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Research report

Perceptual fluency, semantic familiarity and recognition-related familiarity: an electrophysiological exploration

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Abstract

Scalp recorded event-related potentials (ERPs) were used to examine the neuronal activity associated with perceptual fluency, semantic familiarity and recognition-related familiarity. We assume that ERP differences between first and second presentations of non-famous faces in an implicit memory condition reflect perceptual fluency, ERP differences between first presentations of famous and non-famous faces reflect semantic familiarity (i.e., familiarity arising from semantic memory retrieval), and early ERP differences between first and second presentations of non-famous and famous faces in an explicit recognition memory task reflect recognition-related familiarity. Semantic familiarity elicited a broadly distributed effect between 200 and 300 ms after stimulus onset, possibly representing the activation of face recognition units. Between 300 and 450 ms, frontal effects were observed for semantic familiarity and recognition-related familiarity, while perceptual fluency was associated with a centro-parietally focused effect. Thus, familiarity arising from the retrieval of semantic information and recognition-related familiarity depend at least partly on the same neuronal circuits, while these are dissociable from those mediating perceptual fluency.

Theme: Neural basis of behavior
Topic: Learning and memory: physiology

Keywords: Memory; Recognition; Face; ERP; Perceptual fluency; Semantic and recognition familiarity

1. Introduction

Recognition memory, the judgment that a current event corresponds to a previously experienced event is a fundamental aspect of our ability to remember. Some memory models regard recognition as an unitary process that is determined by memory strength [14,42]. In these models, memory strength forms a continuum comprising any kind of information that can be retrieved in response to a recognition cue. Other models assume that recognition memory is composed of at least two processes: familiarity discrimination and recollective matching [6,32,37]; for a recent overview, see Ref. [82]. According to these models, an event can be recognized based on its familiarity and/or based on recollection. Familiarity has been conceptualized as the mere sense of having seen an item before, whereas recollection is seen as the remembering of an item *together* with the retrieval of physical, contextual or other source-specifying information of its prior occurrence [39].

Although this dual process view of recognition memory has received support from behavioral [32,83], clinical [1] and neuroimaging studies [10,11,20,39], it is not unchallenged. In particular, there is some conceptual and operational ambiguity with the concept of "familiarity". Some authors consider familiarity to be dissociable from recol-

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lection mainly on phenomenal grounds [26], for instance, by using the "remember/know" procedure [72]. In this procedure, participants are instructed to accompany old recognition decisions by a judgment of whether the item was old because they explicitly remembered it or because it felt familiar. While "remember" responses are identified with recollection, "know" responses are assumed to reflect recognition based on familiarity. Other authors define familiarity in terms of the absence of memory for a specific episode, including its physical and conceptual attributes [12,70,81]. Particularly relevant for the present study is that in most dual process models of recognition memory familiarity is assumed to arise from a recent exposure of an event in a given task context within an explicit memory test. That is, the prior presentation of a particular event evokes a general feeling of familiarity in such a way that the subject is aware of the repetition [37,72]. In other models, however, familiarity is equated with perceptual fluency or is considered to be part of the semantic memory system, i.e., arising from the retrieval of semantic long-term memory information. Both latter approaches are outlined in more detail below.

Perceptual fluency, one kind of implicit memory, is defined as the facilitation of task performance due to prior experience with a stimulus, without the subject necessarily being aware of the prior exposure to the stimulus [45]. In word-identification tasks, for instance, recently encountered words are identified more accurately and faster than new words. Models that equate recognition-related familiarity with perceptual fluency [31,33] argue that recognition-related familiarity is an automatic process and that it is useful for recognition memory decisions, especially in the absence of recollection of a past episode, because processing fluency indicates whether an item was previously presented. Consequently, it is argued that a single, and relatively homogenous, perceptual familiarity process mediates recognition-related familiarity and perceptual fluency.

The empirical evidence for this account, however, is mixed. For example, Snodgrass and Hirshman [67] found that changing sensory aspects of events between study and test affects performance to the same extent in recognition memory tasks and in tasks that rely on perceptual fluency (see also Refs. [25,52]), whereas Biederman and Cooper [5] showed that changes in object size failed to affect priming, but had pronounced effects on recognition memory performance. This latter finding challenges the view that the processes underlying enhanced perceptual fluency also mediate the familiarity component of recognition memory. Instead, Wagner et al. [78] and Wagner and Gabrieli [79] argued that recognition-related familiarity is more sensitive to conceptual processing than to perceptual processing. In a series of experiments, these authors reported a direct relationship between familiarity-based explicit recognition and conceptual processing, whereas implicit word-identification only increased with increasing study-test perceptual similarity. Evidence for dissociations between perceptual fluency and familiarity discrimination is also provided by neuropsychological studies. For example, amnesia caused by medial temporal lobe damage disrupts recognition performance in a wide variety of tasks [28,36], but spares priming even when patients are encouraged to use recognition-related familiarity [69].

Recent neuropsychologically oriented memory models, on the other hand, consider familiarity to be a property of the semantic memory system. This view is based on clinical studies that show that selective damage to the hippocampus in early childhood can disrupt recall performance, but leave recognition memory performance and semantic memory intact [76]. To account for this dissociation, the authors argued that the hippocampus supports the retrieval of episodic memory (required in recall and recognition tasks) whereas adjacent structures (i.e., the perirhinal cortex) support the retrieval of factual knowledge (i.e., knowing), a form of retrieval that supports recognition-related familiarity, but is not beneficial in recall tasks. Interestingly, the preserved recognition performance in these patients was paralleled by well developed semantic knowledge [76] and the ability to acquire new semantic knowledge under decontextualized learning conditions [1]. This latter finding raises the intriguing possibility that recognition-related familiarity and semantic memory depend on the integrity of the same medio-basal temporal lobe structures (Ref. [18], see also Ref. [10]). This implies that at least some processes underlying recognition related-familiarity and semantic memory may be the same, or at least closely related.

Besides behavioral performance, the measurement of neuroelectric activity in the form of event-related potentials (ERPs) provides another way to untangle the neuronal processes associated with perceptual fluency, semantic familiarity and recognition-related familiarity. Such studies use the ability of ERPs to provide measures of neural activity with a temporal resolution that directly reflect the neural activity associated with cognitive processes (e.g., Refs. [15,56]).

Previous ERP examinations report more positive going ERP waveforms for repeated items than for first presentations starting around 300 ms (e.g., Refs. [16,40,41,49,75]). However, results vary depending on whether the repetition is task-relevant or not, i.e., whether an implicit memory task or an explicit old/new recognition task is used. Evidence for a dissociation between the ERP effects in implicit and explicit tasks is, for instance, provided by a study from Paller and Gross [46]. They manipulated word presentation in Experiment 1; some words were studied by forward letter presentation (e.g., c-a-t), for other words letter order was reversed (e.g., t-a-c). Participants had to read each word and decide whether it was a name or not. Responses to repetitions were faster for forward presentations. This behavioral effect was accompanied by a positive ERP effect at parietal and occipital scalp locations between 300 and 500 ms that was interpreted as a reflection of perceptual fluency. To examine the possibility that this parietal-occipital effect may have been caused by explicit remembering rather than by perceptual fluency, Paller and Gross performed a second experiment in which they changed the task to a recognition test. Results in this explicit memory test showed a widespread ERP response that was dissociable from the effect observed in Experiment 1, confirming the association between the parietal-occipital ERP effect and perceptual fluency in Experiment 1.

Other studies have also associated perceptual fluency with a more parietal-occipital focused positivity between 300 and 500 ms (e.g., Refs. [41,58]), whereas the so called ERP old/new effect in this time range, found in explicit tests of recognition memory, shows a frontally distributed ERP difference [11,58]. The early frontal old/new effect in explicit recognition studies is followed by or partly overlaps with a positive and parietally focused component, which is enhanced by repetition. Depending on stimulus material and testing conditions, this parietal old/new effect reaches its maximum between 500 and 800 ms (for overviews, compare Refs. [24,39]).

Due to the large number of studies showing that variables known to influence recollection (e.g., levels of processing) lead to modulations of the late parietal old/new effect, the association of this ERP effect with recollection is well accepted (e.g., Refs. [17,58,65,73]). In contrast, the functional process underlying the early (300–500 ms) mid-frontal portion of the old/new effect remains controversial [23]. An increasing number of studies suggest that this portion of the old/new effect is related to familiarity-based recognition judgments. It is not affected by a levels-of-processing manipulation [24], suggesting that it is independent from active recollection. Moreover, frontal old/new effects between 300 and 500 ms have been observed for items that share conceptual [44] or perceptual features [11] with studied materials, supporting the view that this effect is associated with familiarity-based recognition (but see Ref. [47]). Based on the aforementioned studies, we assume that the critical time range for the expected dissociation between recognition-related familiarity, perceptual fluency and semantic familiarity should be between 300 and 500 ms.

The present study explored whether familiarity arising from a recent presentation of an event, as discussed in most dual process models of recognition memory, could be dissociated electrophysiologically from perceptual fluency and familiarity that arises from semantic retrieval processes. In particular, we examined event-related potential indices of perceptual fluency, semantic familiarity and recognition-related familiarity using the same stimulus materials, i.e., photographs of famous and non-famous faces that were repeated once, in different task contexts. In Experiment 1, participants made famous vs. non-famous judgments. In Experiment 2, participants detected target stimuli (distorted faces) presented among a stream of face stimuli. Experiment 3 was a recognition memory task in which participants made old/new judgments for the first and second presentations of the faces.

We used the comparison of ERPs elicited by the first presentations of famous and non-famous faces as an index of *semantic familiarity* because presentations of famous faces lead to the retrieval of person identity information from long-term semantic memory. This view is derived from a model of face recognition [9] that posits that the recognition of famous faces involves a match between the products of structural encoding and stored structural codes that are held in recognition units. Such face recognition units can access identity-specific semantic codes (person identity nodes) that are sufficient for identification of the person. Starting from the person identity nodes, additional information about the face can be retrieved from semantic memory (semantic information units) that, however, is not required for face identification. According to this model, the access of person identity nodes is an automatic process and should not be affected by task demands. In the present study, comparison of the ERPs elicited by the first and second presentations of faces when stimulus repetition was task-irrelevant was used as an index of *perceptual fluency*. Repeated presentation confers increased ease or speed of perception, the definition of perceptual fluency [68]. However, non-famous and famous faces were analyzed separately, because famous faces also allow the successful retrieval of person identity information. To avoid confounding perceptual fluency and a possible retrieval of person identity information, only the analysis for non-famous faces was considered as a correlate of perceptual fluency. Retrieval of person identity information does not take place for non-famous faces and, therefore, any differences in the ERP waveforms to first and second presentations of non-famous faces may be attributed to processes underlying perceptual fluency when face repetition is task-irrelevant. As no reference to the repetition of the stimuli is made in Experiments 1 and 2, these tasks can be considered implicit memory tasks [53]. Finally, consistent with prior ERP studies on recognition memory interpreted from dual process perspectives [11,44,58], the comparison of ERPs elicited by first and second presentations of faces in an explicit old/new recognition memory task was taken as an index of recognition-related familiarity and recollection (Experiment 3).

2. Experiment 1

2.1. Methods

2.1.1. Participants

Eighteen volunteers (10 female) between 19 and 29 years of age (mean 23.6 years) participated. They were students at the University of Leipzig, were right-handed and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of the participants had prior experience with the task.

2.1.2. Experimental materials

Black-and-white photographs of famous and non-famous persons from several public databases comprised the stimulus material, which was created using the following steps. First, 80 black-and-white photographs of nationally (Germany) and internationally famous faces (i.e., politicians, actors, TV personalities and athletes) were selected from a set of 252 original portraits of famous faces based on the evaluations of 33 independent raters. The raters saw photographs on a computer screen and indicated on a four-point scale whether they recognized the person as famous or not. They pressed button 1 if they did not know the person, button 2 if they were not sure whether the person was famous, button 3 if they knew that the person was famous, but could not recollect the name, and button 4 if they knew that the person was famous and could recollect the name. The 80 famous faces (22 female) were selected given the constraint that the mean rating of each selected face was higher than 3 and the standard deviation did not exceed the mean–standard deviation for the rating values of all 252 faces (S.D.=1.22). Furthermore, 80 black-and-white portrait photographs of non-famous persons were selected from a separate database and were matched to the famous faces with respect to gender and approximate age. All pictures were digitally edited using Adobe Photoshop. A grey background was applied to all pictures of faces (famous and non-famous) and each face was framed within an area of 220 pixels wide and 250–314 pixels high. Stimuli were of approximately equivalent luminance and contrast. Twelve additional photographs were used for practice and as filler items.

The photographs of famous and non-famous persons were used to construct two different lists in a quasi-random list order. All photographs were repeated after a minimum of six intervening photographs and a maximum of 12 intervening photographs. Faces were presented continuously with the constraint that no more than four photographs of the same type (famous, non-famous) and no more than four first and second presentations were presented consecutively. In order to guarantee these constraints were met at the beginning and at the end of the lists, filler faces were included. Presentation of the two lists was counterbalanced across participants.

