et al., 2006). However, we did not expect such an effect for the self-face, which exhibits a ceiling-level familiarity and thus further experimental presentations are unlikely to increase it (Tong and Nakaywam, 1999; Tacikowski et al., 2011).

Methods

Subjects

We collected data of 29 subjects (16 females, M = 23 years, SD = 3 years, range: 20-29 years, 1 left-handed). They all declared normal or corrected-to-normal vision and no history of psychiatric or neurological disorders.

Data of 6 additional subjects were collected but excluded from the analysis: EEG data of 1 subject has not been properly saved, electrooculographic (EOG) signal of 2 subjects was not properly recorded and could not be used in the analysis, and 3 subjects were excluded due to an insufficient number of epochs remaining after EEG signal preprocessing (detailed criteria are described in the “EEG recording and analysis” section).

All experimental procedures were approved by the local Research Ethics Committee at the SWPS University, Warsaw, Poland. All subjects provided written informed consent and received monetary compensation for their time (100 PLN = c.a. 25 EUR).

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Stimuli

A group of 35 participants were initially recruited for the project (20 females, 15 males). All subjects were first invited to the lab to have a photograph of their face taken in a standardized environment (the same background and lightning conditions) with a 12-megapixel digital camera (Canon Powershot SX130). Subjects were asked to maintain a neutral facial expression when photographed. Next all photographs were cropped to include only the face oval (i.e. without hair) and then normalized in terms of luminance, contrast, and grey-scaled colour using Photoshop CC 2018 (Adobe, San Jose, CA). Further, 35 "masks" were created in order to use them to backward mask the face images during the experiment. Masks were created by randomly relocating the key elements of each face (eyes, nose, mouth) in order to disturb the classic feature configuration of faces and prevent recognition (similarly to our previous work: Wójcik et al., 2019).

Next subjects were invited for an EEG experimental session. For each subject, the following stimuli were used: an image of his/her own face; one face chosen from the pool of same gender faces to constitute an intera-experimentally familiar face; and 10 faces chosen randomly from the pool of same gender faces, which were used as control stimuli (other faces). Masks used for backward masking were also gender-matched for each participant (i.e. male subjects were presented only with male faces, which were masked with masks created from male faces only).

Procedure

The experimental procedure was written in the Presentation software (Neurobehavioral Systems, Albany, CA, USA) and presented on a Flex Scan EV-2450 (Hakusan, Ishikawa, Japan) screen through an Intel Core i3 computer. Participants were sat comfortably in a dimly lit room with a viewing distance of 70 cm, which was maintained by a chinrest. The experimental procedure started with a display providing subjects with information about the structure of a trial, the instruction to focus on detecting and manually responding to a target dot, and information that displayed faces are distractors and thus should be ignored. Next, subjects were presented with the face image chosen to constitute an intra-experimentally familiar face. The image was accompanied with a short fictional story, with which we aimed to establish a basic representation of the person: "This is Ania/Tomek. She/He's from Warsaw. She/He is 23 and studies economy. She/He works at a cafe in the Wola district and likes visiting national parks". Subjects were asked to familiarize themselves with the face and the provided information, and press a "continue" button whenever they feel ready. In the next screen both the self-face and the intra-experimentally familiar face were presented together, with an information that different faces will be presented during an experiment, including subjects own face and "Ania's/Tomek's" face, but the subject's task is to focus on the target dot

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and ignore appearing faces. With this additional presentation we aimed to further familiarize participants with features of both self-face and familiar-face images, so that the familiar face would not exhibit an advantage.

A block design was used in the experiment. The tasks were always presented in the following fixed sequence of blocks: masked dot-probe task, masked identification task, unmasked dot-probe task, unmasked identification task. Masked (unconscious) condition always proceeded the unmasked (conscious) condition as we did not want conscious presentations to increase subjects familiarity with the physical features and consequently lower the perception threshold in the masked trials (e.g. Lamy et al., 2017). Within each block there was a self-face block and a familiar-face block (200 trials each, with a break after 100 trials provided for participants comfort). It was randomly chosen whether the self- or familiar-face block will be first presented.

Dot-probe task

In the self-face blocks of the dot-probe task (and analogously in the familiar-face blocks) the self-face (familiar-face) image was presented in each of 200 trials and was always paired with one of 10 “other” faces (thus, each of these faces appeared 20 times).

