Psychophysiology, 45 (2008), 957–969. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/j.1469-8986.2008.00707.x

Perceiving age and gender in unfamiliar faces: Brain potential evidence for implicit and explicit person categorization

HOLGER WIESE, STEFAN R. SCHWEINBERGER AND MARKUS F. NEUMANN
Department of General Psychology, Friedrich Schiller University of Jena, Jena, Germany

Abstract

We used repetition priming to investigate implicit and explicit processes of unfamiliar face categorization. During prime and test phases, participants categorized unfamiliar faces according to either age or gender. Faces presented at test were either new or primed in a task-congruent (same task during priming and test) or incongruent (different tasks) condition. During age categorization, reaction times revealed significant priming for both priming conditions, and event-related potentials yielded an increased N170 over the left hemisphere as a result of priming. During gender categorization, congruent faces elicited priming and a latency decrease in the right N170. Accordingly, information about age is extracted irrespective of processing demands, and priming facilitates the extraction of feature information reflected in the left N170 effect. By contrast, priming of gender categorization may depend on whether the task at initial presentation requires configural processing.

Descriptors: Event-related potentials, Priming, Unfamiliar faces, Age categorization, Gender categorization

The efficient analysis and representation of person-related information is one of the most challenging and important tasks of human social perception. In particular, whereas processing of familiar people is thought to involve individuation and identification, efficient processing of unfamiliar people is achieved by categorization (e.g., into old vs. young, male vs. female, own vs. other ethnic group, etc.). However, it remains controversial whether relevant categories are activated implicitly during perception. Alternatively, category activation may be determined by controlling factors, such as attention, processing strategies, or goals (Macrae, Bodenhausen, Milne, Thorn, & Castelli, 1997).

The human face, in particular the face of an unknown person, is perhaps the most salient stimulus to elicit categorization. However, although cognitive models of face perception (Bruce & Young, 1986; Burton, Bruce, & Hancock, 1999; Schweinberger & Burton, 2003) largely describe the processes relevant for the identification of familiar faces, they have little to say about the processes concerned with unfamiliar face categorization. Importantly for current purposes, these models distinguish between "visually derived semantic codes" (e.g., age, gender, ethnicity, or emotional expression of a face) and "identity-specific semantic codes" (e.g., occupation, nationality, or name belonging to a face), the latter being only available for familiar faces (Bruce & Young, 1986).

Face Processing and Categorization

It is well established that spontaneous identification of a familiar face primes future perceptual recognition of the same face, a phenomenon known as repetition priming (e.g., Burton, Bruce, & Johnston, 1990). In recent years several priming studies have been carried out that may be related to the question of implicit face processing. In a study by Jenkins, Burton, and Ellis (2002), a dissociation between overt and covert recognition of familiar faces was demonstrated. The authors manipulated perceptual load in a relevant task (low: deciding about the color of a letter string vs. high: detecting a specific letter within the string) while irrelevant faces were presented at the same time and location. In an unexpected subsequent overt recognition test, participants' explicit memory was much better for faces initially shown in the low-load as compared to the high-load condition. By contrast, repetition priming was completely unaffected by perceptual load.

On the one hand, these results suggest implicit recognition of individual familiar faces independent from general capacity limits. On the other hand, there is evidence that categorization and individuation (i.e., the identification of a familiar person) may rely on distinct cognitive and neural operations. For example, it has been argued that individuation requires a configural or

This work was funded by a grant of the Deutsche Forschungsgemeinschaft (Schw 511/8–1) to S.R.S and H.W. The authors thank Christine Seibt, Bettina Kamchen, and Janina Suhrke for their help during stimulus preparation and data acquisition, as well as Markus Kiefer and two anonymous reviewers for thoughtful comments on an earlier version of the manuscript.

Address reprint requests to: Dr. Holger Wiese, Department of General Psychology, Institute of Psychology, Friedrich Schiller University of Jena, Am Steiger 3, 07743 Jena, Germany. E-mail: holger.wiese@uni-jena.de

relational analysis of the available stimulus cues, whereas person categorization can be achieved by processing single features of faces (Turk, Rosenblum, Gazzaniga, & Macrae, 2005; but see Bruce et al., 1993, for a different perspective to gender categorization).