2.1.3. Procedure

The participants sat comfortably in an acoustically and electrically shielded dimly lit chamber approximately 100 cm from a 17-in. computer monitor. During the test phase, they held a small response box in their hands. They were told that photographs would be shown on the screen and that they should indicate as quickly and as accurately as possible whether the presented picture showed a famous or a non-famous person. They responded by pressing the left or the right button of the response box with the thumb of the corresponding hand. Response hand to response category assignment was counterbalanced across participants. After receiving the instructions, all participants performed a short practice block (seven photographs, three of them were repeated). On each trial, a fixation cross appeared in the middle of the screen for 1000 ms, next the screen went blank for 200 ms, then the photograph was presented for 300 ms, and finally, after picture offset, the screen went blank for a further 1700 ms. Responses were recorded during the 2000-ms interval following stimulus onset. The next trial began immediately after the blank screen interval with presentation of the fixation cross. Participants were instructed to blink only when the fixation cross was displayed on the screen. They were further informed that all pictures would be repeated, but that the repetitions were task irrelevant. Including electrode application and removal the session lasted about 1.5 h.

2.1.4. ERP recording

The EEG activity was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electrocap International) from 58 scalp sites of the extended 10–20 system [64]. The ground electrode was positioned on the sternum. The vertical electrooculogram (EOG) was recorded from electrodes located above and below the right eye. The horizontal EOG was recorded from electrodes positioned at the outer canthus of each eye. Electrode impedance was kept below 5 kΩ. The right mastoid was recorded as an additional channel. All scalp electrodes were referenced to the left mastoid and were offline re-referenced to both mastoids. EEG and EOG were recorded continuously with a band pass from DC to 70 Hz and were A–D converted with 22-bit resolution at a sampling rate of 250 Hz.

EEG-data were epoched time-locked to stimulus-onset extending from 200 ms before the onset of the picture presentation until 1600 ms thereafter. Whenever the standard deviation in a 200-ms time interval exceeded 30 μV in an EOG channel or 40 μV in the Pz channel the epoch was rejected. In a second step, the EEG epochs were visually scanned for further artifacts, which were excluded from the averaging procedure. The average voltages in the 200-ms preceding stimulus presentation served as baseline. ERPs for correct responses were selectively averaged for famous and non-famous faces separately for the first and the second presentation.

For statistical analysis, a hypothesis-driven approach was applied. To quantify electrophysiological indices of semantic memory access, ERPs elicited by the first presentation of famous faces were compared with ERPs elicited by the first presentation of non-famous faces. In a separate analysis of perceptual fluency, ERPs elicited by the second presentation of non-famous faces were compared to ERPs elicited by the first presentation of non-famous faces. ERPs elicited by the second presentation of famous faces were also compared to ERPs elicited by the first presentation of famous faces.

For all conditions, the initial statistical analysis included all 58 electrodes. When the face type$\times$electrode (semantic memory access) or presentation$\times$electrode (perceptual fluency) interactions were significant, a more fine grained analysis was performed using six electrodes located over frontal and parietal cortices. Unless otherwise noted, these electrodes were F7, Fz, F8, P7, Pz and P8. ERPs were quantified as mean amplitudes within specific time windows that will be reported in Section 2.2.

Two-way repeated-measures ANOVAs with the factors face type (2 levels: first presentation famous faces vs. first presentation non-famous faces, i.e., semantic memory access) or presentation (second presentation non-famous faces vs. first presentation non-famous faces, i.e., perceptual fluency) and electrode (58 levels) were performed.

All effects with more than one degree of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse–Geisser formula [27]. In the presence of significant interactions, one-way ANOVAs were performed, with p-values adjusted by means of a modified Bonferroni procedure [30], to examine the effects at single electrode sites. ERP effects differing only in magnitude reflect different levels of engagement of the same neurophysiological processes, whereas differences in scalp topography indicate that different neuronal processes contribute to the respective experimental conditions [34,54]. To allow a comparison of scalp topographies that is not confounded with differences in magnitude, two-way repeated-measures ANOVAs were performed on root mean square normalized data [38]. Scalp potential topographic maps based on all 58 electrode sites were generated using a two-dimensional spherical spline interpolation [50] and a radial projection from Cz, which respects the length of the median arcs.

2.2. Results

2.2.1. Behavioral data

Mean reaction times and proportion of correct responses to non-famous and famous faces are presented in Table 1. Accuracy rates for famous faces were somewhat smaller than those for non-famous faces. Participants made more correct responses to the second than to the first presentation of famous faces, but no such effect was obtained for non-famous faces. These observations were confirmed by a two-way repeated-measures ANOVA, with the factors face type (2 levels: non-famous, famous) and presentation (2 levels: first presentation, second presentation). For the proportions of correct responses, there were significant main effects of face type and presentation [F's(1,17)=16.77 and 16.47, respectively, both p's<0.001], as well as a significant face type×presentation interaction [$F(1,17)=17.22$, $p<0.001$]. Separate tests revealed higher accuracy for famous faces in the second presentation as compared to the first [$F(1,17)=19.43$, $p<0.001$], but no difference in accuracy between first and second presentations for non-famous faces [$F(1,17)=0.01$].

A two-way repeated-measures ANOVA with the factors face type and presentation conducted for the reaction times of correct responses revealed no main effect of face type [$F(1,17)=0.37$], but a significant main effect of presentation [$F(1,17)=150.65$, $p<0.001$], reflecting faster responses after the second than after the first presentation. This effect was confirmed by separate t-tests for famous and non-famous faces (p's<0.001). As indicated by a significant face type×presentation interaction [$F(1,17)=54.40$, $p<0.001$], famous faces benefited more from the repetition than non-famous faces. Reactions were faster for non-famous faces than for famous faces after the first presentation [$F(1,17)=4.73$, $p<0.05$], but slower after the second presentation [$F(1,17)=10.49$, $p<0.01$].

Table 1
Experiment 1: Mean reaction times for correct responses and mean accuracy for the first and second presentation of non-famous and famous faces

	Face type	Reaction time (ms)	Proportion correct
First presentation	non-famous	599.4 (20.0)	96.74 (0.80)
	famous	618.7 (22.7)	85.10 (2.98)
Second presentation	non-famous	577.5 (19.8)	96.81 (0.66)
	famous	548.1 (20.7)	92.22 (1.54)

The standard error of the mean is presented in parenthesis.

2.2.2. ERP data

ERP waveforms elicited by the first presentations of famous and non-famous faces, capturing electrophysiological differences associated with the access of semantic memory, are displayed in the left panel of Fig. 1. ERP-waveforms elicited by famous faces are more positive than those elicited by non-famous faces starting around 200 ms. A positive ERP-effect is present at anterior and posterior electrode sites until 300 ms, and displays a frontally focused topography later in time. At around 550 ms, both waveforms show a positive component, especially at centro-parietal locations, with the famous face waveform being more positive. ERPs for famous faces stay more positive than ERPs for non-famous faces till the end of the recording epoch, especially at frontal locations. Scalp topographical maps further illustrating these effects are presented in the right panel of Fig. 1.

The left panel of Fig. 2 shows ERP waveforms elicited by first and second presentations of non-famous faces, which capture electrophysiological differences associated with perceptual fluency. The data pattern is qualitatively different from that obtained for the semantic memory condition. ERPs elicited by the second presentation of non-famous faces are more positive than ERPs elicited by the first presentation of non-famous faces starting around 300 ms, with this effect being focused at posterior electrode locations (right panel of Fig. 2). Both ERP waveforms show a positive peak, especially at centro-parietal locations, at around 550 ms.

Fig. 3 depicts ERP waveforms elicited by first and second presentations of famous faces. Repetition effects seem to start around 200 ms at frontal locations, but are more focused over posterior locations between 300 and 450 ms (see topographic map, Fig. 3).

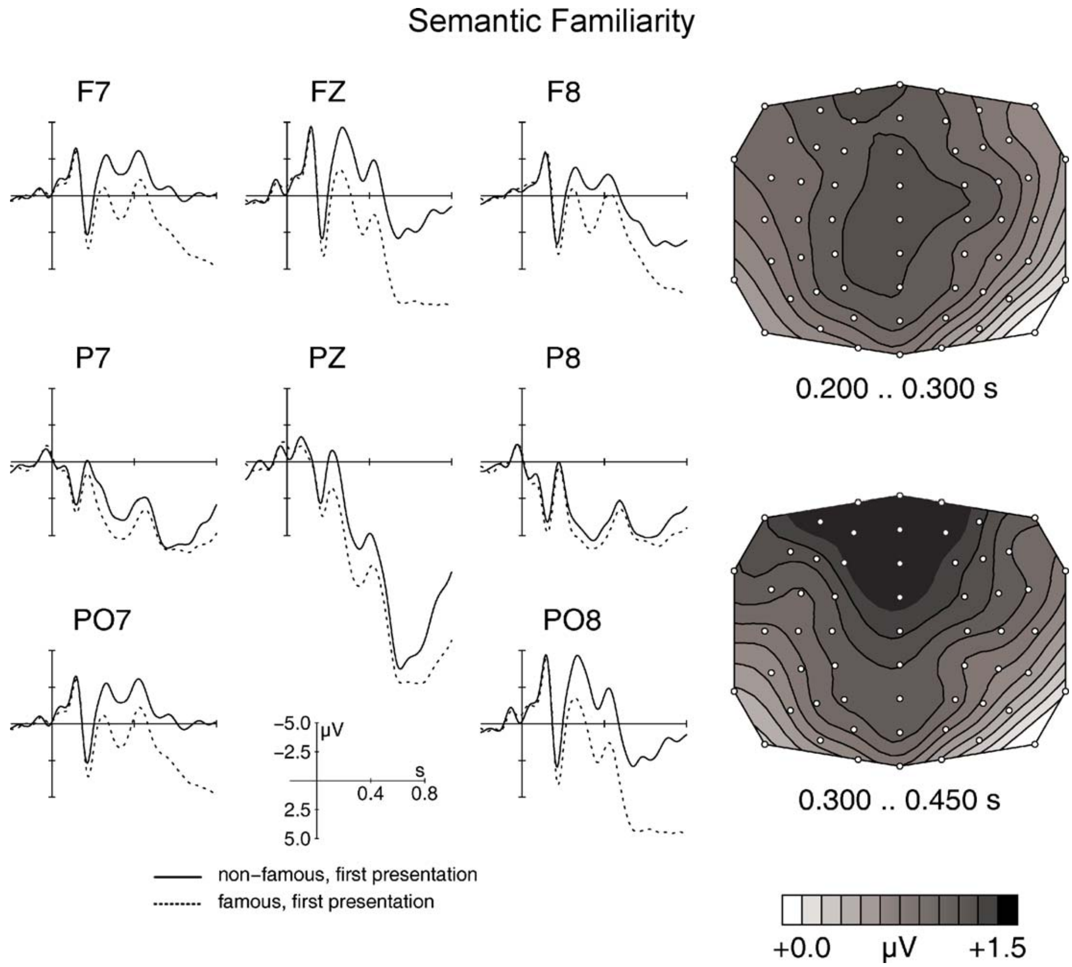

Fig. 1. Experiment 1: Left: ERPs elicited by the first presentation of non-famous and famous faces. In this and the following figures, ERP waveforms are shown at left frontal (F7), middle frontal (Fz), right frontal (F6), left parietal (P7), middle parietal (Pz), right parietal (P8), left parietal-occipital (PO7) and right parietal-occipital (PO8) electrode sites. Negativity is plotted upwards. Right: Topographic distributions of the difference wave for ERPs to the first presentation of famous faces and the first presentation of non-famous faces. The positive effect shows a broad scalp distribution between 200 and 300 ms, but is focused at frontal recording sites between 300 and 450 ms.

Based on these observations, ERP amplitude effects for semantic familiarity and perceptual fluency were statistically examined in three consecutive time windows: An early time window between 200 and 300 ms, a middle time window from 300 to 450 ms, and a late time window between 500 and 650 ms. The late time window was included to capture the parietal effect evident in the waveforms for all three experimental conditions.

Two-way repeated-measures ANOVAs comparing first presentations of famous and non-famous faces were conducted for each time window to examine semantic familiarity. The main effect of face type and the face type×electrode interaction were significant in the early time window (200–300 ms, see Table 2). Separate tests performed on six different electrode positions (F7, Fz, F8, P7, Pz, P8) revealed significant effects at all locations (p's<0.017). However, the largest treatment magnitudes were found at F7, Pz (both ω^2=0.61) and P7 (ω^2=0.64).

In the time window between 300 and 450 ms, the analysis also revealed a significant main effect of face type and a face type×electrode interaction (see Table 2), with the effect being most pronounced at frontal locations (see Fig. 1). Treatment magnitudes were highest at left frontal (F7, ω^2=0.57) and medial frontal locations (Fz, ω^2=0.53) although separate tests revealed significant effects at all tested electrodes (p's<0.023; F8 ω^2=0.28; P7 ω^2=0.49; Pz ω^2=0.39; P8 ω^2=0.22). In the 500–650-ms time window, the main effect of face type and the face type×electrode interaction were significant (see Table 2). Separate tests for each single electrode revealed significant effects at F7 and Fz only (p's<0.006; F8, P7, Pz, P8 p's>0.05).

