



## Research report

# The activation of visual memory for facial identity is task-dependent: Evidence from human electrophysiology



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## ABSTRACT

The question whether the recognition of individual faces is mandatory or task-dependent is still controversial. We employed the N250r component of the event-related potential as a marker of the activation of representations of facial identity in visual memory, in order to find out whether identity-related information from faces is encoded and maintained even when facial identity is task-irrelevant. Pairs of faces appeared in rapid succession, and the N250r was measured in response to repetitions of the same individual face, as compared to presentations of two different faces. In Experiment 1, an N250r was present in an identity matching task where identity information was relevant, but not when participants had to detect infrequent targets (inverted faces), and facial identity was task-irrelevant. This was the case not only for unfamiliar faces, but also for famous faces, suggesting that even famous face recognition is not as automatic as is often assumed. In Experiment 2, an N250r was triggered by repetitions of non-famous faces in a task where participants had to match the view of each face pair, and facial identity had to be ignored. This shows that when facial features have to be maintained in visual memory for a subsequent comparison, identity-related information is retained as well, even when it is irrelevant. Our results suggest that individual face recognition is neither fully mandatory nor completely task-dependent. Facial identity is encoded and maintained in tasks that involve visual memory for individual faces, regardless of the to-be-remembered feature. In tasks without this memory component, irrelevant visual identity information can be completely ignored.

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## 1. Introduction

Are face perception and recognition fully automatic processes or can they be modulated by attention and top-down task

sets? This question has been studied intensively (see Palermo & Rhodes, 2007; for a review), and the answer may depend on which aspects of face processing are being investigated. While the detection of facial configurations may be pre-attentive (e.g., Suzuki & Cavanagh, 1995; Vuilleumier, 2000), it is often

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assumed that recognizing the identity of individuals requires selective attention to those invariant facial cues that define identity (e.g., Palermo & Rhodes, 2002). If this is correct, individual faces may not be recognized automatically, but only in contexts where facial identity is task-relevant. However, results from behavioural repetition priming experiments suggest that the identity of familiar faces is encoded and maintained irrespective of whether or not observers are required to recognize these faces (Ellis, Young, & Flude, 1990). In these experiments, participants first performed familiarity, expression, or gender judgements on a set of familiar or unfamiliar faces. During a second phase, explicit familiarity judgements were required. The recognition of previously seen familiar faces was faster than the recognition of novel faces. Critically, these repetition priming effects were not only observed when faces had to be identified during the initial encounter, but also when gender or expression discriminations were required instead. Based on these results, Ellis et al. (1990) argued that the identity of familiar faces is impossible to ignore, and is encoded and retained in a task-independent mandatory fashion.

Interestingly, no such repetition priming effects were found for unfamiliar faces (Ellis et al., 1990), suggesting that identity-related visual cues from novel faces were not encoded or maintained when they were not task-relevant (but see Goshen-Gottstein & Ganel, 2000; for a demonstration of repetition priming effects with unfamiliar faces). This apparent difference between familiar and unfamiliar face recognition may be linked to the nature of the underlying representations in visual face memory. Representations of famous or personally familiar faces have been formed across time on the basis of numerous previous perceptual episodes, and are thus likely to be well established in visual memory, and easy to maintain and activate when the same individual face is encountered again. In contrast, memory traces of unfamiliar faces are based on a very limited number of prior encounters, and may therefore be more transient and harder to maintain and re-activate. Such differences in the memory representation of familiar as compared to unfamiliar faces may be responsible for the discrepancy between our excellent recognition memory for familiar faces and our poor ability to individuate unfamiliar faces (see Burton & Jenkins, 2011; for review). They may also result in systematic differences in the degree to which identity-related face processing is mandatory: Familiar faces may be recognized regardless of current task demands, whereas identity-relevant information from unfamiliar faces may be processed only when this is relevant for the task at hand.

The aim of the present study was to use event-related brain potential (ERP) measures of face processing to obtain new insights into the question whether face recognition is mandatory or task-set dependent, and to what degree this depends on whether a face is familiar or unfamiliar. Most ERP investigations of face processing have focused on the face-sensitive N170 component, which is triggered at lateral posterior electrodes 150–190 msec after stimulus onset. N170 amplitudes are typically unaffected by face familiarity (Eimer, 2000; Bentin & Deouell, 2000) or face identity repetition (Schweinberger, Pickering, Burton, & Kaufmann, 2002), which suggests that they reflect early stages of face perception that

precede the explicit recognition of individual faces (Rossion et al., 2000; see also Eimer, 2011; Rossion & Jacques, 2011; for recent reviews). ERP components sensitive to identity-related face processing are usually found at latencies beyond 200 msec post-stimulus. In experiments where pairs of faces are presented successively, the repeated presentation of the face of the same individual triggers an enhanced negativity at inferior occipito-temporal electrodes, relative to trials where faces of two different individuals are shown. This N250r component is usually maximal between 220 msec and 280 msec and is accompanied by a broadly distributed anterior positivity (e.g., Schweinberger, Pfütze, & Sommer, 1995; Begleiter, Porjesz, & Wang, 1995; Schweinberger et al., 2002; Schweinberger, Huddy, & Burton, 2004). N250r components can be observed for repetitions of familiar as well as unfamiliar faces (e.g., Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Itier & Taylor, 2004), although this component is often smaller with unfamiliar faces (Pfütze, Sommer, & Schweinberger, 2002).