A recent study by Quinn and Macrae (2005) strongly argues against implicit category activation. In the priming phase of their first experiment, participants were asked to either passively watch a series of unfamiliar faces or to categorize the same faces according to gender. In the subsequent test phase, these faces were presented again, intermixed with new faces, and participants had to categorize them according to gender. The authors found faster reaction times relative to new stimuli only for those faces that had been presented in the active encoding condition. In a second experiment, participants had to categorize unfamiliar faces either according to gender or according to age during the priming phase. In the test phase, these same faces again had to be categorized either according to age or gender. A priming effect for repeated faces was reported only when the dimension of categorization was kept constant between priming and test. Quinn and Macrae concluded from these results (1) that categorization of unfamiliar faces would not occur automatically, but only when the relevant category is actively encoded, and (2) that person categorization would not extend to applicable but task-irrelevant dimensions.

However, to be conclusive, the findings of this study require further consideration. First, the conclusions of Quinn and Macrae (2005) were largely based on collapsing the results across the two different tasks employed. However, it can be argued that age and gender categorization should be considered separately. More specifically, whereas accurate age perception can be based on skin surface texture cues (George & Hole, 2000), gender perception seems to rely on a combination of several broad classes of information, including superficial and local cues (facial hair, skin texture, eyebrows), configural relationships between features, and the three-dimensional structure of the face. Judgments of gender have been observed to be rather poor when participants are unable to use these multiple sources of information (Bruce et al., 1993). Accordingly, perceptual categorization of age and gender may rely on different perceptual and cognitive operations, which in turn might utilize implicit and explicit processes to a different extent and at different points in time during face processing. Second, the experimental basis might be too weak for strongly arguing in favor of either implicit or explicit processing of category information. Recent data suggest that the task dependency of experimental effects does not necessarily mean that the underlying processes are controlled, and even automatic processes appear to depend on top-down influences such as task set and attention (for a recent review, see Kiefer, 2007). Third, the interpretations of Quinn and Macrae are based on behavioral measures alone, that is, reaction times. Allowing for more detailed analyses of the operations underlying face processing, event-related potential (ERP) techniques have been successfully applied to the study of perceptual and semantic priming of faces (Barrett & Rugg, 1989; Begleiter, Porjesz, & Wang, 1995; Itier & Taylor, 2002; Jemel, Pisani, Rousselle, Crommelinck, & Bruyer, 2005; Schweinberger, 1996; Schweinberger, Huddy, & Burton, 2004; Schweinberger, Pfütze, & Sommer, 1995; Trenner, Schweinberger, Jentzsch, & Sommer, 2004). As described in detail below, the application of ERPs might add important new information to the question of implicit versus explicit category activation in unfamiliar face processing.

Event-Related Potentials and Face Processing

Given the high temporal resolution of EEG data, ERPs provide fine-grained chronometric information about the neural operations following stimulus presentation. As is the case for visual stimuli in general, ERPs to faces elicit an early posterior positive peak approximately 100 ms after stimulus onset, with maximum amplitude at occipital electrodes. This P1 component is sensitive to basic stimulus attributes such as contrast, brightness, and spatial frequency, but is not typically regarded to exhibit face selectivity (but see Liu, Harris, & Kanwisher, 2002).

In experiments using faces as stimuli, the P1 is followed by the N170, a negative deflection maximal at right occipito-temporal electrodes, with a peak latency of approximately 170 ms (Bentin, Allison, Puce, Perez, & McCarthy, 1996). The N170 reflects processes prior to the identification of individual faces (Bentin & Deouell, 2000; Eimer, 2000c) and may be engaged in the structural analysis of face components and their configuration (Eimer, 2000b; Sagiv & Bentin, 2001). N170 has been repeatedly shown to be delayed and increased for inverted compared to upright faces (Eimer, 2000b; Itier & Taylor, 2002; Rossion et al., 1999, 2000), which has been interpreted to represent disrupted processing of configural information. However, the processes underlying the N170 may be influenced by task demands, as it has been shown to be sensitive to attentional modulations (Eimer, 2000a).

Whereas the N170 may reflect processes of structural face encoding, the following N250 appears sensitive to the transient activation of a specific structural face representation (Schweinberger & Burton, 2003). In repetition priming experiments, more negative amplitudes for immediately repeated compared to nonrepeated faces were observed over right occipito-temporal regions between approximately 200 and 350 ms (Begleiter et al., 1995; Schweinberger et al., 1995). This N250r effect has been demonstrated to be stronger for familiar compared to unfamiliar faces (Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Pfütze, Sommer, & Schweinberger, 2002) and is diminished or absent for long-term repetitions (Schweinberger, Pickering, Burton, & Kaufmann, 2002).