All stimuli were presented against black background. A dot-probe trial started with a presentation of a fixation cross (subtending 0.3° x 0.3° of the visual angle) at the centre of the screen. The fixation cross remained onscreen for the duration of the trial. After either 750 ms or 1250 ms (the jitter was chosen randomly) a pair of faces were presented bilaterally for 32 ms. Faces subtended 6.2° × 7.9° of visual angle, with their inner edge 3° left and right from the fixation cross. In the masked blocks the faces were followed by backward masks, which remained on a screen for 50 ms. In each trial two masks were chosen randomly from the pool of all gender-matched masks. In the unmasked blocks a blank screen was displayed for 50 ms. Next, a target asterisk subtending 0.3° x 0.3° of the visual angle was presented for 150 ms in the location of the centre of either the self-face/familiar-face (congruent trial) or the other face (incongruent trial). Within each block half trials were congruent and half were incongruent, and their order was random. Subjects were asked to indicate - by pressing one of two buttons using index fingers of their left or right hand - the dots’ presentation side (left or right). Subjects were asked to respond as quickly and accurately as possible. The response time was limited to 3000 ms and the next trial started immediately after the manual response.

Identification task

In the self-face blocks of the identification task (and analogously in the familiar-face blocks) the self-face (familiar-face) image was presented in half of the 200 trials and always paired with one of 10 “other” faces. In the other half of the trials, two “other” faces were displayed. The structure of the trial was the same as in the dot-probe task, but the target dot was not presented. Instead, subjects were asked to make a

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forced-choice whether their own (in the self-face identification task) or the familiar-face (in the familiar-face identification task) was presented on a given trial. Subjects were informed that the response time is unlimited and asked to respond as accurately as possible by pressing one of two buttons of the response pad.

Analysis of behavioral data

All analysis of behavioral data were conducted using custom-made Python scripts. Analysis of the dot-probe task data focused on establishing whether accuracy and reaction times (RT) of a manual responses to the target dots differ between two types of trials: those in which dots followed the potentially attention-grabbing stimulus (self- or familiar-face), and those in which dots followed the neutral stimulus (other face). Reaction times were calculated only for the correct responses. Only trials in which RT between 100 ms and 1000 ms were used in the analysis. Accuracy was calculated as a percentage of correct responses to the dot presentation side.

Sensitivity index (d') was calculated to evaluate whether subjects were able to distinguish between the target (presence of the self- or familiar-face) and the "noise" stimuli (absence of the self- or familiar-face) in the identification task. Hits and false alarms equal to 0 or 1 for each subject were replaced using the log-linear rule, the least biased method of correcting extreme values (Stanislaw and Todorov, 1999).

EEG recording and analysis

EEG signal was recorded with 64 Ag-AgCl electrically shielded electrodes mounted on an elastic cap (ActiCAP, Munich, Germany) and positioned according to the extended 10–20 system. Vertical (VEOG) and horizontal (HEOG) electrooculograms were recorded using bipolar electrodes placed at the supra- and sub-orbit of the right eye and at the external canthi. Electrode impedances were kept below 10 kΩ. The data were amplified using a 128-channel amplifier (QuickAmp, Brain Products, Enschede, Netherlands) and digitized with BrainVisionRecorder® software (Brain Products, Munich, Germany) at a 500 Hz sampling rate. The EEG signal was recorded against an average of all channels calculated by the amplifier hardware.

EEG and EOG data were analyzed using EEGlab 14 functions and Matlab 2016b. First, all signals were filtered using high-pass (0.5 Hz) and low-pass (45 Hz) Butterworth IIR filter (filter order = 2; Matlab functions: *butter* and *filtfilt*). Then data were re-referenced to the average of signals recorded from left and right earlobes, and down-sampled to 250 Hz. All data were divided into 800 epochs (200 epochs per dot-probe condition; conditions: familiar masked, self masked, familiar unmasked, self unmasked). Epochs were created by with respect to the onset of faces ([-200, 800] ms) and the epochs were baseline-corrected by subtracting the mean of the pre-stimulus period ([-200, 0] ms). Further, epochs were rejected

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based on the following criteria: i) when reaction-time (RT) of the manual response to the target dot was < 100 ms or > 800 ms (M = 11.5±2.7; range: [0, 46] epochs per subject); ii) when activity of the HEOG electrode in the time-window [-200, 500] ms exceeded -40 or 40 uV (M = 118.2±21.3; range: [11, 391] epochs); iii) when activity of the P7 or P8 electrode in the time-window [-200, 800] ms exceeded -60 or 60 uV (M = 5.7±2.9; range: [0, 80] epochs). Thus, after applying the described criteria the average number of analyzed epochs per subject was: 664.4±24, range: [372, 788]. A subject was excluded if the number of epochs in any of four conditions was < 50. This criterion resulted in excluding 3 subjects out of 32 (but additional 3 subjects were excluded due to other criteria, as described in the "Subjects" section). The numbers of epochs provided above were calculated based on the final sample of 29 subjects. We found moderate or anecdotal evidence indicating no difference between conditions when compared in terms of number of retained epochs (Bayes Factor < 0.65 for all comparisons).