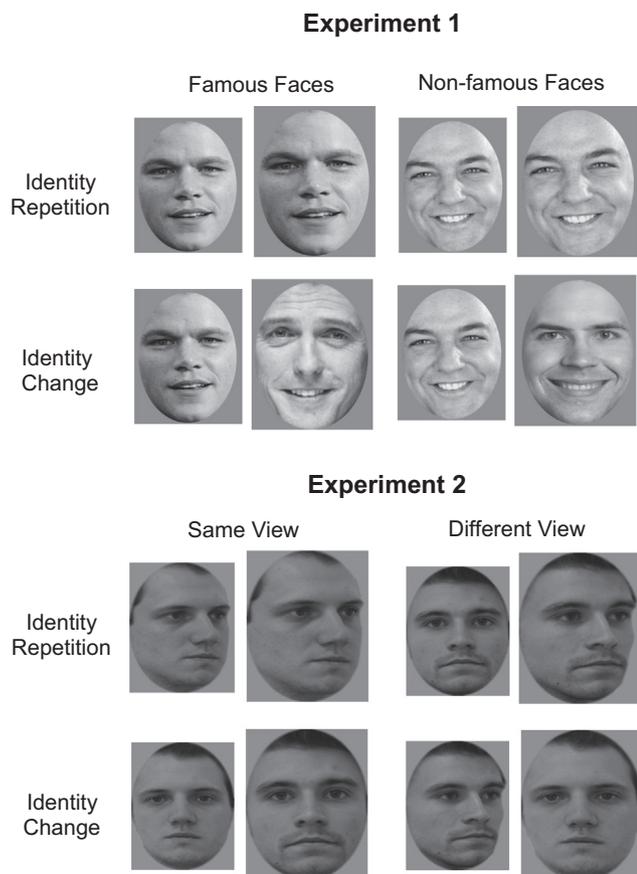
Importantly, N250r components are not just elicited in response to repetitions of physically identical face stimuli, but also when two different images of the same famous individual are presented (e.g., Bindemann, Burton, Leuthold, & Schweinberger, 2008). This image-independence of the N250r, which has also been demonstrated for repetitions of unfamiliar faces (Kaufmann, Schweinberger, & Burton, 2009; Caharel, d'Arripe, Ramon, Jacques, & Rossion, 2009; Zimmermann & Eimer, 2013), demonstrates that this component does not simply reflect repetitions of low-level perceptual features, but is instead related to the processing of facial identity. The N250r component is assumed to be triggered when the representation of a specific individual face in visual memory is activated by a match with the perceptual representation of a currently seen face (Schweinberger & Burton, 2003). In other words, the N250r is interpreted as an electrophysiological marker for the activation of view-independent face recognition units (FRUs; Bruce & Young, 1986; see Kaufmann et al., 2009). This interpretation is supported by the fact that N250 components are not only elicited in face repetition experiments, but have also been observed in response to participants' own faces (Tanaka, Curran, Porterfield, & Collins, 2006) and to previously known famous faces (Gosling & Eimer, 2011). The time course and scalp topography of these N250 components is very similar to the repetition-induced N250r (see Schweinberger, 2011; for a review), suggesting that both may be linked to analogous processes involved in the activation of visual memories of individual faces.

If N250r components reflect an early stage of face recognition where representations in visual face memory are activated by current perceptual input, they can be employed as a tool to investigate whether identity-related visual cues are encoded and retained in a mandatory fashion or only in contexts where facial identity is explicitly task-relevant, and whether this differs as a function of an observer's prior familiarity with an individual face. In an earlier study by Trenner, Schweinberger, Jentzsch, and Sommer (2004), N250r components to repetitions of famous faces were measured during an identity matching task (direct task) and during a different indirect task where participants had to classify the second face in each pair as actor or singer, and the identity of

the first face was not task-relevant. N250r components were elicited not only in the identity matching task but also in the indirect task, suggesting that the identity of famous faces is encoded and maintained even when it is formally task-irrelevant (see also Neumann & Schweinberger, 2008, 2009). However, N250r amplitudes were smaller in the indirect task, which indicates that processes involved in the visual recognition of familiar faces are not triggered in a completely mandatory fashion (as suggested by Ellis et al., 1990), but are subject to strategic modulations by current task demands. The effects of task context on the N250r to unfamiliar face repetitions have not yet been investigated systematically. In one study with unfamiliar faces (Schweinberger et al., 2004), reliable N250r components were observed while participants monitored stimulus sequences for infrequent target objects (butterflies), and face identity was task-irrelevant, suggesting that identity-related visual information from unfamiliar faces is encoded and maintained even when this is not explicitly required. Because task context was not manipulated in this study, this conclusion needs to remain tentative.

The goal of the present study was to employ the N250r component to investigate under which task conditions the identity of famous or unfamiliar faces is processed and maintained. On each trial, face pairs were presented in rapid succession. Each face was shown for 200 msec, and both faces were separated by a 200 msec interstimulus interval (ISI). This rapid sequential presentation procedure can track the rapid encoding and short-term maintenance of identity-related visual memory traces, and was already employed in a previous study (Zimmermann & Eimer, 2013) to investigate the view-independence of unfamiliar face recognition. On half of all trials, the two face images showed the same individual, and two different individuals were shown on the other half (see Fig. 1). In Experiment 1, all faces were shown in a front view, and the critical manipulation concerned the task-relevance of facial identity: In the identity matching task, participants had to report at the end of each trial whether the two successively presented faces showed the same or two different individuals. In this task, facial identity was task-relevant, and identity-related cues from the first face had to be encoded and maintained in order to be matched with the second face. In the other task, participants were instructed to respond to infrequent target stimuli (inverted faces) that appeared with equal probability as the first or second image within a trial. In this target detection task, facial identity was task-irrelevant, as participants only had to monitor the stimulus sequences for the occasional upside-down face.

If visual face recognition, as reflected by the N250r component, is a strictly mandatory phenomenon that is triggered regardless of whether facial identity is task-relevant, N250r components of similar size should be triggered during the identity matching and target detection tasks of Experiment 1. In contrast, if the processing and maintenance of identity-related visual cues was completely task-dependent, N250r components should only be observed in the identity matching task, but should be entirely absent in the target detection task. Because the processing of facial identity may be mandatory for familiar faces, but task-dependent for unfamiliar faces, these alternative hypotheses were tested separately for familiar and unfamiliar faces. On different trials, the face pairs showed either the same or two different famous faces, or the same or two different non-famous faces. Famous and non-famous face pairs appeared with equal probability and unpredictably in each block. If the identity of famous faces is always encoded and maintained regardless of whether or not it is task-relevant, N250r components to famous face repetitions should be observed in both tasks. In contrast, if the identity-related processing of unfamiliar faces was task-dependent, N250r components to non-famous face repetitions should be present only in the identity matching task, but not during the target detection task.



**Fig. 1** – Examples of face pairs presented in Experiments 1 and 2. The second face in each pair was always slightly larger than the first, and identity was repeated or changed on half of all trials. In Experiment 1 (top panel), face pairs showed either famous or non-famous individual faces. In Experiment 2 (bottom panel), only non-famous faces were shown, and face pairs either appeared in the same view or in two different views.

## 2. Experiment 1

### 2.1. Method

#### 2.1.1. Participants

Twelve paid volunteers (five females, mean age 28 years) were tested. Data from two further participants were excluded due

to an insufficient number of artefact-free EEG trials (less than 60% of all trials left after artefact rejection). All participants were right-handed, had normal or corrected-to-normal vision, and gave written informed consent prior to the experiment.

### 2.1.2. Stimuli and procedure

Face stimuli were taken from a stimulus set previously employed by Gosling and Eimer (2011). Photographs of 30 different individuals were shown. There were 15 greyscale images of non-famous faces and 15 images of famous individuals. Famous faces were individuals widely known to the general public in the UK (actors and other celebrities). For each individual famous face, a non-famous face of the same gender was selected from a larger sample to provide a match in terms of approximate age, facial expression, and low-level visual attributes such as contrast and brightness. All face stimuli were cropped into an oval shape to remove their outer contours (Fig. 1, top panel). They were shown in a full front view at the centre of a computer screen against a light grey background ( $16.5 \text{ cd/m}^2$ ). The average luminance of the face photographs was  $21.9 \text{ cd/m}^2$ .