Finally, the N400 (Kutas & Hillyard, 1980), a negative deflection approximately 400 ms after stimulus onset, usually with a centro-parietal maximum, has been suggested to reflect the integration of semantic information required by a current stimulus (Kutas & Federmeier, 2000). Note that this deflection is not necessarily negative in absolute terms, as it often overlaps in time with a late positive component, resulting in less positive-going (and therefore relatively negative) waveforms. N400 is reduced (or the waveform is more positive) for repeated stimuli, such as words, faces, names, or pictures of buildings (Bentin & McCarthy, 1994; Engst, Martin-Loeches, & Sommer, 2006; Pickering & Schweinberger, 2003; Schweinberger et al., 1995). In the context of long-term repetition priming, substantial N400 effects have been observed for familiar faces or words, with much smaller effects for unfamiliar stimuli (Doyle, Rugg, & Wells, 1996; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002). The N400 priming effect has been ascribed to facilitated access to semantic information (Schweinberger & Burton, 2003), which can occur independently from the participants' conscious identification of the prime stimulus (Kiefer, 2002).

The Present Study

In the present study, we examined the neural correlates of rapid person categorization. For that purpose, we recorded ERPs in an experiment investigating repetition priming of unfamiliar faces. In a first prime phase, participants had to categorize face stimuli according to either age or gender. In a second prime phase, different faces were categorized and the relevant dimension (age or gender) of the task switched, respectively. Finally, in the subsequent test phase, participants again categorized unfamiliar faces according to age or gender. The test phase stimuli could be either congruently primed (same task in the prime and test phase), incongruently primed (different tasks in prime and test phase), or new. If priming effects, that is, faster processing of repeated in comparison to new faces, were to be observed for congruent stimuli only, this would argue for task-dependent category activation. By contrast, similar priming effects for both congruent and incongruent stimuli would argue for implicit category activation, independent from current task demands.

In addition to reaction times, we measured the above described P1, N170, N250r, and N400 components in order to determine modulations of perceptual and postperceptual processes by priming. If categorization influenced early perceptual processing, such as the analysis of facial features or the configuration of facial parts, repetition effects might be already detected in the N170. This hypothesis was based on the following considerations: Although previous ERP studies on repetition priming typically did not observe N170 effects, this might stem from the fact that they mainly used familiarity decisions in combination with famous faces. Priming in these tasks presumably depends on the facilitated activation of face representations, which presumably occurs at later processing stages (cf. the N250r effect; see, e.g., Schweinberger & Burton, 2003). Using unfamiliar faces and age or gender categorization tasks might lead to a different situation. These tasks are presumably based on early feature and configural analyses, processes more likely reflected in the N170, which is thought to represent structural encoding processes. Accordingly, a repeated presentation may facilitate these processes. By contrast, as described above, the N250r is reduced for the repetition of unfamiliar faces and abolished in long-term repetition priming. Accordingly, we did not predict priming effects in the N250 in the context of the present design. Finally, the N400 priming effect has been suggested to reflect the facilitation of accessing postperceptual or semantic memory codes (Schweinberger & Burton, 2003), which should be more accessible for familiar than unfamiliar faces. In the absence of evidence that the access of semantic memory is influenced by prior categorization of unfamiliar faces, we again did not expect the N400 to exhibit priming effects.

Methods

Participants

Thirty-two undergraduate students from the University of Jena (21 female, mean age = 23.8 years) participated in the study. Participants either received course credits or were paid €5 per hour. All participants were right-handed according to an adapted version of the Edinburgh Handedness Inventory (Oldfield, 1971) and reported normal or corrected-to-normal vision. The study was approved by the local ethic committee. All participants gave informed written consent.