Next, each EEG-EOG data-set was decomposed into 50 components using Independent Component Analysis as implemented in the EEGlab *pop_runica* function. To remove residual oculographic artefacts from the data the following procedure was used: the time-course of each component was correlated with time-courses of HEOG and VEOG electrodes and a component was subtracted from the data if either value of the Spearman correlation coefficient exceeded -0.3 or 0.3. Using this procedure M = 3.2±0.3; range: [2, 6] components per subject were removed.

After applying the described preprocessing steps, data were divided with respect to the condition and presentation side of the self/familiar face. To calculate the N2pc component we used the P8 and P7 electrodes. Specifically, when self/familiar face was presented on the left side, P8 was the contralateral electrode and P7 was the ipsilateral electrode. When self/familiar face was presented on the right side, P7 was the contralateral electrode and P8 was the ipsilateral electrode. For each condition contralateral and ipsilateral signals were first concatenated and then averaged, to obtain waveforms presented in the top panel of **Fig. 1**. For each subject and condition, the difference between the contralateral and ipsilateral waveforms was calculated, and the difference waveforms averaged across subjects are presented in the bottom panel of **Fig. 1**. All statistical analyses were conducted on the difference waveforms averaged within the defined time-windows.

Statistical analysis

All statistical analyses were conducted in the JASP software and cross-checked with Statcheck (http://statcheck.io/index.php). The values are reported as Mean±SEM, unless stated otherwise.

In the present study, Bayes Factor (BF) was used as the primary statistical measure. The main reason for choosing BF was that, unlike the classic frequentist statistics, BF evaluates how strongly both alternative and null hypotheses are supported by data. Specifically, BF is a ratio of the probability (or

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likelihood) of observing the data given the alternative hypothesis is true to the probability of observing the data given the null hypothesis is true. Thus, in our particular case, BF allows providing further evidence either in favour or against attention capture by the self- and the familiar-face.

In all Bayesian tests, the medium prior scale (Cauchy scale 0.707) was used. In the results section we provide interpretations of the BF according to Wagenmaker et al. (2018), with $0.33 < BF < 3$ indicating inconclusive (anecdotal) evidence. Additionally, for each comparison we also provide results of a frequentist test to complement BF. Data distribution was first tested with the Shapiro-Wilk test, and a t-test was used when the distribution was Gaussian, or a nonparametric Wilcoxon test when it deviated from normality.

For comparisons of d' and confidence ratings two-tailed tests were used. To test for the presence of the dot-probe task effects (accuracy, RT, and N2pc) one-tailed (directional) t-tests were used, with the alternative hypothesis of: 1) higher accuracy in congruent than incongruent dot-probe trials; 2) shorter RT in congruent than incongruent dot-probe trials; and 3) values of the difference (i.e. ipsi - contra) waveform < 0. When comparing first and second half of trials one-tailed (directional) t-tests were used with the alternative hypothesis that the difference (i.e. ipsi - contra) waveform was more negative in the second half of the trials. Finally, analysis of the late (400 - 800 ms) contralateral negativity in the masked familiar condition was conducted in an exploratory manner and thus two-tailed tests were used.

Data availability statement

Alle data (including raw EEG data) and scripts used for presentation of stimuli and for analysis will be shared by authors per request.

Results

Identification task

Sensitivity index d' was calculated to evaluate subjects' ability to recognize the self-face and the familiar face. In the unmasked condition d' values were high for both the self-face ($M = 2.79 \pm 0.206$; 95% CI = [2.37 3.21]; BF > 1000; $t(28) = 13.56$, $p < 0.001$) and the familiar face ($M = 2.61 \pm 0.193$; 95% CI = [2.22 3.01]; BF > 1000; $t(28) = 13.56$, $p < 0.001$) indicating that perception was fully conscious, despite short display times. In the masked condition relatively low d' values were observed for both the self-face ($M = 0.31 \pm 0.073$; 95% CI = [0.16 0.46]) and the familiar face ($M = 0.18 \pm 0.055$; 95% CI = [0.07 0.29]), and there was no difference between the conditions (BF = 0.42, null hypothesis 2.3 more likely; $t(28) = 1.31$, $p = 0.20$). However, even though subjects perception was highly degraded, comparisons of d' to 0

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indicate performance was above chance-level in both self-face (BF = 123; $t(28) = 4.22$, $p < 0.001$) and "familiar" face conditions (BF = 18; $t(28) = 3.42$, $p = 0.002$).