Two-way repeated-measures ANOVAs comparing first and second presentations of non-famous faces were conducted for each time window to examine perceptual fluency. The main effect of presentation and the presentation×electrode interaction were not significant in the early time window (200–300 ms), but were significant between 300 and 450 ms (see Table 2). Separate tests in the latter time range revealed significant effects at F7, Fz, P7, Pz and P8 (p's<0.022; F8 p>0.05), with the highest

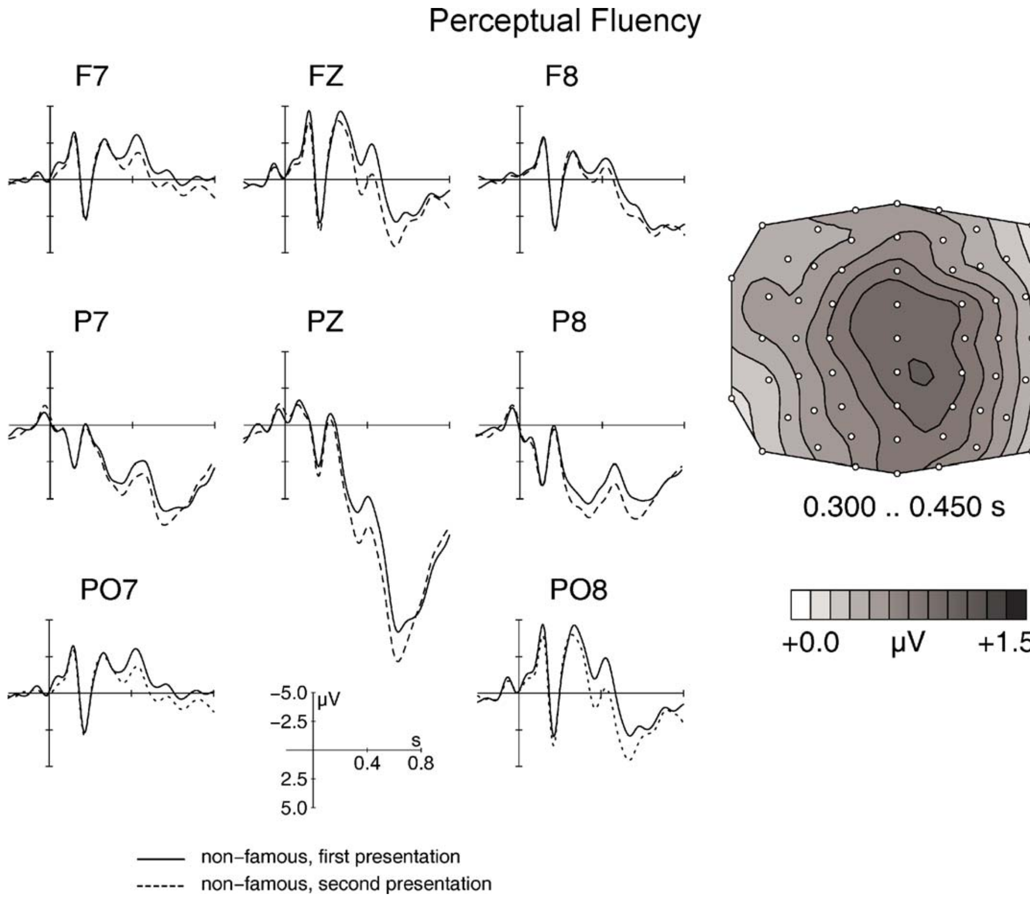

Fig. 2. Experiment 1: Left: ERPs elicited by the first and second presentation of non-famous faces. Right: The topographic distribution of the difference wave for ERPs to the second and first presentation of non-famous faces indicates largest effects at posterior electrode sites between 300 and 450 ms.

treatment magnitude evident at Pz (ω^2=0.44). Finally, between 500 and 650 ms, there was a significant main effect of presentation, but no significant interaction (see Table 2).

To examine the extent to which the perceptual fluency effects in the ERP are modulated by the fame status of the face, similar two-way repeated-measures ANOVAs were also performed for the first and second presentations of famous faces (see Table 2). There were significant main effects of presentation and interactions between presentation and electrode in each time window. Separate tests indicated significant effects at Fz, F8 and Pz between 200 and 300 ms (p's<0.017, modified Bonferroni correction). Although there was a widely distributed effect between 300 and 450 ms (significant effects for Fz, F8, P7, Pz, P8), treatment magnitudes were highest at P8 (ω^2=0.59) and Pz (ω^2=0.54). Finally, in the late time window, significant amplitude differences were limited to parietal recording sites (P7, Pz, P8; p's<0.001).

2.2.2.1. Topographic profile analyses. As outlined in the Introduction, the critical time period for the dissociation of semantic familiarity and perceptual fluency was assumed to be between 300 and 500 ms. In support of this view, significant effects for semantic familiarity and for perceptual fluency were found in the 300–450-ms time range, but the scalp topography of those effects was different (compare Figs. 1 and 2). Semantic familiarity elicited an effect with a maximum at frontal locations, whereas the effect of perceptual fluency was centered at parietal recording sites. To examine whether different neuronal sources contributed to these effects, ERP waveforms elicited by the first presentation of famous faces were compared to those elicited by the second presentation of non-famous faces. For this analysis, midline electrodes (Fpz, Afz, Fz, Fcz, Cz, Cpz, Pz, Poz, Oz) were chosen as topographical differences along the anterior–posterior dimension were of major interest. Two-way repeated-measures ANOVAs with the factors face type (two levels) and electrode (nine levels) performed for the time range between 300 and 450 ms, revealed a main effect of face type [F(1,17)=3.68, p=0.07] and a significant face type×electrode interaction [F(8,136)=8.92, p<0.001]. Tests for selected single electrodes showed significant differences for Fpz, Afz and Fz (p's<0.018) but not for any other location (Fcz, Cz, Cpz, Pz, Poz, Oz; p's>0.1). However, it is possible that the topographic effects obtained for the raw-ERP data are confounded with differences in magnitude. Consequently, two-way repeated-measures ANOVAs were

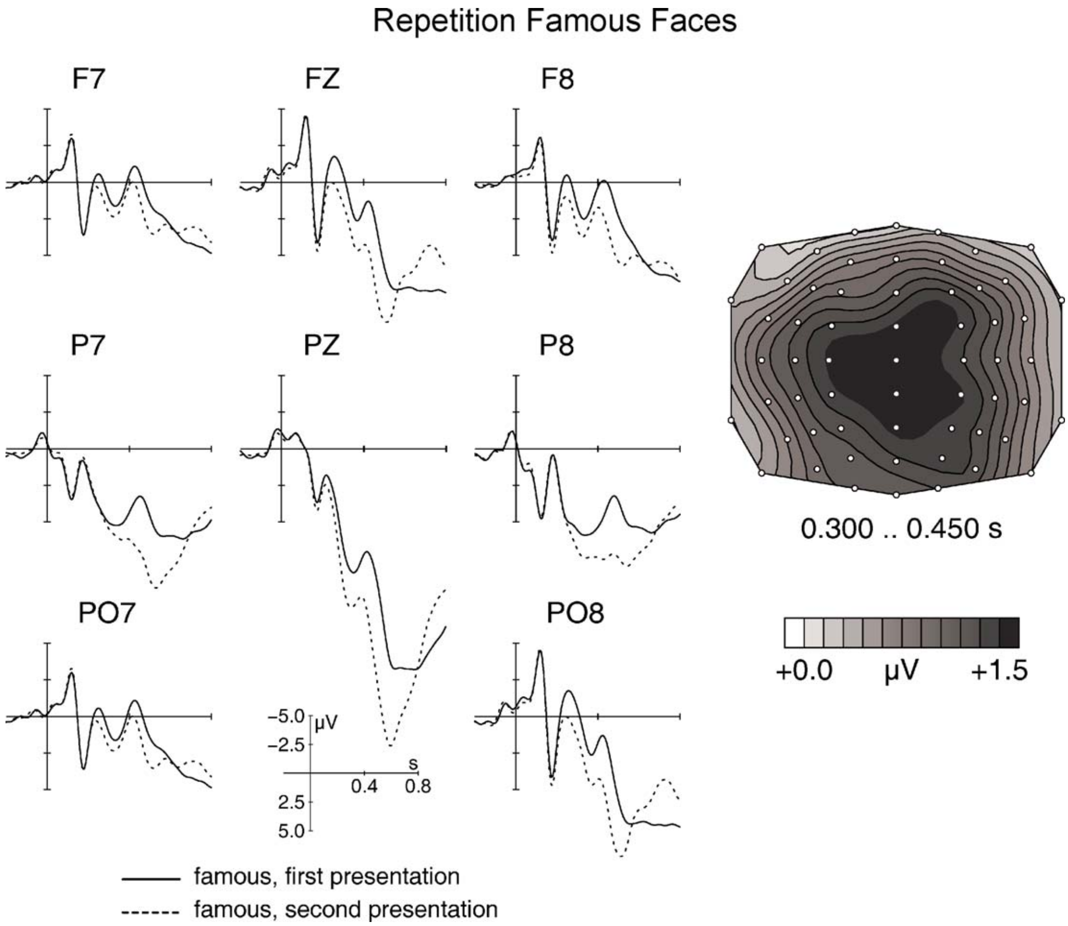

Fig. 3. Experiment 1: Left: ERPs elicited by the first and second presentation of famous faces. Right: The topographic distribution of the difference wave for ERPs to the second and first presentation of famous faces gives rise to a posteriorly focused effect between 300 and 450 ms.

also performed on root mean square normalized data [38]. This procedure preserves the profile of the scalp topography while eliminating any remaining overall amplitude differences. Qualitative differences in scalp topography of different effects demonstrate that these effects must have been generated by at least partially different brain sources, suggesting different cognitive processes (but cf. Ref. [74]). The face type×electrode interaction was also significant for the normalized data [$F(8,136)=12.63$, $p<0.001$], indicating that different neuronal configurations were active in the 300–450-ms time window for the semantic familiarity and the perceptual fluency condition.

Table 2
Experiment 1: Results for the ANOVAs for the ERPs to the first presentation of famous and non-famous faces (semantic memory access, face type× electrode), for the ERPs to the second and first presentation of non-famous faces (perceptual fluency, presentation×electrode), and for the ERPs to the second and first presentation of famous faces (presentation×electrode)

	df	200–300 ms	300–450 ms	500–650 ms
Semantic memory access				
Face type	1.17	39.28***	21.49***	8.50**
Face type×electrode	57.969	3.69*	6.23***	5.28**
Perceptual fluency (non-famous faces)				
Presentation	1.17	1.56	16.45***	8.25*
Presentation×electrode	57.969	2.17	3.10*	1.68
Repetition famous faces				
Presentation	1.17	7.20*	18.13***	8.63**
Presentation×electrode	57.969	3.52**	6.78***	6.68**

df=degrees of freedom.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

2.3. Discussion

The present experiment was conducted to determine whether semantic familiarity can be differentiated from perceptual fluency by means of electrophysiological measurements. Photographs of famous and non-famous faces were used in an implicit memory paradigm in which participants had to judge the fame of the person.

A behavioral priming effect, indicated by faster reaction times to second presentations, was evident for both famous and non-famous faces. This is in line with a large number of prior studies (Refs. [8,21], for overviews see Refs. [53,59,60]), which show that the processing of a stimulus is facilitated when it is repeated. Consistent with prior studies using faces as stimulus materials, performance facilitation was greater for famous than for non-famous faces [21,29].

Electrophysiological data for the semantic familiarity condition (ERP difference between famous and non-famous faces) revealed an early and broadly distributed effect that started around 200 ms. This effect was followed by a frontal effect extending from about 300 to 450 ms and a late positive component. Conversely, for the perceptual fluency condition (ERP difference between the second and the first presentation of non-famous faces), the ERP effects emerged later and showed a centro-parietal distribution between 300 and 450 ms. This electrophysiological evidence suggests that semantic familiarity and perceptual fluency are associated with qualitatively different ERP effects.

These results suggest that face familiarity exerts an electrophysiological effect before the structural encoding process is completed. ERP differences based on face familiarity started around 200 ms, whereas the perceptual fluency effect did not emerge before 300 ms. As described in the Introduction, some models of face perception [9] claim that perceptual face recognition units exist for famous faces that activate person identity nodes. It is conceivable that a special advantage of such a system is an early and fast access. Face recognition units may become activated immediately following perception of unique features. Then, further processing parallels both structural encoding processes and the access of person identity information. In line with the results of earlier studies [51,62], the second presentation of famous faces further enhanced this early frontal positive effect. It has been argued that a repetition strengthens the connection between face recognition units and person identity nodes, an argument that is in accordance with faster reaction times found for the second presentation of famous faces in the current study.

However, there are some critical challenges to these interpretations. One objection is that the condition in which semantic familiarity was examined may have been confounded with recollection processes. It is conceivable that the first presentation of a famous face elicits retrieval of contextual or source-specifying information about the person and that this leads to a recollection experience. To examine the extent to which recollection processes contributed to the ERP waveforms correlated with semantic familiarity an additional analysis, in which we tried to minimize the contribution of recollection to the processing of famous faces, was performed.