On each trial, two face stimuli were presented sequentially for 200 msec, separated by a 200 msec ISI. To avoid identical retinal stimulation on trials where stimulus pairs showed the same face, the visual angle subtended by the first face was always smaller ( $6.9^\circ \times 4.3^\circ$ ) than the size of the second face ( $8.0^\circ \times 5.2^\circ$ ). The interval between the offset of the second face and the onset of the first face on the next trial was 1500 msec. The stimulus pairs shown on each trial were always either both famous or both non-famous faces. On 50% of all trials, two identical faces were presented successively (identity repetition trials). On the other half of all trials, faces of two different individuals were shown (identity change trials). Identity repetition and identity change trials with famous or non-famous face pairs were equiprobable and randomly distributed in each block.

The experiment consisted of two separate parts of eight consecutive blocks with 80 trials per block, in which participants performed two different tasks. In the *identity matching task*, explicit judgements about the identity of each face pair were required. Participants were instructed to press a left-hand response key when the second face was identical to the first face, and a right-hand key when two different individuals were shown, irrespective of whether these were faces of famous or non-famous individuals. Each block contained 20 trials for each combination of repetition (identity repetition vs identity change) and familiarity (famous faces vs non-famous faces). In the *target detection task*, facial identity and the identity relationship between the first and second face in each pair were task-irrelevant. Participants were instructed to detect and respond with a right-hand key press to infrequent target stimuli (inverted faces). Inverted faces were generated by rotating each photograph in the stimulus set by  $180^\circ$ . Each block contained 64 non-target trials (i.e., trials without an inverted face), with 16 trials for each combination of repetition and familiarity. In the remaining 16 target trials, an inverted face was presented with equal probability as the first or second face within each face pair. Inverted face targets were equally likely to be famous or non-famous, and equally likely to be paired with an upright image of the same or a different individual. The order in which these two tasks were

delivered was counterbalanced across participants. Prior to the start of the first experimental block in each task, participants completed a training block of 80 trials.

At the end of the experiment, participants' ability to recognize the famous faces used here was tested. All famous and non-famous face were shown in random order for 600 msec each, with an 800 msec blank interval between successive face presentations. Participants pressed left or right response keys to signal the presence of a famous or non-famous face, respectively. Famous face recognition performance was very high: On average, participants correctly classified 88% of all famous faces. A first analysis of electroencephalogram (EEG) data was conducted after the exclusion of those famous faces that were subsequently not recognized, and another analysis was performed across all famous faces. Because these two sets of analyses produced virtually identical results, the EEG analyses reported below are based on the complete set of all famous faces.

### 2.1.3. EEG recording and data analyses

EEG was DC-recorded with a BrainAmps DC amplifier (upper cut-off frequency 40 Hz, 500 Hz sampling rate) and Ag–AgCl electrodes mounted on an elastic cap from 25 scalp sites (Fpz, F7, F3, Fz, F4, F8, FC5, FC6, T7, C3, Cz, C4, T8, CP5, CP6, P7, P3, Pz, P4, P8, PO7, PO8, P9, P10, and Oz), according to the extended international 10–20 system. Horizontal electrooculogram (HEOG) was recorded bipolarly from the outer canthi of both eyes. An electrode placed on the left earlobe served as reference for online recording, and EEG was re-referenced off-line to the average of the left and right earlobe. Electrode impedances were kept below 5 k $\Omega$ . No additional off-line filters were applied. EEG was segmented and averaged from 50 msec prior to 400 msec after the onset of the second face in each stimulus pair, relative to a 100 msec baseline (from 50 msec before to 50 msec after the onset of the second face stimulus; see Eimer, Kiss, & Nicholas, 2010; Eimer, Gosling, Nicholas, & Kiss, 2011; Zimmermann & Eimer, 2013; for the same baseline correction procedures in experiments where two successive images were also separated by a 200 msec interval). Epochs with EEG activity exceeding  $\pm 30 \mu\text{V}$  in the HEOG channel (reflecting horizontal eye movements) or  $\pm 60 \mu\text{V}$  at Fpz (indicating eye blinks or vertical eye movements) were excluded from analysis, as were epochs with voltages exceeding  $\pm 80 \mu\text{V}$  at any other electrode. The mean rate of excluded trials across all participants was 13%. Following artefact rejection, EEG waveforms were averaged separately for trials with famous and non-famous faces, for all four combinations of the factors task (identity matching vs target detection) and repetition (identity repetition vs identity change). For the target detection task, only non-target trials (i.e., trials where no inverted face was presented) were included in the EEG analyses.

Mean amplitude values were computed at posterior electrode pairs P7/8 and P9/10 for the N170 time interval (160–190 msec after the onset of the second face) and the N250r time interval (210–260 msec after the onset of the second face). Separate repeated-measures analyses of variance (ANOVAs) were performed for trials with famous and non-famous faces. These analyses included the factors task, repetition, recording hemisphere (left vs right), and electrode site (P7/8 vs P9/10).

## 2.2. Results

### 2.2.1. Behavioural performance

Accuracy in both tasks was close to ceiling. Participants correctly discriminated identity repetitions and changes on 98% of all trials in the identity matching task, and detected 99% of all inverted face targets in the target detection task. In the identity matching task, responses to identity repetitions were faster than to identity changes [424 msec vs 457 msec;  $F(1,11) = 11.2, p < .01$ ]. Mean reaction time (RT) was 441 msec in the target detection task. Face familiarity (famous vs non-famous faces) had no effect on accuracy or RTs in either task.

### 2.2.2. ERP markers of visual face memory

Fig. 2 shows ERPs triggered in Experiment 1 by the second face stimulus in each pair at lateral occipital electrode pairs P7/8 and P9/10 on identity repetition and identity change trials. Results are shown for famous faces (left) and non-famous faces (right), separately for the identity matching task that required explicit judgements about facial identity (top panels), and the target detection task where identity was task-irrelevant (bottom panels). The face-sensitive N170 component appeared to be largely unaffected by identity repetitions versus identity changes. The subsequent N250r component

was strongly task-dependent: It was present in the identity matching task, but appeared to be entirely absent in the target detection task. Importantly, this strong task-dependence of the N250r seemed to be independent of whether famous or non-famous faces were presented.