Dot-probe task - behavioral results

Further, we analyzed the accuracy and reaction times (RT) of manual responses to target dots in the dot-probe task. Specifically, we investigated whether accuracy was higher and RT was shorter when target followed a potentially attention-grabbing self-face or familiar-face stimulus (i.e. congruent trials), in comparison to trials when it followed a control stimulus (i.e. incongruent trials). In all conditions we observed high accuracy values for both congruent and incongruent trials. Calculated Bayes Factors indicate moderate or anecdotal evidence in favour of the no difference between congruent and incongruent trials in both masked (self: 95.1±0.7 vs. 94.5±0.7%, BF = 0.58; familiar: 94.5±0.9 vs. 95.2±0.9%, BF = 0.10) and unmasked conditions (self: 94.0±0.8 vs. 94.3±0.7%, BF = 0.13; familiar: 94.6±0.8 vs. 95.5±0.5%, BF = 0.09). Similarly, the analysis of RT indicates moderate or anecdotal evidence in favour of the null hypothesis in both masked (self: 383.7±13.3 vs. 381.0±12.3 ms, BF = 0.12; familiar: 392.2±12.6 vs. 387.6±12.2 ms, BF = 0.56) and unmasked conditions (self: 359.8±11.5 vs. 365.1±13.9 ms, BF = 0.74; familiar: 355.3±10.4 vs. 358.8±12.2 ms, BF = 0.74).

Dot-probe task - N2pc results

Analysis of the electrophysiological data focused on the early (200-300 ms) and late (300-400 ms) parts of the N2pc component (**Fig. 1**), consistently with our previous study (Wójcik et al., 2019). Unconscious perception of the self-face evoked the early N2pc (M = -0.22±0.08; BF = 5.36; $t(28) = 2.50$, $p = 0.009$; $d = 0.46$), but the late N2pc was absent (M = -0.07±0.07; BF = 0.11, null hypothesis 9 times more likely; $t(28) = 0.93$, $p = 0.82$; $d = 0.17$). However, when the self-face was perceived consciously (i.e. in the unmasked condition) both early N2pc (M = -0.55±0.11; BF = 1480; $t(28) = 4.95$, $p < 0.001$; $d = 0.91$) and late N2pc were robustly evoked (M = -0.59±0.14; BF = 233; $t(28) = 4.20$, $p < 0.001$; $d = 0.78$). This indicates that both conscious and unconscious perception of the self-face image results in automatic attention shifts.

Further, when the familiar face was presented unconsciously Bayes Factor provides inconclusive evidence in case of both early N2pc (M = -0.13±0.09; BF = 0.94; $t(28) = 1.46$, $p = 0.07$; $d = 0.23$) and late N2pc (M = -0.15±0.09; BF = 1.32; $t(28) = 1.69$, $p = 0.050$; $d = 0.31$). But when the familiar face was processed consciously moderate evidence supporting absence of N2pc was observed in both early (M = -0.03±0.11; BF = 0.26, null hypothesis 3.8 times more likely; $t(28) = 0.33$, $p = 0.36$; $d = 0.06$) and late time window (M = 0.15±0.19; BF = 0.11, null hypothesis 9 times more likely; Z = 237, $p = 0.66$; $d = 0.09$).

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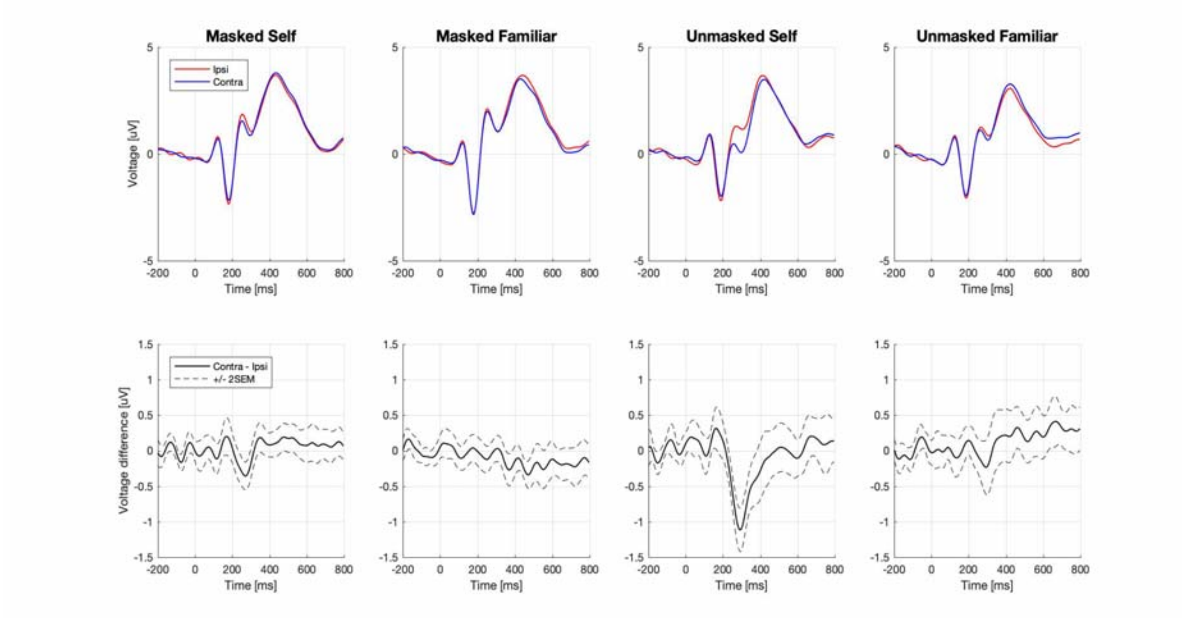