We subdivided the 80 famous faces into two groups based on the outcome of the pilot rating study described in Section 2.1. Those faces (n=39) for which most raters indicated that they knew the person's name were categorized as faces associated with active recollection (name faces), whereas faces for which most raters could not recall the name were categorized as faces not associated with active recollection (n=41, no name faces).[1] Although it is clearly possible for participants to actively recollect information about a person independent of recollecting her name (e.g., the name of a movie that an actress starred in), we believe that name recollection is a good general indicator of the degree of active recollection present for each of the famous face stimuli. Notably, reaction times were faster for name faces than for no name faces at first presentation (608 and 630 ms, respectively; t=3.7, p<0.01).

Moreover, the direct comparison of both types of faces at first presentation (see Fig. 4) revealed more positive going waveforms between 500 and 650 ms for faces for which the name was retrievable (name faces), a difference confirmed by a significant main effect of face type $F(1,17)$=16.59, p<0.001, although the face type×electrode electrode interaction was not significant (p>0.05). Crucially, between 200 and 300 ms and between 300 and 450 ms, there were no statistically significant differences between name and no name faces (all p's>0.05). The late effect corresponds in its temporal and spatial characteristics to ERP effects interpreted as reflecting recollection [24,39,45,55], whereas the absence of any differences between conditions in the earlier time windows suggests that active recollection processes failed to modulate the ERP waveforms between 200 and 450 ms. However, as similar parietal positive deflections after 500 ms have also been reported to correlate with decision confidence [35], we can not rule out an alternative interpretation, namely that the larger parietal positivity to name as compared to no name faces reflects the higher decision confidence of the fame responses for name than for no name faces.

To provide a more robust determination of the ERP correlates of semantic familiarity, we minimized the contribution of active recollection and/or decision confidence processes to the estimate of semantic familiarity by repeating the analysis (first presentation of famous vs. first presentation of non-famous faces) with only those famous faces for which the name was not retrievable (see Table 3). The results were highly similar to the initial analysis between 200 and 300 ms and 300 and 450 ms. There were significant main effects of face type and significant face type×electrode interactions in both early time windows. Between 200 and 300 ms, the largest effects were revealed at left frontal, left and middle parietal locations. Between 300 and 450 ms, treatment magnitudes were maximal at frontal electrodes (highest F7, ω^2=0.54). In contrast to the initial analysis involving all famous faces, the face type effect in the late time interval did not reach significance although the face type×electrode interaction was significant. Separate tests for single electrodes, however, failed to reveal any significant

[1] Faces with a mean rating in the pilot study higher than 3.5 were categorized as faces associated with recollection, whereas famous faces with a mean rating smaller than 3.5 formed the group of faces not associated with recollection.

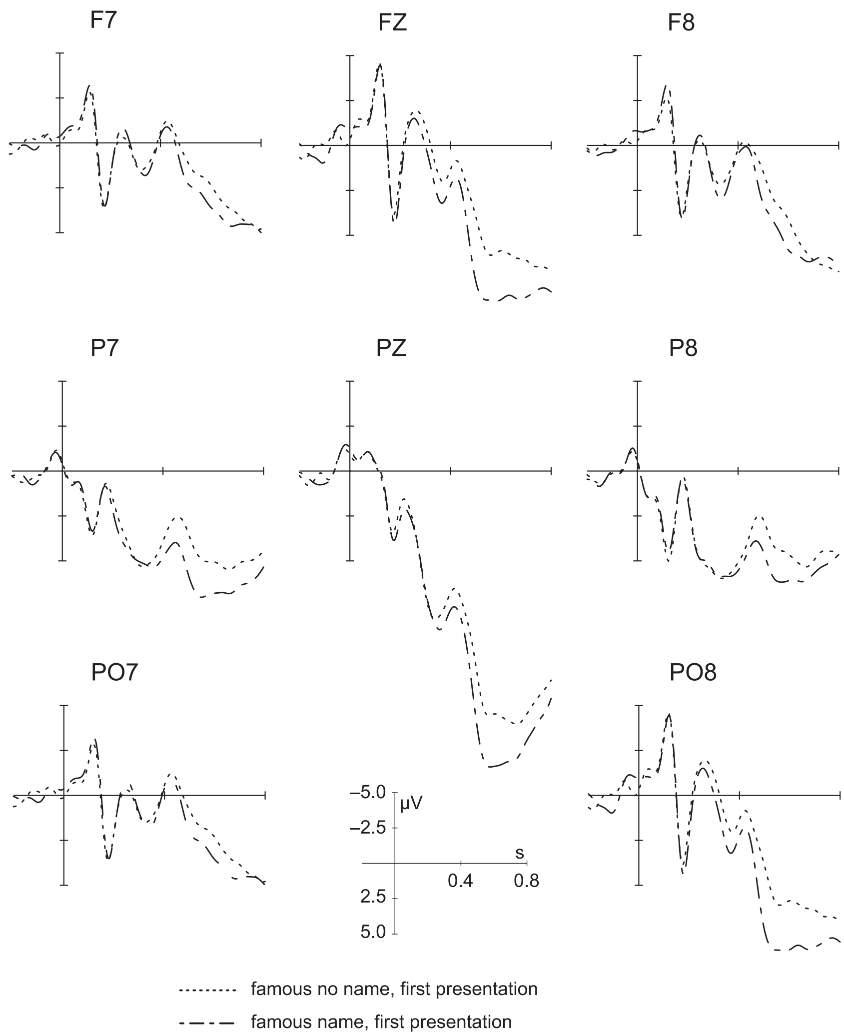

Fig. 4. Experiment 1: ERPs elicited by the first presentation of famous name and famous no name faces.

effects (p's>0.03, none of the effects was significant by means of the modified Bonferroni procedure [30]).

This additional analysis supports the view that the ERP effects obtained in the first two time intervals reflect a semantic familiarity process (i.e., the activation of person-identity nodes) that is independent of active recollection, whereas ERP effects starting around 500 ms more likely reflect recollection-related neuronal activity caused by the retrieval of names or other contextual information associated with famous persons.

Table 3
Experiment 1: Results for the ANOVA (face type×electrode) for the ERPs to the first presentation of famous faces not associated with recollection (famous no name faces) and non-famous faces (familiarity based on semantic memory)

	df	200–300 ms	300–450 ms	500–650 ms
Semantic memory access				
Face type	1.17	21.77***	13.45**	2.54
Face type×electrode	57.969	3.06*	4.41**	4.58**

df=degrees of freedom.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

The view that recollection processes contribute to the ERP waveforms for famous faces starting around 500-ms post-stimulus onset may also account for the late positive deflection elicited by second presentations of non-famous faces relative to first presentations of non-famous faces (the perceptual fluency comparison). As the participants were required to make fame judgments to first and second presentations, it is conceivable that second presentations caused the retrieval of contextual information from the first exposure.

Furthermore, the fame judgment task employed in the present experiment may have biased our results towards finding processes that support the retrieval of person identity information from long-term memory. If accessing person identity information in semantic memory is automatically triggered by the presentation of famous faces [9], the effects obtained in the semantic memory condition should also be present when the task does not require participants to retrieve pre-existing semantic information.

This prediction was tested in a second experiment. Rather than indicating the fame status of the faces, participants were required to monitor the series of face stimuli for the rare occurrence of a target. To control for recollection effects for famous faces and to achieve a better estimate for semantic familiarity, only those famous faces for which the name was not retrievable were considered in the semantic familiarity analysis of Experiment 2. Similar results in Experiments 1 and 2 would strengthen the claim of a differentiation between semantic familiarity and perceptual fluency.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Twenty-one volunteers (10 female) between 18 and 30 years of age (mean 23.7 years) participated. They were students at the University of Leipzig, were right-handed and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of these participants had participated in Experiment 1 or had any prior experience with the task.

3.1.2. Experimental materials and procedure

The same photographs of famous and non-famous faces as in Experiment 1 were used. Forty-four additional photographs of non-famous faces were distorted, using the program Adobe Photoshop (see Fig. 5), in such a way that they could not easily be detected based on texture or contour features. In a preliminary rating study, 10 participants were asked to differentiate between distorted and non-distorted faces. They sat in front of a 17-in. computer monitor and held a small response box in their hands. They were told to indicate as quickly and accurately as possible whether photographs presented on the computer screen were distorted or not. Each trial started with presentation of a fixation cross in the middle of the screen for 500 ms, then the screen went blank for 200 ms, and then the photograph was presented for 300 ms. After picture offset, the screen was blank for 2000 ms. Responses were recorded from picture onset to 2300 ms thereafter. Distorted pictures were included in the current experiment if at least seven out of 10 participants in a preliminary rating study classified it as distorted. An additional distortion was applied to photographs that did not meet this criterion.

Fig. 5. Two examples of distorted faces.

The photographs of famous faces, non-famous faces and distorted faces were used to construct two quasi-random list orders. List presentation was counterbalanced across participants. As in Experiment 1, photographs were presented in a continuous series with the constraint that no more than four faces of the same type (famous, non-famous, distorted) or presentation category (first, second) were presented consecutively. All photographs were repeated after a minimum of 6 intervening faces and a maximum of 12 intervening faces. Filler faces were included to guarantee these constraints were met at the beginning and at the end of the lists.

Participants were asked to respond as quickly and as accurately as possible to distorted faces by pressing one button of the response box with the thumb of the right or left hand. The response hand was counterbalanced across participants. Non-distorted faces did not require a response. Participants were further informed that they would see photographs of famous and non-famous persons and that the photographs would be repeated, but that this was not task-relevant. To familiarize the participants with the task and the stimuli, a practice block, containing seven non-distorted and two distorted faces (three non-distorted and both distorted faces were shown twice), was performed prior to the experimental task. Including electrode application and removal the session lasted about 1.5 h.

3.1.3. ERP recording and analysis

The recording procedure was the same as in Experiment 1 with the exception that a sampling rate of 500 Hz rather than 250 Hz was used. The same logic of data analysis was employed as in Experiment 1. Only those famous faces for which the name was not retrievable (famous no name faces) in the pilot study were used in the analysis of semantic familiarity. Because the distorted faces were inserted merely as a means of providing a task that forced participants to process all faces in detail, the ERPs to distorted faces were not of interest.

3.2. Results

3.2.1. Behavioral data

Reaction times to distorted faces were 636.1 ms (S.D.=22.9) and 626.1 ms (S.D.=24.0) for the first and second presentations, respectively. Target faces were identified correctly at a rate of 56.8% (S.D.=3.6) in the first presentation and at a rate of 53.9% (S.D.=3.8) in the second presentation. Although the hit rate for distorted faces was low, the false alarm rate to non-distorted faces was also quite low (7.3% (S.D.=1.8) and 4.7% (S.D.=1.5), first and second presentation, respectively) suggesting that participants did process the faces in detail. This interpretation is supported by the high sensitivity values for the first and second presentations (A'=0.86, S.D.=0.03; A'=0.86, S.D.=0.03, respectively) (nonparametric signal detection procedure [13,66]). However, participants showed a conservative response bias ($B''D$=0.76, S.D.=0.35; $B''D$=0.82, S.D.=0.35).

3.2.2. ERP data

The ERP waveforms elicited by the first presentations of famous no name and non-famous faces, which capture the electrophysiological differences associated with semantic familiarity, are displayed in the left panel of Fig. 6. Waveforms elicited by first presentations of famous no name faces were again more positive than those elicited by first presentation of non-famous faces beginning around 200 ms, although the amplitude differences were smaller than those obtained in Experiment 1. As indicated by the topographical distributions of the ERP-differences (right panel of Fig. 6), the effect was broadly distributed across the scalp, but seemed to become larger at frontal recording sites around 300 ms.