These observations were confirmed by statistical analyses. There was no main effect of repetition on N170 mean amplitudes (160–190 msec post-stimulus) on trials with famous faces [ $F(1,11) = .15, p = .837$ ] or non-famous faces [ $F(1,11) = .03, p = .863$ ], and no significant interaction between task and repetition [ $F(1,11) = 3.4$  and  $2.7, p < .091$  and  $.127$ , for famous and non-famous faces, respectively]. Follow-up analyses conducted on N170 amplitudes to famous and non-famous faces separately for the identity matching and target detection tasks found no reliable effects of repetition [all  $F(1,11) < .92$ ; all  $p > .36$ ], indicating that the N170 component was not differentially modulated by identity repetitions versus changes. No other significant main effects or interactions were present in the N170 time window.

The analysis of ERP mean amplitudes on trials with famous faces obtained in the subsequent N250r measurement window (210–260 msec post-stimulus) at electrodes P7/8 and P9/10 obtained a main effect of task [ $F(1,11) = 13.4, p < .004$ ]. ERPs were generally more negative in the identity matching task

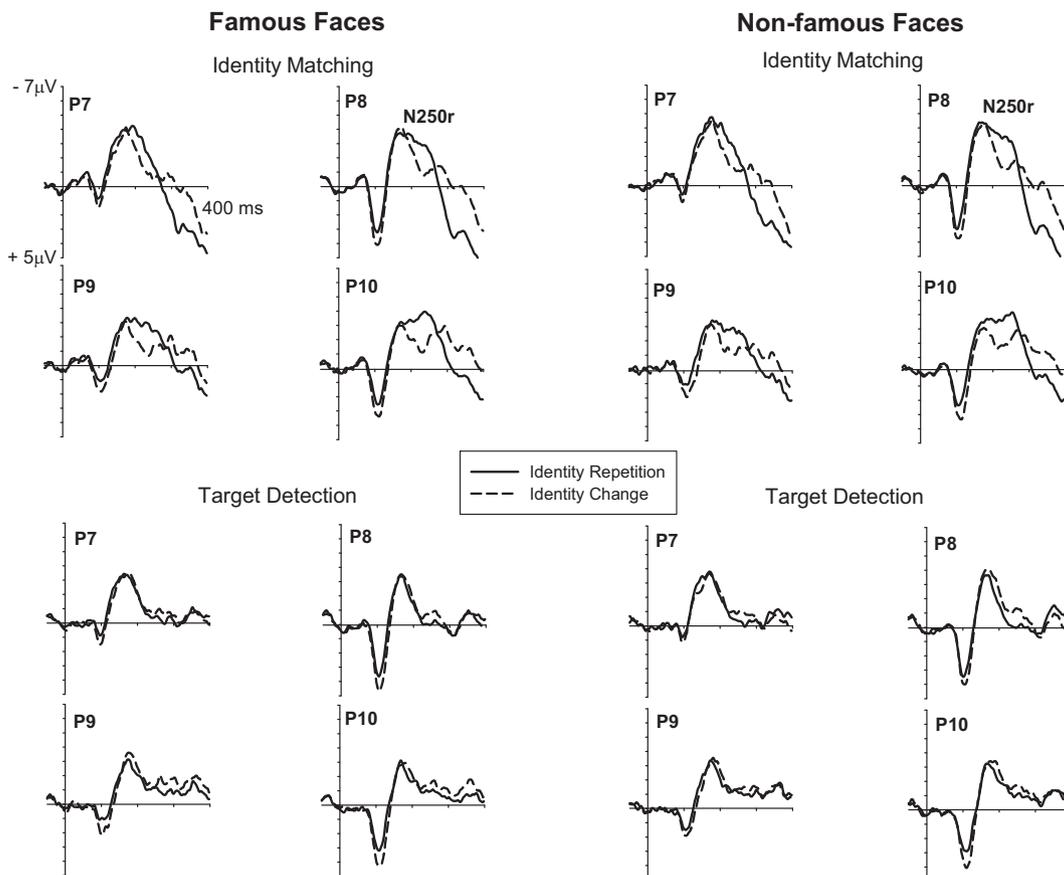
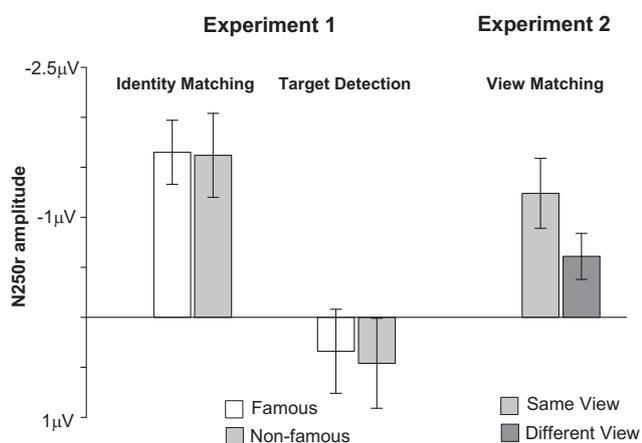


Fig. 2 – Grand averaged ERPs measured in Experiment 1 at lateral posterior electrodes pairs P7/8 and P9/10 in the 400 msec interval after the onset of the second stimulus in a face pair, for identity-repetition trials (solid lines) and identity-change trials (dashed lines). ERPs are shown for famous faces (left panel) and for non-famous faces (right panel), separately for the identity matching task where identity information was relevant, and the target detection task where it was irrelevant.

relative to the target detection task (see Fig. 2), presumably reflecting the demands of the matching task on visual working memory. The main effect of repetition did not reach significance [ $F(1,11) = 3.7, p = .081$ ]. Critically, there was an interaction between task and repetition [ $F(1,11) = 27.5, p < .001$ ], suggesting that the N250r to famous faces was strongly task-dependent. No other main effects or interactions were significant in this ANOVA. Follow-up analyses conducted separately for both tasks revealed the presence of a reliable N250r component to famous face repetitions in the identity matching task [ $F(1,11) = 14.7, p < .01$ ]. In contrast, this component was absent in the target detection task [ $F(1,11) = .57, p = .465$ ]. A very similar pattern of N250r results was found for trials with non-famous faces. There was a main effect of task [ $F(1,11) = 12.6, p < .004$ ], reflecting more negative posterior ERPs in the identity matching task, but no reliable main effect of repetition [ $F(1,11) = 2.45, p = .145$ ]. Importantly, the interaction between task and repetition was again highly significant [ $F(1,11) = 22.6, p < .001$ ]. Follow-up analyses confirmed the presence of a N250r component to repetitions of non-famous faces in the identity matching task [ $F(1,11) = 14.7, p < .001$ ], and the absence of this component in the target detection task [ $F(1,11) = 1.13, p = .312$ ].