Figure 1. Event related potentials in the dot-probe task. Electrodes P7/P8 were chosen for the analysis. Waveforms from electrodes ipsi- and contra-lateral to the self- and familiar-face images are presented in the top row. Difference waveforms (i.e. contra - ipsi-lateral) are presented in the bottom-row.

Dot-probe task - changes across time

In the reported experiment participants were presented with a block of 200 trials in each condition. Thus, we hypothesized that the familiar face might capture attention only in the second part of the block, when it reaches a certain level of familiarity. To test this hypothesis within each condition we divided all trials into first and second half and compared N2pc between them. We indeed found that in the second half of the masked familiar-face block the late N2pc (0.12±0.14 vs. -0.42±0.16; BF = 3.18; Z = 328, p = 0.008; d = 0.50) exhibited more negative values. Similar trend was found for the early N2pc (0.02±0.13 vs. -0.30±0.14; BF = 1.05; t(28) = 1.05, p = 0.067; d = 0.28). One sample t-tests confirmed that both early and late N2pc were absent in the first half of trials (early N2pc: BF = 0.17; t(28) = 0.19, p = 0.57; d = 0.03; late N2pc: BF = 0.11; t(28) = 0.86, p = 0.80; d = 0.16), and present in the second (early N2pc: BF = 2.56; t(28) = 2.09, p = 0.022; d = 0.39; late N2pc: BF = 6.85; t(28) = 2.62, p = 0.007; d = 0.48). Therefore, presence of N2pc only in the second part of the block explains the inconclusive results obtained when all trials were analysed together (reported in the previous paragraph).

However, no similar effect was found when the familiar-face was perceived consciously. Here no differences between first and second halves were observed, neither for early N2pc (-0.05±0.10 vs. -0.006±0.18; BF = 0.16; t(28) = 0.22, p = 0.58; d = 0.04), nor for late N2pc (0.16±0.16 vs. 0.16±0.26; BF = 0.20; t(28) = 0.01, p = 0.49; d = 0.003). Similarly, no difference between first and second half was

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found in case of masked self-face (early N2pc: -0.26±0.11 vs. -0.19±0.14; BF = 0.15; t(28) = 0.36, p = 0.64; d = 0.06; late N2pc: 0.08±0.09 vs. 0.04±0.14; BF = 0.23; t(28) = 0.19, p = 0.42; d = 0.03) and unmasked self-face blocks (early N2pc: -0.63±0.15 vs. -0.45±0.18; BF = 0.12; Z = 143, p = 0.94; d = 0.34; late N2pc: -0.52±0.19 vs. 0.65±0.17; BF = 0.31; t(28) = 0.55, p = 0.29; d = 0.10). Therefore, the effect of stronger attention capture in the second half of the block was found for unconscious presentations of the familiar-face only.