ERP waveforms for the first and second presentations of non-famous faces, which capture electrophysiological differences associated with perceptual fluency, are shown in the left panel of Fig. 7. Beginning at 300 ms, the waveforms elicited by second presentations of non-famous faces were more positive than those elicited by first presentations. As indicated by the topographical maps illustrated in the right panel of Fig. 7, this effect was focused at parietal electrode locations and was

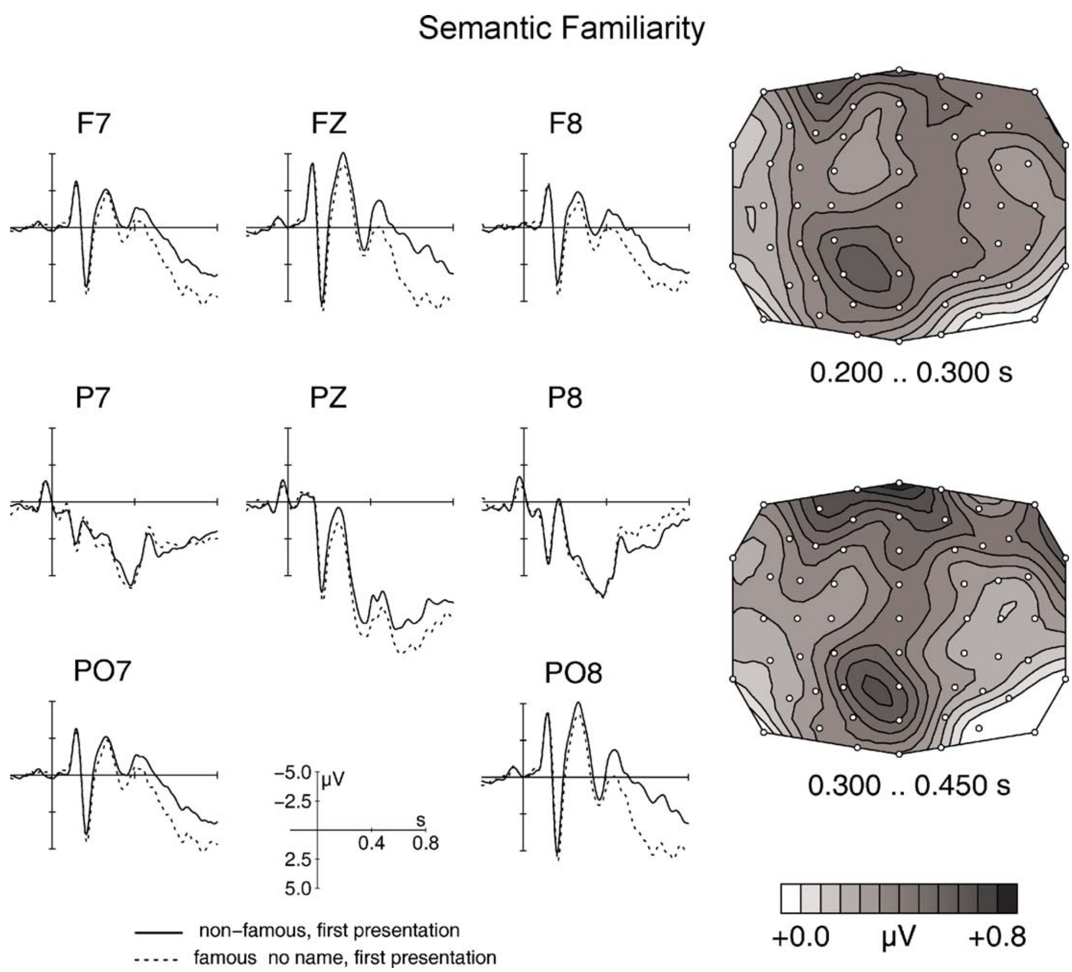

Fig. 6. Experiment 2: Left: ERPs elicited by the first presentation of non-famous and famous no name faces. Right: Topographic distributions of the difference wave for ERPs to the first presentation of famous no name faces and the first presentation of non-famous faces between 200 and 300 ms and between 300 and 450 ms. The positive effect is broadly distributed over the scalp in both time windows but seems to become larger at frontal electrodes around 300 ms.

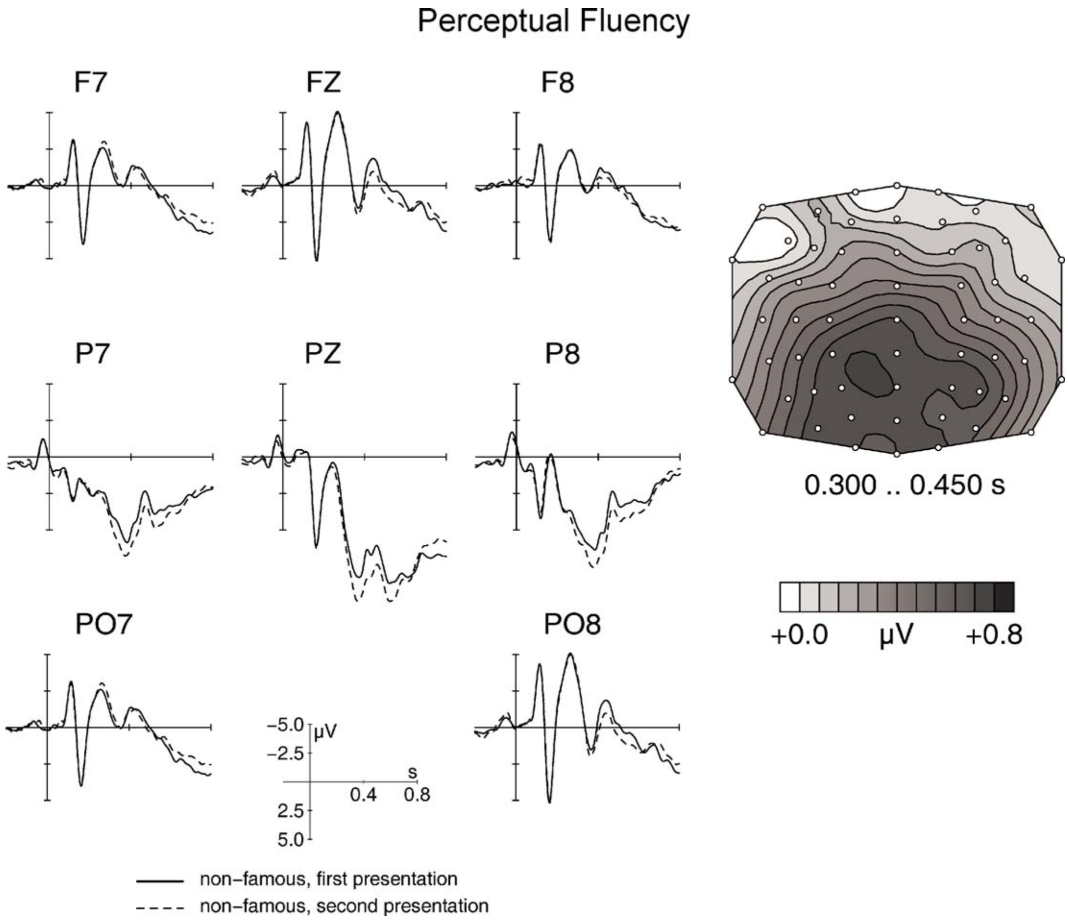

Fig. 7. Experiment 2: Left: ERPs elicited by the first and second presentation of non-famous faces. Right: The topographic distribution of the difference wave for ERPs to the second and first presentation of non-famous faces shows a posterior maximum between 300 and 450 ms.

slightly smaller than the corresponding effect obtained in Experiment 1 (see Fig. 2). Both ERP waveforms show a positive peak especially at posterior locations around 550 ms.

As shown in Fig. 8, the ERP waveforms for the first presentation and the repetition of famous faces seem to differentiate starting around 200 ms. Early effects between 200 and 300 ms are widespread over the scalp, while between 300 and 450 ms they are most pronounced over posterior recording sites.

Two-way repeated measures ANOVAs using the same analysis framework as in Experiment 1 were conducted. For the analysis of semantic familiarity, that is to say, first presentations of famous no name faces vs. first presentations of non-famous faces, there was a main effect of face type in the early time window (200–300 ms) and in the 300–450-ms time window (Table 4). The face type×electrode interaction was not significant in either time window; however, effect sizes increased at frontal recording sizes in the later time range (e.g., 200–300 ms AFz ω^2=0.09, FPz ω^2=0.21; 300–450 ms AFz ω^2=0.14, FPz ω^2=0.38). In the 500–650-ms time window, there was a main effect of face type and a significant face type×electrode interaction. Separate tests for single electrodes revealed significant effects at F7 and Fz only (F7 ω^2=0.28; Fz ω^2=0.38; none of the other effects was significant by means of the modified Bonferroni procedure [30]).

The perceptual fluency analysis, i.e., first vs. second presentations of non-famous faces, failed to reveal any significant effects in the early time window (200–300 ms, see Table 4). Between 300 and 450 ms, however, there was a main effect of presentation and a significant presentation×electrode interaction. Separate tests revealed significant effects at all parietal electrode locations (P7, Pz, P8; p's<0.003), but no effect at frontal electrode locations (F7, Fz, F8; p's>0.05). There was no significant effect for the analysis between 500 and 650 ms.

The ANOVAs comparing first and second presentations of famous faces (see Table 4) revealed a main effect of presentation between 200 and 300 ms. In the later two time windows, analyses gave rise to significant main effects and interactions. Separate tests showed significant effects for Fz, P7, Pz and P8 (p's<0.023) between 300 and 450 ms, with highest treatment magnitudes at P8 (ω^2=0.49). In the late time window, significant amplitude

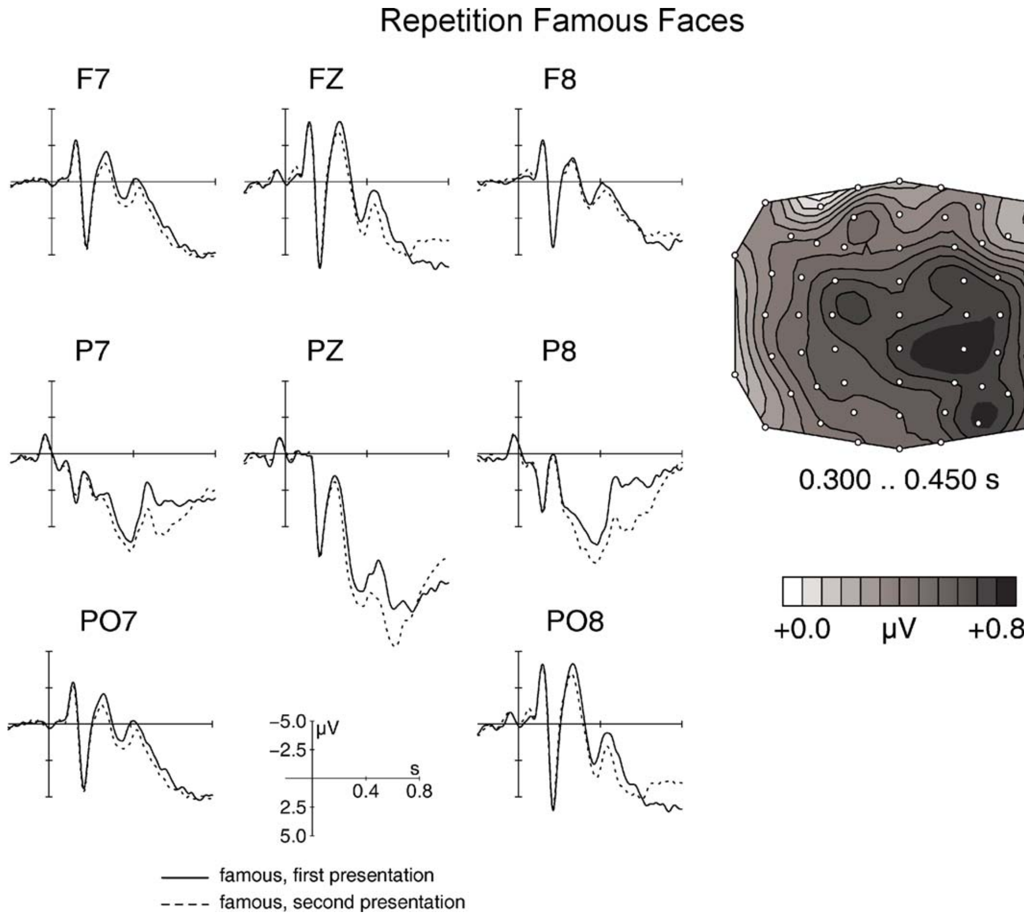

Fig. 8. Experiment 2: Left: ERPs elicited by the first and second presentation of famous faces. Right: The topographic distribution of the difference wave for ERPs to the second and first presentation of famous faces indicates a posterior maximum between 300 and 450 ms.

differences were found for parietal sites only (P7, Pz, P8; p's<0.027).[2]

3.2.2.1. Topographic profile analyses. Similar to Experiment 1, significant ERP effects were evident for semantic familiarity and perceptual fluency between 300 and 450 ms and the scalp topography for the conditions appeared to be different in this time range. Effects for perceptual fluency were limited to parietal locations, while effects for familiarity based on semantic memory access were evident at frontal and parietal locations. To examine whether different neuronal sources contributed to these effects, ERP waveforms elicited by the first presentation of famous no name faces were compared to those elicited by the second presentation of non-famous faces. A two-way repeated-measures ANOVA with the factors face type (two levels: first presentation of famous no name faces vs. second presentation of non-famous faces) and electrode (nine levels) performed for the 300–450-ms time period failed to reveal a main effect of face type [$F(1,20)<1$], but the face type×electrode interaction was significant [$F(8,160)=4.55$, $p<0.05$]. Separate tests for

[2] Target faces did not elicit an ERP repetition effect. Previous studies report absent repetition effects for impossible objects (e.g., Ref. [48]) or orthographically illegal non-words. Based on such results, it has been proposed that the repetition effect reflects processes that operate on items that can be encoded into some form of unitized representation [57]. It is conceivable that such an encoding was not successful for distorted faces and that, consequently, no ERP repetition effect was elicited.

Table 4
Experiment 2: Results for the ANOVA for the ERPs to the first presentation of famous no name faces and non-famous faces (familiarity based on semantic memory access, face type×electrode), for the ERPs to the second and first presentation of non-famous faces (perceptual fluency, presentation×electrode), and for the ERPs to the second and first presentation of famous faces (presentation×electrode)

	df	200–300 ms	300–450 ms	500–650 ms
Semantic memory access				
Face type	1.20	6.24*	4.36*	8.03**
Face type×electrode	57.1140	0.85	1.63	9.22***
Perceptual fluency (non-famous faces)				
Presentation	1.20	0.39	7.77**	2.88
Presentation×electrode	57.1140	1.04	4.23**	0.79
Repetition famous faces				
Presentation	1.20	11.34**	16.07***	5.84*
Presentation×electrode	57.1140	1.49	2.48*	4.51**

df=degrees of freedom.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

single electrodes showed significant amplitude differences for Fpz only (p=0.012). A marginally significant interaction for the amplitude-normalized data [$F(8,160)=2.63$, p=0.08] supports the notion of at least partially different neural sources for semantic familiarity and perceptual fluency.