Fig. 3 (left and middle panels) shows mean N250r amplitudes measured at posterior electrode pairs P7/8 and P9/10 on trials with famous and non-famous faces in the identity matching and target detection tasks of Experiment 1. The amplitude values shown here were obtained by subtracting ERP mean amplitudes recorded in the N250r time window on trials with an identity change from ERPs measured on identity



**Fig. 3 – Amplitudes of N250r components observed in the identity matching and target detection tasks of Experiment 1 (left and middle panels) and in the view matching task of Experiment 2 (right panel). N250r amplitude values were computed by subtracting ERP mean amplitudes measured at lateral posterior electrodes (collapsed across P7/8 and P9/10) in the 210–260 msec post-stimulus interval on identity-change trials from ERP mean amplitudes measured on identity-repetition trials. Data are shown separately for trials with famous and non-famous faces (Experiment 1) and for same-view and different-view trials (Experiment 2). Error bars represent standard errors of the mean.**

repetition trials. N250r components of similar size were observed for repetitions of famous and non-famous faces in the identity matching task. In contrast, no N250r was present for either famous or non-famous faces in the target detection task. To statistically test the observation that the task-dependence of the N250r component was equivalent for famous and non-famous faces, an additional analysis was conducted across all trials in Experiment 1, with the additional factor familiarity (famous vs non-famous faces). There was a significant interaction between repetition and task [ $F(1,11) = 32.8, p < .001$ ], again demonstrating that the N250r component was strongly modulated by task demands. Importantly, the three-way interaction between repetition, task, and familiarity was far from significant [ $F(1,11) = .97, p = .345$ ], in line with the hypothesis that the N250r to famous and non-famous faces was similarly affected by the task relevance of facial identity.

### 2.3. Discussion of Experiment 1

In the identity matching task, N250r components were elicited in response to repeated presentations of the same face, demonstrating that identity-related visual cues were encoded and maintained in line with the demands of this task. This was the case not only for famous faces, but also for non-famous faces. These results show that when two face images are presented in rapid succession, and facial identity is task-relevant, identity-related visual information can be extracted very fast, and this information is then immediately available to be compared to perceptual representations of another face (see also Zimmermann & Eimer, 2013; for analogous findings). For this rapid comparison process, the strength of pre-existing long-term representations of individual faces appears to be largely irrelevant, as N250r components were similar in size for repetitions of famous and non-famous faces.

In marked contrast to the results observed in the identity matching task, no N250r components were triggered by face repetitions in the target detection task where facial identity was irrelevant. Importantly, this was not only the case for repetitions of non-famous faces, but also when famous faces were repeated (see Fig. 2). These observations suggest that identity-related visual face processing, as reflected by the N250r, is not mandatory. It is not triggered regardless of task demands, but is instead strongly task-dependent. Under conditions where participants monitor rapidly presented sequences of upright face pairs to detect occasional inverted target faces, the identity of the first face does not seem to be explicitly represented and maintained in order to be matched with the second face. The absence of an N250r to famous face repetitions in the target detection task is particularly remarkable, since it suggests that even for famous faces, identity-related processing is strongly modulated by task demands. At least in the context of the rapid sequential presentation procedure employed here, identity-related information about famous faces does not appear to be encoded or maintained in a mandatory fashion. In other words, the formation and maintenance of perceptual representations of individual famous faces seems to depend on the requirement to explicitly encode and retain facial identity information,

even though there are already pre-existing long-term visual memory representations of these faces. We will return to this conclusion, and how it relates to previous N250r studies of famous face recognition, in the General Discussion.

Overall, the results of Experiment 1 suggest that visual representations of the identity of famous and non-famous faces are only encoded and maintained when identity is task-relevant, but not when the identity of individual faces can be ignored. However, before this conclusion can be accepted, another potentially important difference between the identity matching and target detection tasks of Experiment 1 needs to be considered. In the identity matching task, participants had to make a *relational judgement* with respect to the face pair shown on each individual trial (“same or different?”). In order to perform this judgement, information about the first face needed to be maintained and compared to perceptual information from the second face. In contrast, no relational judgement of any kind was required in the target detection task. When the first face appeared in an upright position, participants did not need to encode or maintain a representation of this face, because they were now only required to judge the orientation of the second face. It is possible that the presence of an N250r in the identity matching task and its absence in the target detection task was not directly linked to the task-relevance of facial identity, but instead to the fact that relational judgements were only required in the former task. If this interpretation was correct, N250r components should also be triggered under conditions where facial identity is task-irrelevant, but a different kind of relational judgement with respect to successively presented face pairs is required. This was investigated in Experiment 2.

### 3. Experiment 2

The strong task-dependence of identity-related face processing observed in Experiment 1 suggests that facial identity needs to be explicitly task-relevant in order for N250r components to be elicited by face repetitions. But is the specific task to match the identity of faces really necessary for the N250r to emerge, or is the requirement to perform any kind of relational judgement with respect to face pairs sufficient to trigger this component? To decide between these two alternatives, participants in Experiment 2 performed a task that required relational judgements, but facial identity was irrelevant and had to be ignored. Face pairs showing the same or two different individuals were presented in the same or two different views (Fig. 1, bottom panel). Identity repetitions versus changes and view repetitions versus changes were independent and uncorrelated. Only non-famous faces were employed in Experiment 2. Participants had to decide on each trial whether the two faces showed the same or two different views, regardless of whether they were the faces of the same or two different individuals. As in the target detection task of Experiment 1, identity-related information was completely irrelevant for this view-matching task, and had to be ignored. However, as in the identity matching task of Experiment 1, participants performed relational judgements with respect to each face pair, and thus had to retain visual information about

the first face in visual memory in order to match it with the second face.

The critical question was whether an N250r would be elicited to repetitions of the same individual face in Experiment 2. If facial identity needs to be formally task-relevant in order for identity-related visual information to be encoded and retained, this component should be absent. If the requirement to match the view of each face pair (and thus the need to maintain view-related visual information about the first face) is sufficient for information about facial identity to be encoded and maintained, an N250r component should be reliably present in Experiment 2.

#### 3.1. Method

##### 3.1.1. Participants

Twelve paid volunteers (nine females, mean age 30 years) were tested. All were right-handed, had normal or corrected-to-normal vision, and gave written informed consent.

##### 3.1.2. Stimuli and procedure

The stimulus set consisted of naturalistic photographs of 30 unfamiliar individuals (15 female faces) taken from the FEI face database (<http://fei.edu.br/~cet/facedatabase.html>). These faces were converted into greyscale and cropped into an oval shape using Adobe Photoshop 6.0 (Adobe Systems Inc.). There were two different images for each individual face – one showing the face in a front view, and the other in a right-facing side view at an angle of 45° (see Fig. 1, bottom panel). The average luminance of these face images was 7.7 cd/m<sup>2</sup>, and they were presented centrally against a light grey background (16.5 cd/m<sup>2</sup>). As in Experiment 1, the second stimulus in each face pair was larger than the first, in order to avoid identical retinal stimulation on trials where the same face image was repeated. The first face of each pair subtended a visual angle of 6.9° × 4.3°, and the second face an angle of 8.0° × 5.2°.