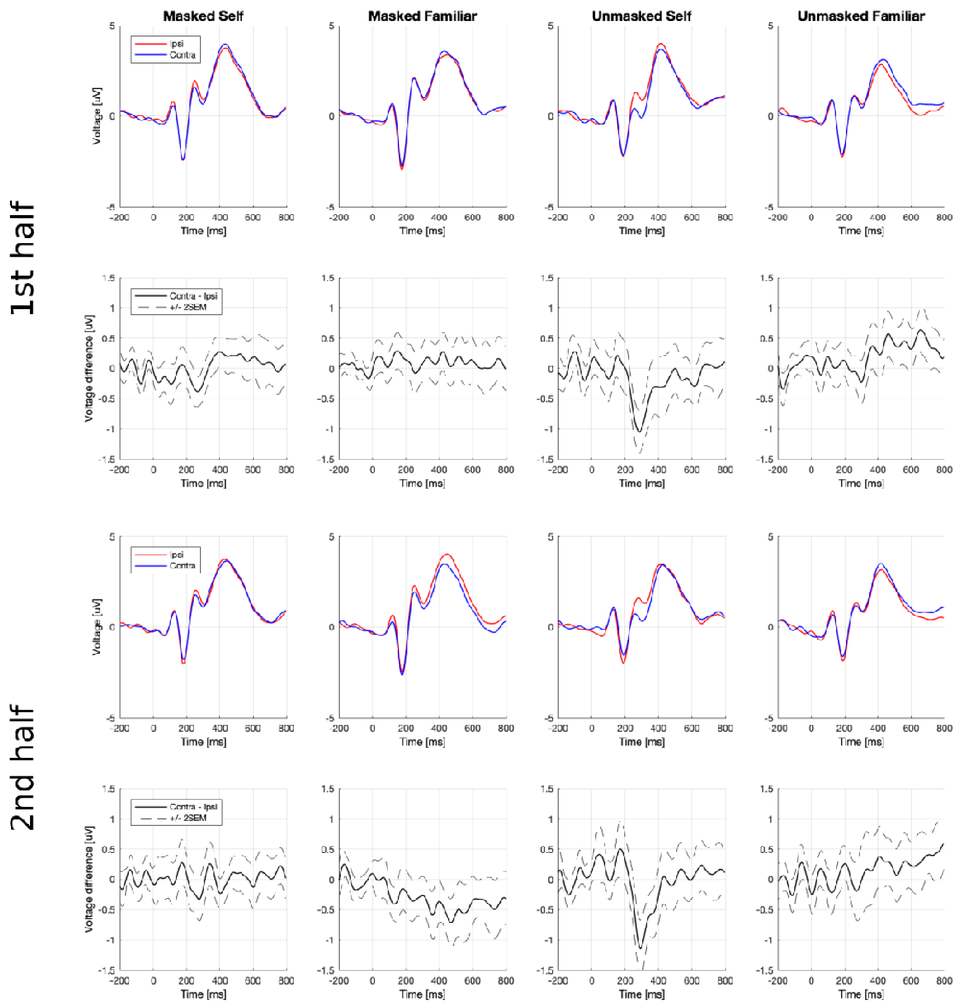

Figure 2. Event related potentials in the first and second half of trials in each block of the dot-probe task. Data are presented in the same way as in Fig. 1.

Finally, the visual inspection of the ERP waveforms suggests that the late (400-800 ms) contralateral negativity is also present exclusively in the second half of masked familiar-face presentations. Comparing the values between the first and the second half confirms more negative values in the latter (0.09±0.14 vs. -0.45±0.17; BF = 1.39; t(28) = 2.13, p = 0.042). Statistical tests confirmed that the negativity occurred in

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the second half of the block (BF = 3.1; t(28) = 2.58, p = 0.015; d = 0.48), but was not present in the first half of trials (BF = 0.24, null hypothesis 4.1 times more likely; t(28) = 0.67, p = 0.50; d = 0.12).

Correlation of perceptual sensitivity and N2pc

To evaluate whether the above chance performance in the masked identification task might have driven the unconscious attention capture effect we correlated d' and early N2pc. For the masked self-face we found anecdotal evidence for lack of correlation when d' was correlated with early N2pc (r = -0.22; BF = 0.44; p = 0.24). Similarly, the N2pc observed in the second half of the masked familiar-face trials was not correlated with d' for the masked familiar-face presentations (early N2pc: r = 0.08; BF = 0.25; p = 0.67; late N2pc: r = -0.23; BF = 0.47; p = 0.21). However, a significant correlation between d' and N2pc was found for the unmasked self-face presentations (r = -0.44; BF = 3.15; p = 0.019), which closely replicates our previous finding (Wójcik et al., 2019) and suggests that in the unmasked condition the ability to recognize one's own face better was related to stronger attention capture.

Discussion

The ability to recognize oneself is fundamental for creating and maintaining a coherent personal identity (Sui and Gu, 2017). Preferential allocation of attention to self-related stimuli is likely a key mechanism allowing fast and efficient self-recognition (Sui and Rotshtein, 2019). In the present study we demonstrate that both conscious and unconscious perception of the self-face image results in an automatic attention capture. Thus, our results suggest that self-identification and self-prioritization mechanisms operate already at the very early, pre-attentive processing stage. We further investigated the role familiarity plays in the attention capture, focusing specifically on *intra-experimentally* familiarity, which was established by repeatedly presenting a previously unfamiliar face during the experiment. We did not find any evidence that the familiar-face captured attention in the conscious condition. But unexpectedly, we found it did attract attention when presented unconsciously, but only in the second half of the trials, when visual familiarity was already well established. This finding will help to further clarify the role of basic visual familiarity in conscious and unconscious attentional selection of faces.