3.3. Discussion

Experiment 2 examined whether the ERP effect obtained for semantic familiarity in Experiment 1 reflects the particular task demands of Experiment 1, namely the requirement to process the fame status of the faces. To minimize the contribution of recollection and/or decision confidence processes to the ERP effect of semantic familiarity, only famous faces for which the name was not retrievable were analyzed for this condition.

Three important results were revealed: First, the ERP effects associated with semantic familiarity resembled those obtained in Experiment 1, even though the task did not require participants to retrieve person identity information from long-term memory. This is in line with the assumption that knowledge about famous faces is automatically activated by the mere presentation of these faces [9]. Additionally, as in Experiment 1, the second presentation of famous faces enhanced the early positive effect (200–300 ms), suggesting that person identity information is not only automatically activated, but also accessed faster when stimuli are repeated. However, for the semantic familiarity condition amplitude differences between famous and non-famous faces were smaller than in Experiment 1, suggesting that semantic retrieval is not entirely task-independent, but may be modulated by attentional processes. Such a view is in line with the idea that top-down information might have an early influence at the level of the person identity nodes [80].

Second, the topographic dissociation between ERP effects for the semantic familiarity condition and the perceptual fluency condition between 300 and 450 ms was replicated in Experiment 2. Similar to Experiment 1, the ERP effect found for perceptual fluency in Experiment 2 was clearly parietally focused. Third, the target detection task employed here failed to elicit late (500–650 ms) parietally focused effects for the semantic familiarity and the perceptual fluency conditions suggesting that retrieval of contextual information for famous and non-famous faces played a minor or no role in this task.

In Experiment 2, the semantic familiarity condition was associated with a biphasic ERP response comprising an early onsetting broadly distributed positivity between 200 and 300 ms, followed by a larger effect at frontal recording sites between 300 and 450 ms. As this effect is highly similar to the corresponding effect in Experiment 1, this result suggests that retrieving person identity information from long term memory may be automatically triggered by the presentation of a famous face, even though it is not explicitly required by the task at hand. Despite its early onset at around 200 ms, this effect is reminiscent of the mid-frontal ERP effect, held to be an electrophysiological correlate of familiarity arising from a recent exposure of a stimulus in an experimental context [39]. Thus, an important issue to be addressed is whether semantic familiarity can be dissociated electrophysiologically from familiarity arising from a prior exposure in an explicit old/new recognition task, i.e., recognition familiarity. We approached this issue by conducting an old/new recognition memory task with famous and non-famous faces. To ensure comparability between the experiments, stimuli and characteristics of the design were kept as similar as possible to those of the first two experiments. Following the logic of prior ERP studies of recognition memory, recognition of previously presented faces, irrespective of their fame status, should be based on familiarity and recollection processes. Consequently, we predicted that correct old judgments for both face types, should elicit a mid-frontal old/new effect (reflecting familiarity) followed by a parietal old/new effect (reflecting recollection).

4. Experiment 3

4.1. Methods

4.1.1. Participants

Twenty volunteers (11 female) between 20 and 31 years of age (mean 23.7 years) participated. They were students at the University of Leipzig, were right-handed and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of the participants had participated in Experiment 1 or 2 or had any prior experience with the task.

4.1.2. Experimental materials and procedure

The same photographs of famous and non-famous faces as in Experiments 1 and 2 were used to construct two quasi-random list orders. List presentation was counterbalanced across participants. As in Experiments 1 and 2, photographs were presented in a continuous series with the constraint that no more than four faces of the same type (famous, non-famous) and no more than four first and second presentations were presented consecutively. All photographs were repeated after a minimum of 6 intervening faces and a maximum of 12 intervening faces. Filler faces were included to guarantee these constraints were met at the beginning and at the end of the lists.

Participants indicated whether each face was presented for the first (new response) or second (old response) time in this experiment. They responded by pressing the left or the right button of the response box with the thumb of the corresponding hand. Response hand was counterbalanced across participants. They were informed that they would see pictures of famous and non-famous faces, but that the fame status was irrelevant for the task. To familiarize the participants with the task and the stimuli a practice block, containing seven faces (three were repeated) was performed

Table 5
Experiment 3: Mean reaction times for correct responses and mean accuracy for the first presentation (new-response) and the second presentation (old-response) of the different types of photographs

	Face type	Reaction time (ms)	Proportion correct
First presentation	non-famous	812.3 (27.5)	76.44 (2.75)
	famous	781.3 (24.7)	94.27 (1.66)
Second presentation	non-famous	790.9 (28.1)	88.38 (2.54)
	famous	775.6 (27.0)	92.32 (1.60)

The standard error of the mean is presented in parenthesis.

prior to the experimental task. Including electrode application and removal the session lasted about 1.5 h.

4.1.3. ERP recording and analysis

The recording procedure was the same as in Experiment 2. ERPs were selectively averaged for correct responses to famous faces and non-famous faces separately for the first and the second presentation. As in Experiments 1 and 2, only famous faces for which the name was not retrievable (famous no name faces) were included in the semantic familiarity condition.

4.2. Results

4.2.1. Behavioral data

Mean reaction times for correct responses and the percentage of correct old and new responses for both face types are presented in Table 5. Responses were faster and more accurate for famous faces than for non-famous faces. Two-way repeated-measures ANOVAs with the factors face type (two levels) and presentation (two levels) were conducted on the reaction times for correct responses and on the accuracy data. For the accuracy data, there was a significant main effect of face type [$F(1,19)=162.03$, $p<0.001$] and a significant face type×presentation interaction [$F(1,19)=13.21$, $p<0.01$]. Separate analyses showed that accuracy increased from first to second presentation for non-famous faces [$F(1,19)=6.73$, $p=0.018$], but not for famous faces [$F(1,19)=1.55$, $p>0.05$]. For reaction times of correct responses, there was a significant main effect of face type [$F(1,19)=16.89$, $p<0.001$]. The main effect of presentation [$F(1,19)=1.92$, $p>0.05$] and the face type×presentation-presentation interaction [$F(1,19)=2.02$, $p>0.05$] were not significant.

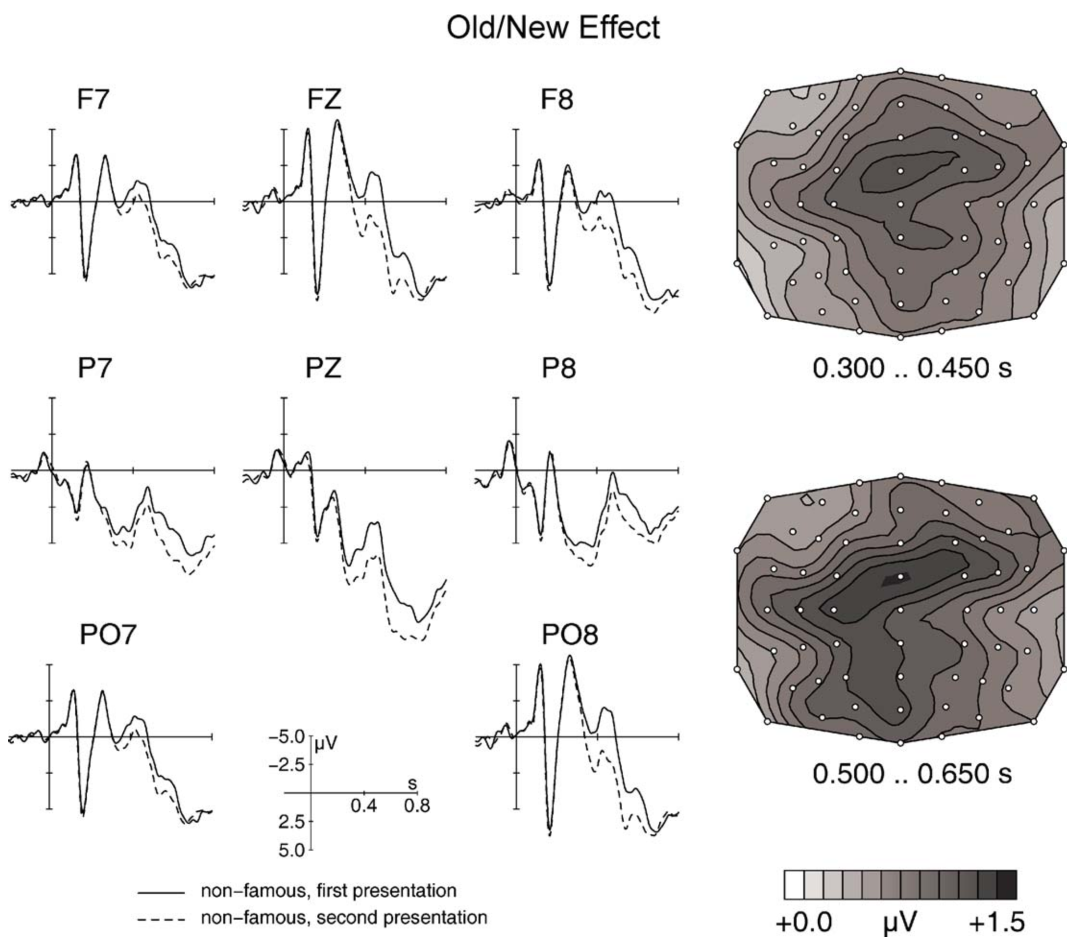

Fig. 9. Experiment 3: Left: ERPs elicited by the first and second presentation of non-famous faces. Right: Topographic distributions of the difference wave for ERPs to the second and first presentation of non-famous faces between 300 and 450 ms and between 500 and 650 ms. The frontally focused effect between 300 and 450 ms seems to be accompanied by larger posterior activity between 500 and 650 ms.

4.2.2. ERP data

4.2.2.1. ERP old/new effects. The ERP waveforms for the first and second presentations of non-famous faces are displayed in the left panel of Fig. 9 and those for famous faces are shown in the left panel of Fig. 10. Both comparisons capture the electrophysiological effects associated with recognition and, as is apparent from the figures, the old/new ERP effects were highly similar for both face types. ERP waveforms elicited by the second presentation of non-famous and famous faces were more positive than the waveforms elicited by the first presentation of non-famous and famous faces starting at around 300 ms. As is apparent from the topographic maps, presented in the right panel of each figure, the effects were focused at mid-frontal recordings sites between 300 and 450 ms.

ERP old/new effects were examined statistically in three consecutive time windows (200–300, 300–450, 500–650 ms) separately for non-famous faces and famous faces. For non-famous faces there were no effects in the early time range, but there were significant main effects of presentation in the two later time intervals (see Table 6). Additionally, a significant presentation×electrode interaction was evident between 300 and 450 ms. Separate tests for single electrodes showed significant effects at all tested locations (F7, Fz, F8, P7, Pz, P8; p's<0.05), but these effects were largest at frontal electrodes (Fz ω^2=0.54; F8 ω^2=0.56). For famous faces, a main effect of presentation was evident between 200 and 300 ms. Similar to the results for non-famous faces, there were main effects of presentation in the later time windows and a

Table 6
Experiment 3: Results for the ANOVAs (presentation×electrode) for ERP old/new effects for famous faces and for non-famous faces

	df	200–300 ms	300–450 ms	500–650 ms
Non-famous				
Presentation	1.19	2.62	28.43***	13.56**
Presentation×electrode	57.1083	<1	3.58*	2.08
Famous				
Face type	1.19	10.07**	27.17**	15.59***
Face type×electrode	57.1083	1.34	3.76*	2.02

df=degrees of freedom.
* p<0.05.
** p<0.01.
*** p<0.001.