The time course of stimulus presentation was identical to Experiment 1. On each trial, the two successively presented faces were equally likely to show the same or two different individuals, and the same or two different views. These four different trial types appeared with equal probability and in random order. Participants performed a view matching task. They were instructed to respond with a left-hand button press on trials where both faces showed the same view, and with a right-hand button press when the two faces within a pair appeared in different views. Because these same-view versus different-view responses were unrelated to whether the two faces showed the same or two different individuals, facial identity was task-irrelevant. Eight experimental blocks consisting of 80 trials were run, with 20 trials for each combination of view (same vs different) and repetition (identity repetition vs change). One training block of 80 trials was run prior to the first experimental block.

##### 3.1.3. EEG recording and data analysis

Recording and artefact exclusion procedures were identical to Experiment 1. The mean number of excluded trials across participants was 15%. Analysis procedures were similar to Experiment 1, except that the factors task and familiarity were absent. Analyses included the factors repetition (identity

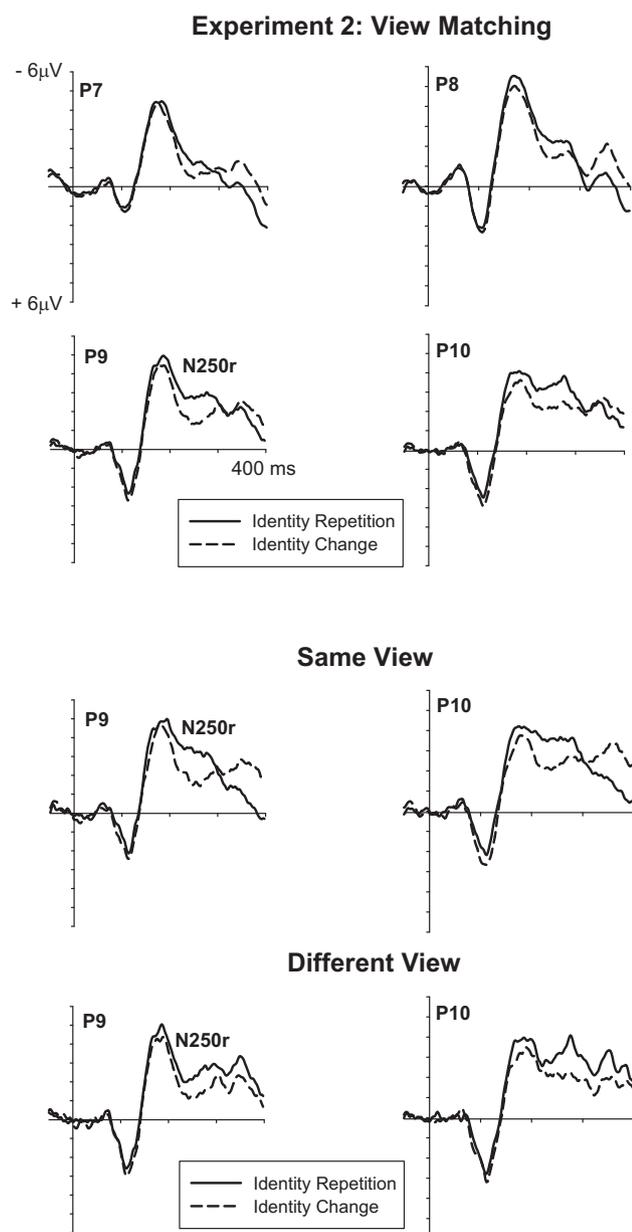
repetition vs identity change), recording hemisphere (left vs right), electrode site (P7/8 vs P9/10), and the new factor view (same view vs different view).

### 3.2. Results

#### 3.2.1. Behavioural performance

Mean accuracy in the view matching task was 95%. Responses were slightly more accurate on trials where the same

individual face was repeated in the same view (97%) relative to trials with a change in view, a change in identity, or a change in both (all 95%). This was reflected by a nearly significant repetition  $\times$  view interaction [ $F(1,11) = 4.2, p < .07$ ]. Mean RTs were also faster on trials with identity and view repetitions (505 msec) as compared to the other three types of trials (568 msec, 578 msec, and 575 msec, respectively), and the corresponding interaction between repetition and view was highly significant [ $F(1,11) = 87.1, p < .001$ ] for RTs.



**Fig. 4** – Top panel: Grand averaged ERPs measured in Experiment 2 at posterior electrodes P7/8 and P9/10 after the onset of the second stimulus in a pair, for identity repetitions (solid lines) and identity changes (dashed lines). ERPs are collapsed across same-view and different-view trials. Bottom panel: ERPs obtained in Experiment 2 at posterior electrode pair P9/10 for identity repetitions versus changes, shown separately for trials where face pairs showed the same view or two different views.

#### 3.2.2. ERP markers of visual face memory

Fig. 4 (top panel) shows ERPs triggered by the second face in each pair on identity repetition and identity change trials at lateral posterior electrodes P7/8 and P9/10, averaged across trials with view repetitions and view changes. Although identity was task-irrelevant for the view matching task of Experiment 2, identity repetitions triggered clear N250r components. The bottom panel of Fig. 4 shows ERPs at P9 and P10 on identity repetition and identity change trials, separately for trials where the two faces showed the same view or two different views. These data suggest that N250r components were elicited not just on same view trials, but also when there was a view change. This can also be seen in Fig. 3 (right panel), which shows mean N250r amplitudes obtained by subtracting lateral posterior ERPs on identity change trials from ERPs for identity repetitions, separately for trials where both faces showed the same view and trials with a change in view.

As in Experiment 1, there was no significant effect of repetition on N170 mean amplitudes [160–190 msec;  $F(1,11) = 2.88, p = .118$ ]. No other significant main effects or interactions were present in the N170 time window. During the subsequent N250r measurement window (210–260 msec post-stimulus), a reliable main effect of view was observed [ $F(1,11) = 9.2, p < .02$ ], as ERP mean amplitudes at lateral posterior electrodes were generally more negative on view repetition as compared to view change trials ( $-2.46 \mu\text{V}$  vs  $-1.81 \mu\text{V}$ ). More importantly, there was also a significant main effect of repetition [ $F(1,11) = 14.1, p < .005$ ], demonstrating that the N250r component was reliably elicited during the view-matching task of Experiment 2. Even though N250r amplitudes were larger on view repetition trials relative to view change trials (Fig. 3, right panel), the interaction between identity and view only approached significance [ $F(1,11) = 3.5, p = .089$ ]. There were no other significant main effects or interactions in this analysis of N250r mean amplitudes. Follow-up analyses were conducted separately for trials where both faces showed the same view and trials where there was a view change. These analyses confirmed the presence of reliable N250r components on not only same-view trials [ $F(1,11) = 12.4, p < .01$ ], but also on different-view trials [ $F(1,11) = 6.9, p < .05$ ].