The role of attention in perception of self-related stimuli

A significant body of evidence indicates that self-related information benefits from preferential processing at the late, cognitive processing stages. This is suggested for instance, by greater amplitude of the P3b ERP component evoked by the self-name or face (e.g. Tacikowski and Nowicka; review: Knyazev, 2013) or better memory of the self-related stimuli (meta-analysis: Symons and Johnson, 1997).

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However, it is controversial whether the self-prioritization effect occurs already at the perceptual processing stages and in an automatic manner. Automatic effects can be defined as unintentional, unconscious, and not dependent on the availability of perceptual or cognitive resources. While several studies suggest that the self-bias meets these criteria (Tong and Nakayama, 1999; Brédart et al., 2006; Alexopoulos et al., 2012; Yamada et al., 2012; Yang et al., 2013), others claim the observed effects do not comply with this definition of automaticity (Bundesen et al., 1997; Gronau et al., 2003; Harris and Pashler, 2004; Devue and Brédart, 2008; Devue et al., 2009a, 2009b; Keyes and Dlugokencka, 2014; Qian et al., 2015). Here we support the former view by showing that the self-face attracts attention even when displayed as task-irrelevant distractor and when perception is highly degraded, which suggests the effect is unintentional and preconscious. However, as we did not investigate the role of perceptual resources in self-face processing, this will be a goal of future studies.

Controversies regarding the self-preference effect might be potentially explained by variability in types of self-related stimuli used across experiments. While the "cocktail party" effect is considered a classic demonstration of the early and preattentive ability to identify an auditorily presented self-name (Cherry, 1953; Moray, 1959; but see the criticism of Lachter et al., 2004), the visually presented self-name it typically related with relatively late brain activations, specifically the P3b component (review: Knyazev, 2013; but see: Alexopoulos et al., 2012). In contrast, the visual image of the self-face seems to cause also earlier effects, likely reflecting perceptual or attentional stages of processing. Several studies found ERP signatures of the self-face processing around 250 ms (Caharel et al. 2002; Sui et. al 2006; Tanaka et al., 2006), or even around 170-200 ms after the stimulus onset (e.g. enhanced N170 component; Keyes et al., 2010). These observations are in line with our data, suggesting that the self-face is identified and prioritized already around 200 ms after the stimulus onset.

While we found a robust N2pc effect in the dot-probe task, we did not find any behavioral effects, neither on RT, nor on accuracy. Such a dissociation between electrophysiological and behavioral measures has been already observed in previous studies (e.g. Kappenman et al., 2015; Wójcik et al., 2018, 2019). The most plausible reason is that these behavioral indices measure an outcome of a whole chain of processes (perceptual, cognitive, motor) occurring between stimulus presentation and the manual response, and thus might not be sensitive enough. ERPs, however, provide a continuous measure of neuronal engagement and thus are able to uncover even transient and covert attention shifts. Indeed, Kappenman and colleagues (2015) demonstrated moderate reliability of the N2pc, but poor reliability of the RT index in the dot-probe task (see also Schmukle, 2005). It would be important for future research to define how the N2pc component relates to behavior, particularly that recent studies suggest N2pc might not reflect attention shifts, but rather down-stream processes, like attentional engagement and features integration (Zivony et al., 2018).

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Unconscious processing of the self-face

We demonstrate that self-face captures attention even without gaining access to awareness, which strongly suggests an automatic and preattentive nature of the self-bias. Our finding is in line with several previous observations. First, the subliminally presented self-name can cause both priming (Pannese and Hirsch, 2010; Pfister et al., 2012) and interference effects (Alexopoulos et al., 2012). Second, self-related stimuli, both names and faces, break into awareness faster in the attentional blink or continuous flash suppression (CFS) paradigm (Shapiro et al., 1997; Geng et al., 2012; Macrae et al., 2017; but see: Stein et al., 2016). Of note, even though in our study the self-face did capture attention, but the familiar-face did not, the d' analysis indicates there was no difference between these stimuli with respect to access to awareness. Finally, Sui and colleagues (2012) found that low-intensity stimuli are detected more accurately when they are related to self, which also indicates they are boosted at an early, presumably preconscious processing stage (but see: Tacikowski and Ehrsson, 2016).