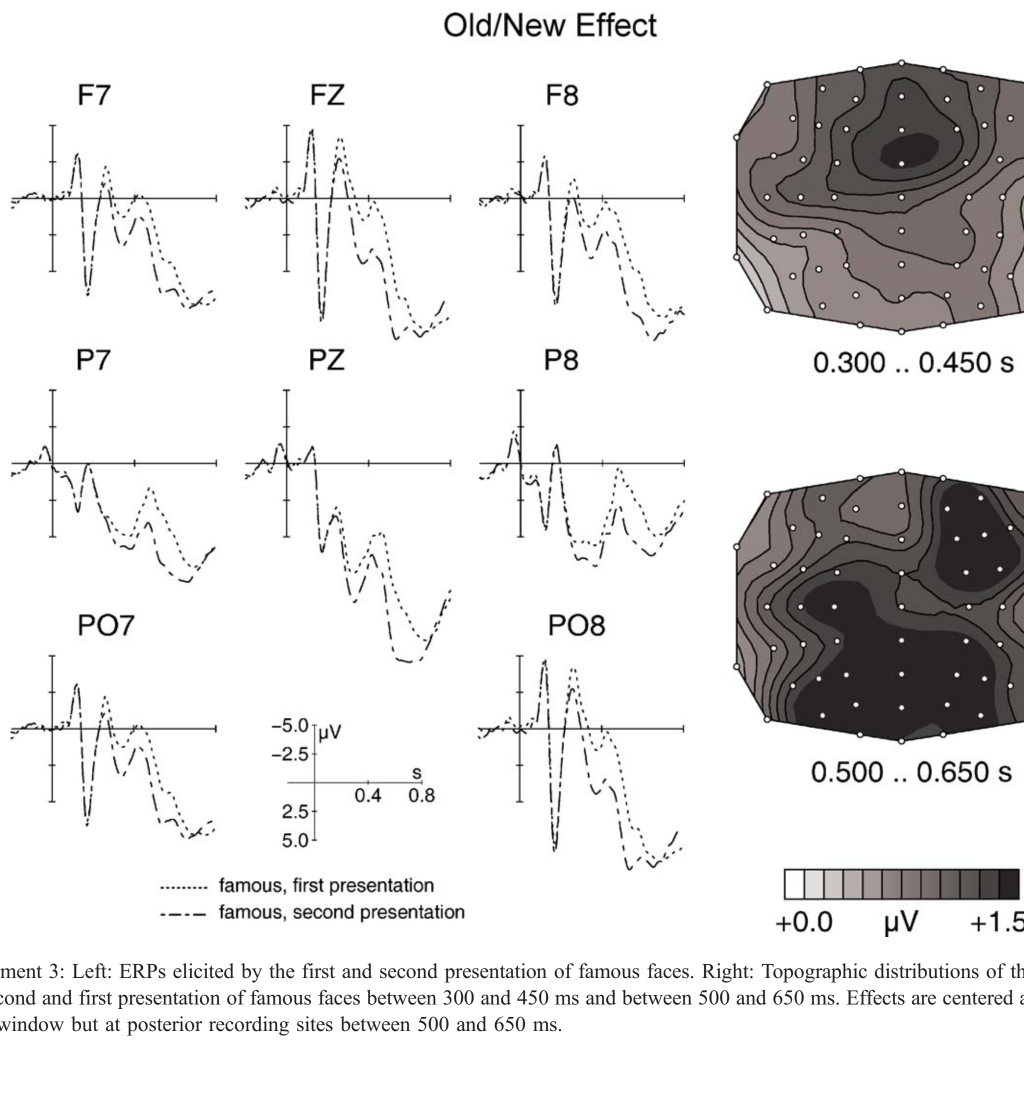

Fig. 10. Experiment 3: Left: ERPs elicited by the first and second presentation of famous faces. Right: Topographic distributions of the difference wave for ERPs to the second and first presentation of famous faces between 300 and 450 ms and between 500 and 650 ms. Effects are centered at frontal electrodes in the early time window but at posterior recording sites between 500 and 650 ms.

significant presentation×electrode interaction between 300 and 450 ms. Separate tests revealed significant effects at all tested locations (F7, Fz, F8, P7, Pz, P8; p's<0.05), but the effect was largest at Fz (ω^2=0.53).

4.2.2.2. Semantic familiarity. The ERP waveforms elicited by the first presentation of famous no name and non-famous faces, which we assume capture the electrophysiological differences associated with semantic familiarity, are presented in Fig. 11. As in Experiments 1 and 2, waveforms elicited by the first presentation of famous no name faces are more positive than those elicited by the first presentation of non-famous faces beginning around 200 ms. As indicated by the topographical distributions of the ERP-differences (right panel of Fig. 11), the effect showed a frontal distribution in the two early time windows.

Two-way repeated measures ANOVAs were conducted to examine the effect of semantic familiarity. As listed in Table 7, there were significant main effects of face type and face type×electrode interactions in all three time windows (200–300, 300–450 and 500–650 ms). Between 200 and 300 ms, separate tests for single electrodes revealed significant effects at all tested frontal locations (F7, Fz, F8) and at Pz (p's<0.012; P7, P8 p's>0.05). Significant effects for frontal locations and at Pz were also revealed between 300 and 450 ms (p's<0.015; P7, P8 p's>0.05). However, a decrease in the effect at parietal locations over time could be observed (200–300 ms, Pz ω^2=0.52; 300–450 ms, Pz ω^2=0.36). Tests for single electrodes were only significant at Fz and F8 in the late time window (p's<0.012; P7, P8 p's>0.05).

Table 7
Experiment 3: Results for the ANOVA for the ERPs to the first presentation of famous no name faces and non-famous faces (familiarity based on semantic memory access, face type×electrode)

	df	200–300 ms	300–450 ms	500–650 ms
Semantic memory access				
Face type	1.19	11.85**	12.14**	7.13*
Face type×electrode	57.1083	4.8**	3.11*	6.06***

df=degrees of freedom.
* p<0.05.
** p<0.01.
*** p<0.001.

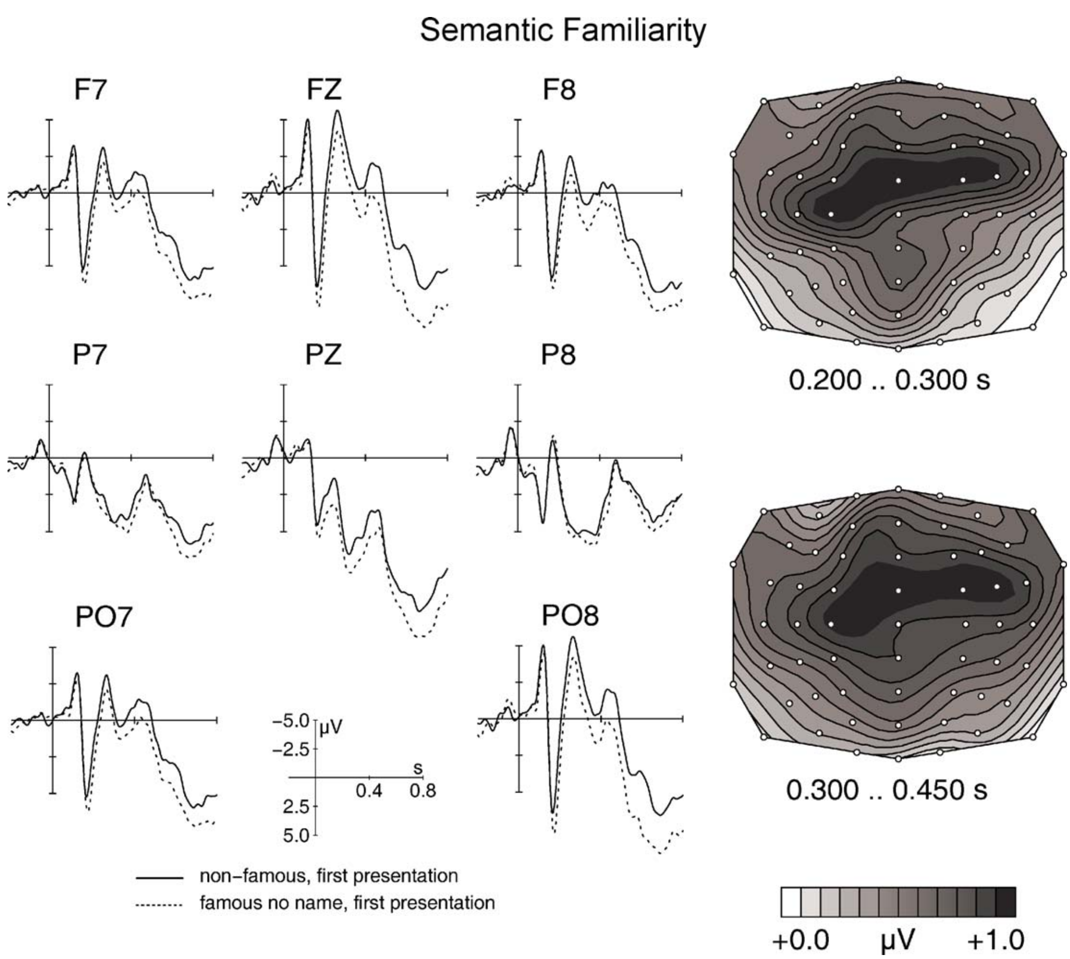

Fig. 11. Experiment 3: Left: ERPs elicited by the first presentation of non-famous and famous no name faces. Right: Topographic distributions of the difference wave for ERPs to the first presentation of famous faces and the first presentation of non-famous faces show frontally focused effects between 200 and 300 ms and between 300 and 450 ms.

4.2.2.3. Topographic profile analyses. Significant ERP effects, between 300 and 450 ms, were evident for recognition-related familiarity for non-famous as well as for famous faces and were also evident for the semantic familiarity condition. However, the critical question is whether these effects are based on the same or on different underlying neural sources. To address this issue, ERP difference waveforms were computed. Recognition-related familiarity was defined as (1) the difference wave of ERPs to second presentations of famous faces minus ERPs to first presentations of famous faces and (2) the difference wave of ERPs to second presentations of non-famous faces minus ERPs to first presentations of non-famous faces. Consistent with Experiments 1 and 2, semantic familiarity was defined as the ERP difference between first presentations of famous no name faces and first presentations of non-famous faces.

A first analysis compared the difference waveform for recognition-related familiarity in non-famous faces and the difference waveform for semantic familiarity, whereas a second analysis used the difference waveform for famous faces as a measure of recognition-related familiarity. Both two-way repeated-measures ANOVAs with the factors face type (two levels: recognition-related familiarity, semantic familiarity) and electrode (nine levels) failed to reveal significant main effects or interactions [non-famous: $F(1,19)<1$, $F(8,152)=1.20$, $p>0.1$; famous: $F(1,19)<1$, $F(8,152)<1$]. Consequently, the electrophysiological activity measured for semantic familiarity and for recognition-related familiarity between 300 and 450 ms does not seem to be driven by different neuronal sources.

4.3. Discussion

In the present experiment, participants saw famous and non-famous faces and had to indicate whether they had seen the photograph before in the course of the experiment or not. This explicit memory task allowed the comparison of the electrophysiological activity elicited by recognition-related familiarity with the electrophysiological activity elicited by semantic familiarity.

Recognition accuracy was high for famous faces and somewhat lower for non-famous faces. Non-famous faces elicited more correct responses on second than first presentations. Irrespective of these slight differences in performance, reliable and highly similar ERP old/new effects were obtained for both types of faces. These effects took the form of an early (300–450 ms) frontally focused effect followed by a more posteriorly distributed effect between 500 and 650 ms. Furthermore, similar to Experiments 1 and 2, second presentations of famous faces elicited a positive effect between 200 and 300 ms.

Consistent with prior studies using verbal stimulus materials that took the effects between 300 and 450 ms and between 500 and 650 ms as reflections of recognition-related familiarity and recollection judgments respectively (for an overview, see Ref. [39]), the present results suggest that the ERP-correlates of both subcomponents of recognition memory can be reliably observed using faces as stimulus materials (see also Ref. [41]).

More interesting, however, is that ERP effects associated with semantic familiarity in Experiment 3 resembled those obtained in Experiments 1 and 2. A semantic familiarity effect was observable starting around 200 ms and showed a clear frontal distribution between 300 and 450 ms. This latter effect was similar to the effect found for recognition-related familiarity for famous and non-famous faces, suggesting that similar neuronal structures may have been involved. However, the semantic familiarity effect between 300 and 450 ms in this explicit old/new recognition tasks seemed to be distributed less frontally than the respective effects in Experiments 1 and 2. Cross-experimental comparisons are reported in the following and implications for current memory models are considered in the general discussion.

5. Cross-experiment comparisons

Experiments 1–3 were set out to examine whether semantic familiarity, perceptual fluency and recognition-based familiarity can be dissociated electrophysiologically. However, statistical comparison of the topographical distribution for the effects found for perceptual fluency and recognition-related familiarity is, due to the nature of the task (repetition task-irrelevant vs. task-relevant), only possible across experiments. The effect of recognition-related familiarity for non-famous faces in Experiment 3 (second presentation minus first presentation, 300–450 ms) was separately compared with the effect of perceptual fluency for non-famous faces in Experiment 1 (second presentation minus first presentation, 300–450 ms), and with the effect of perceptual fluency for non-famous faces in Experiment 2.[3] Because anterior–posterior differences were of main interest, ANOVAs were performed using nine midline electrodes (Fpz, Afz, Fz, Fcz, Cz, Cpz, Pz, Poz, Oz). The between-experiment analyses for the difference waveforms revealed no experiment×electrode interaction for the comparison between Experiments 1 and 3 [$F(8,288)<1$]. However, a marginal effect was found for the analysis comparing the perceptual fluency effect in Experiment 2 with the effect of recognition-related familiarity in Experiment 3, [$F(8,312)=2.74$, $p=0.07$]. ERP-difference waveforms were more positive at frontal locations for the recognition-related familiarity condition than for the

[3] As a response was required to each face in Experiment 3, but not in Experiment 1, the ERP data of both experiments may not be entirely comparable. However, as only difference waves were considered in the cross-experiment analysis, we assume that the confounding effect of differential response requirements is diminished.

perceptual fluency condition (t-test Fz $p<0.05$; Pz $p>0.1$). To allow a comparison of scalp topographies between Experiments 2 and 3 that is not confounded with differences in magnitude, ERP difference waveforms were normalized. Analysis for the normalized values revealed a significant interaction [$F(8,312)=3.75$, $p<0.05$], suggesting that different neuronal processes contribute to perceptual fluency and recognition-related familiarity.