### 3.3. Discussion of Experiment 2

The results of Experiment 2 were clear-cut: Reliable N250r components were triggered when a face of the same non-famous individual was repeated, in spite of the fact that participants now performed a view matching task, and facial identity had to be ignored. While the N250r tended to be larger on trials where the two successive faces showed the same

view relative to different-view trials (see Fig. 3, right panel), this difference was not reliable. The fact that significant N250r components were present on same-view as well as different-view trials suggests that the N250r to non-famous faces is largely view-independent (see also Zimmermann & Eimer, 2013; for similar observations).

The presence of N250r components in the view matching task of Experiment 2 provides an answer to the question that was raised by the results of Experiment 1. It demonstrates that facial identity does not need to be explicitly task-relevant in order for identity-related information about individual faces to be encoded and maintained. The critical factor appears to be the requirement to perform relational judgements, that is, to assess the match versus mismatch of a specific visual feature between successively presented faces, regardless of whether this feature is identity-related or not. Such relational tasks obviously require the encoding and retention of information about some facial features in visual face memory. The results of Experiment 2 suggest that even when facial identity has to be ignored, identity-specific information is still represented in newly acquired visual memory traces, and is immediately available to be matched to identity-related visual features from the second face. As can be seen in Fig. 3, N250r amplitudes to non-famous face repetitions in the identity matching task of Experiment 1 were only moderately larger relative to N250r amplitudes observed in same-view trials in Experiment 2 ( $-1.64 \mu\text{V}$  vs  $-1.24 \mu\text{V}$ ), and this difference was far from significant ( $t(22) = .7, p = .493$ ).

#### 4. General discussion

The question whether or not the processing of facial identity is automatic has been discussed intensively (e.g., Palermo & Rhodes, 2007). For example, it has been argued that the identity of familiar faces is impossible to ignore, because identity information is encoded and maintained in a mandatory fashion when a face has been encountered many times (Ellis et al., 1990). In the present study, we employed ERP markers of visual face recognition in order to find out whether the encoding and maintenance of identity-related information from faces is obligatory or only takes place when identity is task-relevant. We measured N250r components in response to face repetitions versus alternations under conditions where face pairs were presented in rapid succession. The results of Experiment 1 demonstrated that the processing of facial identity is strongly task-dependent, and that this is the case not only for non-famous faces, but also for famous faces, suggesting that the recognition of familiar faces may not be as mandatory as is often assumed (Ellis et al., 1990). Experiment 2 demonstrated that facial identity does not have to be explicitly task-relevant for N250r components to emerge. Instead, it is the requirement to form and retain a perceptual representation of an individual face for a subsequent comparison with another face that is sufficient for the presence of an N250r, regardless of the nature of the to-be-retained facial feature (e.g., identity or view). This suggests that different features of an individual face are represented in an integrated fashion, and that a currently task-relevant attribute (such as view in Experiment 2) cannot be represented without facial identity

being represented as well. Overall, the results of Experiments 1 and 2 imply that face recognition, as reflected by the N250r component, is neither fully mandatory nor entirely restricted to task contexts where facial identity is relevant. The absence of an N250r in the target detection task of Experiment 1 demonstrates that the identity-sensitive mechanisms that underlie this component are not activated under all circumstances, and may not be triggered in situations where no visual memory trace of individual faces needs to be retained across successive presentations. The results of Experiment 2 showed that when a task requires the formation of visual memory traces, facial identity will be processed and retained, even when it is task-irrelevant.

These findings also have general implications for models of visual selective attention and visual working memory. The hypothesis that faces are represented as integrated objects rather than independent features is in line with the idea that selective attention operates in an object-based fashion (e.g., Duncan, 1984). When attention is directed to one particular relevant feature (e.g., the view of a face), other features of the same object are processed as well, even when they are irrelevant to the task in hand (see also Melcher, Papathomas, & Vidnyanszky, 2005; for corresponding findings for combinations of colour and motion). Our results are also in line with previous suggestions that information in working memory is represented as integrated objects and not as independent features (Luck & Vogel, 1997; but see Wheeler & Treisman, 2002). If different aspects of a remembered face are always stored in a bound fashion in visual working memory, a currently task-relevant attribute cannot be maintained without other irrelevant properties of the same face being represented as well. While previous evidence for the object-based nature of visual working memory has mainly come from experiments that investigated conjunctions of simple visual features such as colour, orientation, or size (e.g., Luck & Vogel, 1997), the current findings suggest that the same principles might also apply to working memory representations of higher-level features of more complex objects, such as individual faces.

The pattern of N250r results observed in the present study is only partially consistent with the findings of previous experiments that employed the N250r component as a marker of visual face recognition. The observation of Experiment 1 that the N250r to famous face repetitions was absent in the target detection task where facial identity was irrelevant appears to conflict with previous findings that repetitions of famous faces trigger an N250r even when their identity is not task-relevant (e.g., Neumann & Schweinberger, 2008, 2009). For example, Trenner et al. (2004) measured N250r components to famous faces in a direct task where facial identity was relevant and in an indirect task where it was not. They found larger N250r amplitudes in the direct task, but a significant N250r also in the indirect task, suggesting some degree of task-independence of famous face recognition. However, even the indirect task used by Trenner et al. (2004) required access to person-specific semantic information about the second face (actor vs singer), which might have produced a general bias in favour of processing identity-specific facial cues, even for the first task-irrelevant face in each pair. In contrast, the target detection task in Experiment 1 did not

involve any judgement based on semantic information about individual faces, but could be based entirely on low-level structural properties of a face (i.e., inversion), which are available prior to identity-related face processing (Bruce & Young, 1986). Another potentially important difference between the current study and earlier experiments which found an N250r to task-irrelevant famous face repetitions (e.g., Neumann & Schweinberger, 2008, 2009) is that the interval between successive face stimuli was considerably longer in these previous studies. It is possible that the identity of irrelevant famous faces will be processed when this does not interfere with the temporal demands of a current task. In the target detection task of Experiment 1, the requirement to detect the presence of an inverted face in a rapidly presented sequence of two faces may have been sufficiently demanding to prevent the additional simultaneous processing of identity-related cues, even for famous faces. Even though the recognition of famous faces may appear to be mandatory under other less temporally demanding circumstances, the absence of an N250r to famous face repetitions in the target detection task of Experiment 1 suggests that famous face recognition is not mandatory in the strict sense that it will always take place regardless of the specific conditions of an experimental task.