An emerging consensus concerning the relation between attention and consciousness is that at least minimal attention is necessary for perceptual consciousness, but consciousness is not necessary for attentional selection (Van Boxtel et al., 2010; Cohen et al., 2012; Pitts et al., 2018). Indeed, a growing body of evidence suggests that invisible stimuli might nevertheless capture attention (Woodman and Luck, 2003; Ansorage and Heumann, 2006; Hsieh et al., 2011; Lamy et al., 2015). However, previous experiments typically used simple singleton stimuli, while our work demonstrates an unconscious selection of faces. Importantly, while there is evidence that emotional expression of a face can be detected unconsciously (review: Axelrod et al., 2015; Hedger et al., 2016), it is still being debated whether an identity of a face can be processed without awareness. The results reported so far indicate that identity of an already familiar face (of a famous or personally close person) can be processed unconsciously (Henson et al., 2008; Kouider et al., 2009; Gobbini et al., 2013), but recognizing identity of an unfamiliar face requires awareness (Moradi et al., 2005; Stein and Sterzer, 2011; Axelrod and Rees, 2014). This suggests that unconscious processing is based on activation of a pre-established representation, and our results are in line with this conclusion.

The role of visual familiarity

A face might be familiar either because a person is close to us (e.g. a friend or family member) or just visually familiar (celebrity or somebody we see regularly; review: Ramon and Gobbini, 2018). Another type of familiarity is *intra-experimental familiarity*, which in our study was established by presenting an initially unfamiliar face before the experiment (and providing some fictional information about the person) and then repeatedly displaying it during the experiment. Thus, the intra-experimental familiarity

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constitutes the "weakest" form of familiarity, but it allows the most precise experimental control and sets a lower-bound on the effects that other forms of familiarity might cause.

Here we found that an intra-experimentally familiar face was not processed preferentially in the conscious condition, which seems to disagree with several previous studies. For instance, Tong and Nakayama (1999) revealed that reaction times in a search task decreases rapidly across trials when the unfamiliar face constitutes a target, but there is no improvement in case of the self-face (for which performance exhibits a ceiling level from the beginning). Further, Tanaka et al. (2006) asked subjects to detect a previously unfamiliar face of "Joe/Jane" and found that amplitude of the N250 - an ERP component indexing familiarity - increased across trials (but again, processing of the self-face did change over time). However, the main difference between these and our experiment is that in our study faces were presented not as targets, but as task-irrelevant distractors. This might thus be the main reasons why we did not observe any "learning effect" of a familiar face in the conscious condition.

Yet, considering no effect in the conscious condition - neither in the first, nor in the second half of the block - it is peculiar that unconscious presentations of the familiar face did in fact attract attention. This effect was observed only in the second half of trials, thus only after a sufficient number of presentations. We speculate that subliminal perception of the familiar but highly degraded face features caused attention shifts in order to facilitate further recognition. It is well established that when a stimulus is degraded or ambiguous then expectations and other top-down factors play a greater role in perception, but here we show that the attention was shifted to a familiar but degraded stimulus in a bottom-up manner. We thus argue that the dissociation between the role of familiarity in conscious and unconscious processing requires further investigation. Of note, the unconscious block was always presented first, and conscious block second, thus during conscious presentations familiarity was already firmly established. Considering this, the presence of the attention capture effect in the unconscious, but not in the conscious condition, is even more striking.

Limitations and conclusions

One of the possible limitations of our study is that even though d' values observed in the masked conditions were low (self-face: $M = 0.31 \pm 0.073$; familiar-face: $M = 0.18 \pm 0.055$), they were statistically greater than 0, indicating above chance-level performance. Thus, one can claim that perception was highly degraded but not fully unconscious, and that residual awareness drives the "unconscious" attention capture. We present three arguments to mitigate this concern. First, N2pc amplitude was not correlated with d', neither in the masked self-face, nor in the masked familiar-face condition. Second, d' was estimated based on the identification task data, in which self- and familiar-face were considered task relevant targets. Because in the dot-probe task faces were supposed to be ignored as distractors, subjects

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were likely less perceptually sensitive to faces in the dot-probe than in the identification task. Third, it is not known to what extent the above chance-level d' indicates subjective awareness, in contrast to an unconscious "blind-sight" type of processing, which has been documented in case of face perception (review: Axelrod et al., 2015).

In conclusion, we found that the self-face robustly captures attention when presented consciously and unconsciously. This finding adds to the body of evidence suggesting an early and automatic prioritization mechanisms for self-related information. However, the intra-experimentally familiar face was not prioritized in the conscious condition, but did capture attention when processed unconsciously. This suggests that familiarity with basic physical features of a face might contribute differently to early preconscious and later conscious processing stages. In general, our study demonstrates that complex stimuli might be processed and capture attention without consciousness, providing further evidence that attention and consciousness can be dissociated.

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