Cross-experiment analyses were also performed to evaluate whether the electrophysiological correlates of semantic familiarity differed across experiments. This was motivated by the finding that the effects of semantic familiarity were similar to effects of recognition-based familiarity between 300 and 450 ms, but also appeared to be less frontally distributed than the corresponding effects in Experiments 1 and 2.

The effect of semantic familiarity in Experiment 3 (i.e., first presentation no name famous faces minus first presentation non-famous faces, 300–450 ms) was separately compared with the effect of semantic familiarity in Experiments 1 and 2. The between-experiment analyses used nine midline electrodes and revealed a marginally significant experiment×electrode interaction for the comparison between Experiments 1 and 3 [$F(8,288)=2.93$, $p=0.06$], but not for the comparison between Experiments 2 and 3 [$F(8,312)=2.38$, $p>0.1$]. Based on the marginally significant interaction for the comparison between Experiments 1 and 3, an analysis was performed for normalized data. This analysis only revealed a trend towards a significant interaction [$F(8,288)=2.56$, $p=0.09$].

Consequently, there appears to be no evidence for a different cortical involvement for the semantic familiarity effect in Experiments 2 and 3. On the basis of the marginally significant effect for the comparison between Experiments 1 and 3, the assumption that an additional and more frontally located source contributed to the semantic familiarity effect in Experiment 1 is not indicated.

6. General discussion

The goal of this study was to explore whether familiarity arising from the access of semantic memory (semantic familiarity) could be dissociated electrophysiologically from perceptual fluency and from familiarity that arises from a recent presentation of an event in an explicit old/new recognition task (recognition familiarity).

Three experiments were performed in which different groups of participants were presented with famous and non-famous faces. Participants indicated either the fame status of the faces (Experiment 1), monitored the faces for the occurrence of rare target stimuli (Experiment 2), or made old/new recognition judgments for first and second presentations of the faces (Experiment 3). The ERP-findings revealed the following dissociations between the three forms of memory.

Semantic familiarity was associated with an early onset, broadly distributed effect (200–300 ms), and followed by a more frontally distributed effect between 300 and 450 ms in all three experiments. Moreover, in Experiment 3, the semantic familiarity effect between 300 and 450 ms was similar to the frontal ERP effect obtained by the comparison of hit and correct rejection responses for famous and non-famous faces that we consider to be a reflection of recognition-familiarity.

In contrast, perceptual fluency, operationally defined as the ERP-difference between the second and the first presentation of a non-famous face when this repetition was not task-relevant (Experiments 1 and 2), gave rise to posteriorly focused effects between 300 and 450 ms and was thereby dissociable from semantic familiarity and recognition familiarity.

In the following, we begin with a discussion of perceptual fluency effects, and then turn to semantic familiarity and recognition-related familiarity.

6.1. Isolating ERP effects associated with perceptual fluency

Perceptual fluency, one form of implicit memory, is seen as the facilitation of task performance due to prior experience [45]. Consistent with this definition, Experiment 1 revealed behavioral facilitations for second as compared to first presentations of non-famous and famous faces. The ERP correlate of this facilitation took the form of a positive difference between first and second presentations focused at parietal locations between 300 and 450 ms. This effect is similar in its temporal and topographical characteristics to perceptual fluency effects observed in prior ERP-experiments using faces [41], words [18,46,58] and line drawings of objects [48] as stimulus materials. Note, that different ERP results have been found for immediate task-irrelevant stimulus repetitions [49]. These topographic characteristics dissociate the perceptual fluency effect from the frontally focused semantic familiarity effect that occurred between 300 and 450 ms in Experiments 1 and 2.

Another comparison of interest is whether different topographies are evident for perceptual fluency and recognition-based familiarity. A statistical comparison of these effects, performed across experiments for non-famous faces revealed a significant interaction between Experiments 2 and 3, but not when the scalp topographies of the aforementioned effects were contrasted between Experiments 1 and 3. It is conceivable that the non-significant result arose from the fact that in Experiment 1 (to a larger extent than in Experiment 2) participants may have explicitly noticed the repetition of some faces. This may have weakened the comparison of the perceptual fluency effect in Experiment 1 and the explicit (familiarity) effect in Experiment 3.

A similar dissociation between implicit processes and recognition-based familiarity was reported by Rugg et al. [58], who examined ERPs in the test phase of a recognition memory test with concrete nouns. ERPs from parietal locations were more positive for missed old words than for new words between 300 and 500 ms. This parietal effect, also replicated in an implicit memory test [58], has been taken as a neuronal correlate of memory in the absence of conscious recognition and resembles the perceptual fluency effect obtained in the present study. In the same time range, the authors found a frontally focused effect elicited by old words that was insensitive to a levels-of-processing manipulation in the study phase. This effect, taken to reflect recognition familiarity, resembles our putative recognition familiarity effect. Moreover, Munte et al. [41] reported frontal old/new effects between 300 and 500 ms for non-famous faces, but more posteriorly distributed effects for the same stimulus material when an implicit task was performed (see also Ref. [23]).

The finding of different neuronal correlates for perceptual fluency and recognition-related familiarity argues against models of recognition memory that equate recognition-familiarity with perceptual fluency [33,77]. Rather, our results indicate that the mere facilitation of processing conferred by a prior task-irrelevant presentation and recognition-related familiarity are functionally dissociable and mediated by different brain systems. By this, the present result adds to the converging evidence that enhanced perceptual fluency and recognition familiarity are dissociable [39,58,69,82].

6.2. Fractionating ERP effects associated with semantic familiarity and recognition-related familiarity

In all three experiments, electrophysiological activity associated with semantic familiarity (famous first presentation vs. non-famous first presentation) was evident starting around 200 ms. While this early effect was broadly distributed across the scalp, with left-parietal and frontal maxima, a shift toward stronger effects at prefrontal locations was evident starting around 300 ms. Although this shift was not observable in Experiment 3, topographical comparisons between the experiments suggest a similar distribution for the semantic familiarity effect in all three experiments. Moreover, the effect for semantic familiarity between 300 and 450 ms in Experiment 3 was similar to the ERP effects associated with recognition-related familiarity.

Even though the early dissociation due to face familiarity (starting around 200 ms) was obtained in all three experiments and has also been reported by others [62], it is surprising in light of models of face perception [9] that claim that accessing person identity information presupposes the completion of structural encoding processes. These early structural encoding stages in face processing have been shown to be reflected in a negative component at posterior temporal sites around 170 ms after stimulus onset, the N170 [3,4]. The N170 peaks between 150 and 180 ms after stimulus onset is usually larger over the right than over the left hemisphere and has been reported not to be affected by face familiarity [2,19]. Consequently, rather than reflecting a modulation of the N170 component, the early effect reported in the present study may reflect an early ERP correlate of accessing stored facial representations (face recognition units) or early links between face recognition units and person identity information.[4]

Other studies examining ERP correlates of face familiarity revealed mixed results with respect to the time course of accessing person identity information. For instance, Eimer [19], who used a nose tip reference, did not report ERP differences between famous and non-famous faces before 400 ms. Another difference from the ERP results obtained in the present experiments, which show positive ERP effects for famous faces, is that Eimer [19] reported larger N400-like components for famous than for non-famous faces at parieto-central recording sites. In the latter study, famous and non-famous faces were randomly presented together with non-face objects (houses, hands) and the task required a response to the hand stimuli (Part 1) or to an alphanumerical string (Part 2). It is conceivable that these task requirements triggered less processing of facial details in the Eimer study than in the current experiments. These differential processing requirements may have resulted in semantic evaluation and integration processes that modulated the ERPs in the N400 time range.

Our finding of early ERP differences between famous and non famous faces is supported by a recent study by Bentin and Deouell [2], who also used a nose-tip reference. Participants silently counted the faces of politicians that were presented randomly intermixed with famous and non-famous faces. ERP differences between famous and non-famous faces, similar to our findings, were present at around 250 ms at frontal recordings sites. However, this early effect was more negative going for famous faces than for non-famous faces. The exact reasons for the polarity inversion between the latter experiment and our experiments are unclear. Further research will be required to elucidate the nature of this early ERP sign of semantic (face) familiarity.

In the current experiments, early ERP differences between 200 and 300 ms were also evident for the repetition of famous faces in all three experiments, while the repetition of non-famous faces did not result in any effect between 200 and 300 ms. This can be taken as additional support for the association of this early effect with accessing facial representations in long-term memory.

[4] Physical differences between the photographs could be responsible for the early ERP differences. However, this is unlikely for the following reasons. First, efforts were made to homogenize the faces. Second, a physical difference between famous and non-famous faces would not explain the reported early frontal effects. Physical differences typically affect the P100 at occipital recording sites, which was not the case in the current experiments (compare PO7 and PO8 electrodes, Figs. 1, 6 and 11).

Other studies report more negative going waveforms for repeated famous faces at temporal recording sites and more positive going waveforms at frontal locations between 200 and 300 ms [51,61,63] (all cited studies used an average-reference). Interestingly, in resemblance of the present findings, Schweinberger et al. [63] found an increased positivity after immediate repetition of famous faces at midfrontal electrodes between 200 and 300 ms. In the same time interval, however, there also was an enhanced N250 at inferior temporal electrodes for famous faces. Rather than equating this early effect to perceptual repetition, similar to our interpretation the authors claimed it reflected stimulus-triggered access to stored facial representations. Finally, results by Pfutze et al. [51], showing similar effects for famous faces and for famous names, but not for non-famous faces and non-fames names in an explicit recognition task, indicate that this early effect is not only present for faces, but is related to the contact with semantic representations.

In sum, the early ERP effects for semantic familiarity found in the present study and reported by others (Refs. [51,63], also Ref. [2]) support the claim that, during face recognition, structural encoding and accessing person identity information do not operate in a strictly serial fashion The view that two pathways are involved in face recognition is also supported by data from patients suffering from prosopagnosia and patients suffering from Capgras Delusion (see Ref. [22]). Prosopagnosia patients are unable to recognize familiar faces although they show higher autonomic responses like higher skin conductance to familiar faces than to non-familiar faces. Patients with Capgras Delusion, on the other hand, believe that familiar persons have been replaced by robots or dummies. They recognize familiar faces, but do not show autonomic, covert responses to them. Based on this dissociation Ellis and Lewis [22] propose a dual-route model that involves core recognition stages followed by parallel face identification and affective-response stages. Our findings, showing that electrophysiological signs of familiarity processing can become apparent in close temporal proximity to those indicating structural processing of face information, are consistent with the dual route proposal.

The second ERP expression of familiarity based on semantic memory access was a frontally focused positive difference between first presentations of famous and non-famous faces in the time range between 300 and 450 ms. In an old/new recognition experiment (Experiment 3), this semantic familiarity ERP-effect showed close similarity to that found for the recognition of faces (recognition-familiarity). The similarity between the semantic familiarity effect and recognition familiarity in the later time range (300–450 ms) suggests that these two effects share at least partly similar processes. Such an interpretation is in line with the observation that patients with selective damage to the hippocampus in early childhood, despite a lack of capacity to recollect learned information, are still capable of acquiring new semantic information and experiencing recognition-familiarity [10,18,76]. The results are also consistent with the view of a continuous transition from recency familiarity to semantic familiarity, with semantic knowledge being a function of the number of prior exposures.

Starting around 500 ms, there was pronounced positive slow wave activity for famous faces and, to a smaller extent, to the second presentation of non-famous faces. Two observations support the view that, for the most part, the latter component can be taken as a reflection of active recollection processes initiated by famous faces or the repeated exposure of non-famous faces. First, it was substantially reduced when only those faces for which the person's name was unknown entered the analyses (see Fig. 4). Even though retrieving a person's name is just one way to recollect source or contextual information (e.g., profession, books written or roles played) associated with a face, it can be assumed that named faces were associated with more recollection experience than non-named faces. Second, the positive slow wave was also diminished for non-famous faces when the task did not explicitly require the access of person identity information from long-term memory, as in Experiment 2 where participants had to recognize distorted faces.

An important issue concerns the neuronal mechanism that gave rise to differential memory-related ERP effects. One possibility is that the present scalp recorded effects reflect neuronal responses to novelty relative to the experimental context or relative to pre-existing semantic knowledge. It is conceivable that the scalp recorded memory effects are modulations of negative ERP components, with these negative components reflecting the processing consequences evoked by novel stimuli [39,71]. Stimuli that have previously been encoded, or for which pre-existing long-term memory knowledge can be accessed, lead to attenuations of these negative components at different points in time relative to the eliciting event. Recent investigations of the mnemonic functions of the perirhinal cortex (for an overview, see Refs. [6,7]) identified groups of neurons that showed selective reductions of firing for recently encoded stimuli and for highly familiar stimuli (i.e., stimuli seen many times on previous days (see Ref. [7]). As the perirhinal cortex is strongly interconnected with the orbital frontal cortex and uni- and multimodal temporal lobe regions [43], it is not unlikely that the scalp recorded ERP memory effects arise from differential mnemonic neuronal activations within these interconnected brain regions.

In showing an electrophysiological dissociation for three forms of memory retrieval and in tracing the time course of these processes, our results provide a first step for further research aimed at identifying the nature of neuronal processing involved in familiarity based on semantic memory access, perceptual fluency and recognition familiarity.

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