In summary, the current findings provide new electrophysiological evidence for a strong modulation of visual face recognition by task-dependent strategic processing. Facial identity is encoded and retained whenever a task requires the formation of a visual memory trace of an individual face, even when identity itself is task-irrelevant. In contrast, irrelevant identity-related information can be completely ignored during tasks that do not have this memory component, but impose high temporal demands on visual stimulus processing. Surprisingly, this is the case not only for unfamiliar faces, but also for faces of famous individuals. Overall, these results highlight the flexible and adaptive nature of the neural processes that underlie the acquisition of identity-specific visual face memories.

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## REFERENCES

- Begleiter, H., Porjesz, B., & Wang, W. Y. (1995). Event-related brain potentials differentiate priming and recognition to familiar and unfamiliar faces. *Electroencephalography and Clinical Neurophysiology*, 94(1), 41–49.
- Bentin, S., & Deouell, L. Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology*, 17(1–3), 35–54.
- Bindemann, M., Burton, A. M., Leuthold, H., & Schweinberger, S. R. (2008). Brain potential correlates of face recognition: geometric distortions and the N250r brain response to stimulus repetitions. *Psychophysiology*, 45(4), 535–544.
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, 77(3), 305–327.
- Burton, A. M., & Jenkins, R. (2011). Unfamiliar face perception. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 287–306). New York: Oxford University Press.
- Caharel, S., d'Arripe, O., Ramon, M., Jacques, C., & Rossion, B. (2009). Early adaptation to repeated unfamiliar faces across viewpoint changes in the right hemisphere: evidence from the N170 ERP component. *Neuropsychologia*, 47(3), 639–643.
- Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, 113(4), 501–517.
- Eimer, M. (2000). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology*, 111(4), 694–705.
- Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 329–344). New York: Oxford University Press.
- Eimer, M., Gosling, A., Nicholas, S., & Kiss, M. (2011). The N170 component and its links to configural face processing: a rapid neural adaptation study. *Brain Research*, 1376, 76–87.
- Eimer, M., Kiss, M., & Nicholas, S. (2010). Response profile of the face-sensitive N170 component: a rapid adaptation study. *Cerebral Cortex*, 20(10), 2442–2452.
- Ellis, A. W., Young, A. W., & Flude, B. M. (1990). Repetition priming and face processing: priming occurs within the system that responds to the identity of a face. *The Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, 42(3), 495–512.
- Goshen-Gottstein, Y., & Ganel, Y. (2000). Repetition priming for familiar and unfamiliar faces in a sex-judgment task: evidence for a common route for the processing of sex and identity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(5), 1198–1214.
- Gosling, A., & Eimer, M. (2011). An event-related brain potential study of explicit face recognition. *Neuropsychologia*, 49(9), 2736–2745.
- Herzmann, G., Schweinberger, S. R., Sommer, W., & Jentsch, I. (2004). What's special about personally familiar faces? A multimodal approach. *Psychophysiology*, 41(5), 688–701.
- Itier, R. J., & Taylor, M. J. (2004). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *NeuroImage*, 21(4), 1518–1532.
- Kaufmann, J. M., Schweinberger, S. R., & Burton, A. M. (2009). N250 ERP correlates of the acquisition of face representations across different images. *Journal of Cognitive Neuroscience*, 21(4), 625–641.
- Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, 390, 279–281.
- Melcher, D., Papatomas, T. V., & Vidnyanszky, Z. (2005). Implicit attentional selection of bound visual features. *Neuron*, 46(5), 723–729.
- Neumann, M. F., & Schweinberger, S. R. (2008). N250r and N400 ERP correlates of immediate famous face repetition are independent of perceptual load. *Brain Research*, 1239(6), 181–190.
- Neumann, M. F., & Schweinberger, S. R. (2009). N250r ERP repetition effects from distractor faces when attending to another face under load: evidence for a face attention resource. *Brain Research*, 1270, 64–77.
- Palermo, R., & Rhodes, G. (2002). The influence of divided attention on holistic face perception. *Cognition*, 82(3), 225–257.

- Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia*, 45(1), 75–92.
- Pfütze, E.-M., Sommer, W., & Schweinberger, S. R. (2002). Age-related slowing in face and name recognition: evidence from event-related brain potentials. *Psychology and Aging*, 17(1), 140–160.
- Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., et al. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: an electrophysiological account of face-specific processes in the human brain. *NeuroReport*, 11(1), 69–72.
- Rossion, B., & Jacques, C. (2011). The N170: understanding the time-course of face perception in the human brain. In S. J. Luck, & E. S. Kappenman (Eds.), *The Oxford handbook of ERP components* (pp. 115–141). New York: Oxford University Press.
- Schweinberger, S. R., & Burton, A. M. (2003). Covert recognition and the neural system for face processing. *Cortex*, 39(1), 9–30.
- Schweinberger, S. R. (2011). Neurophysiological correlates of face recognition. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 345–366). New York: Oxford University Press.
- Schweinberger, S. R., Huddy, V., & Burton, A. M. (2004). N250r – a face-selective brain response to stimulus repetitions. *NeuroReport*, 15(9), 1501–1505.
- Schweinberger, S. R., Pfütze, E.-M., & Sommer, W. (1995). Repetition priming and associative priming of face recognition: evidence from event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(3), 722–736.
- Schweinberger, S. R., Pickering, E. C., Burton, A. M., & Kaufmann, J. M. (2002). Human brain potential correlates of repetition priming in face and name recognition. *Neuropsychologia*, 40(12), 2057–2073.
- Suzuki, S., & Cavanagh, P. (1995). Facial organization blocks access to low-level features: an object inferiority effect. *Journal of Experimental Psychology: Human Perception and Performance*, 21(4), 901–913.
- Tanaka, J. W., Curran, T., Porterfield, A. L., & Collins, D. (2006). Activation of preexisting and acquired face representations: the N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience*, 18(9), 1488–1497.
- Trenner, M. U., Schweinberger, S. R., Jentzsch, I., & Sommer, W. (2004). Face repetition effects in direct and indirect tasks: an event-related brain potentials study. *Cognitive Brain Research*, 21(3), 388–400.
- Vuilleumier, P. (2000). Faces call for attention: evidence from patients with visual extinction. *Neuropsychologia*, 38(5), 693–700.
- Wheeler, M. E., & Treisman, A. M. (2002). Binding in short-term visual memory. *Journal of Experimental Psychology: General*, 131(1), 48–64.
- Zimmermann, F. G. S., & Eimer, M. (2013). Face learning and the emergence of view-independent face recognition: an event-related brain potential study. *Neuropsychologia*, 51(7), 1320–1329.