Stimuli and Apparatus

Stimuli consisted of photographs of 240 unfamiliar faces in frontal views and with neutral expressions taken from the CAL/PAL database (Minear & Park, 2004). Face stimuli differed on the two orthogonal dimensions of gender (female vs. male) and age (old vs. young). Accordingly, 60 stimuli per group (female/old, female/young, male/old, male/young) were used in the main part of the experiment. Mean age of the stimuli used in this study was 75.4 years (range: 63–91) for female/old, 75.3 years (range: 63–91) for male/old, 22.6 years (range: 18–28) for female/young, and 22.3 (range: 18–29) for male/young faces. Additional stimuli were used for practice trials. Pictures were edited using Adobe Photoshop and converted to gray-scale with white background so that all information apart from the face (clothing, background, etc.) was deleted. All stimuli were framed within an area of 170×216 pixels (6.0×7.6 cm), corresponding to a visual angle of approximately $3.8^\circ \times 4.8^\circ$ at a viewing distance of 90 cm. All stimuli were presented on a computer monitor using E-Prime software. Responses were recorded using an E-Prime response box attached to the computer.

Procedure

Participants were seated in a dimly lit, electrically shielded cabin (IAC) with their heads in a chin rest and their eyes approximately 90 cm in front of the monitor. Each trial of the experiment consisted of a fixation cross presented for 500 ms, followed by the face stimulus presented for 1500 ms, again followed by a fixation cross for 500 ms. The trial ended with a blank screen for 500 ms. Participants had to respond via button presses within 2000 ms after face onset.

The experiment consisted of two experimental blocks, each consisting of two prime phases and one test phase (for an example, cf. Figure 1). During one of the prime phases, participants had to categorize the presented faces according to gender (male vs. female); during the other prime phase different stimuli were to be categorized according to age (old vs. young). Forty faces per prime phase were presented, 10 of each stimulus group (female/old, female/young, male/old, male/young), in randomized order. In the subsequent test phase, participants had to categorize faces according to either age in one block or gender in the other block. During each of the two test phases, 120 faces were presented that had been categorized either on the same dimension during the prime phase (40 congruently primed trials) or on the other dimension (40 incongruently primed trials). Additionally, 40 new unfamiliar faces were shown. Again, stimuli within the test phase were shown in randomized order. Age of the young and old faces was matched between conditions. Aside from that restriction, stimuli were randomly assigned.

Each new condition (prime and test phases) was preceded by a short practice phase in order to familiarize participants with the task at hand. The sequence of conditions during priming and test phases was counterbalanced across participants. For half of the participants, congruent prime stimuli were presented in Prime Phase 1, whereas for the other half the congruent priming condition was presented in Prime Phase 2. At test, half of the participants executed the age categorization task in Block 1, whereas the other half attended to the age categorization task in Block 2. These two factors were varied orthogonally, resulting in four different sequences. Participants were instructed to respond as fast and accurately as possible during the whole experiment.

EEG Data Acquisition and Analysis

During the experiment, 144-channel electroencephalogram (EEG) was recorded using a BioSemi Active II system

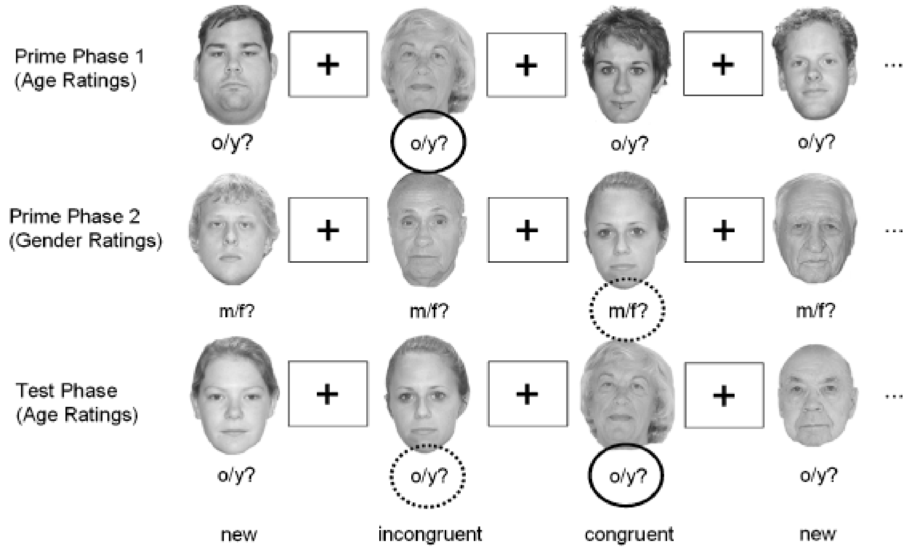

Figure 1. Illustration of a sample block from the experiment. Participants categorized unfamiliar faces according to age or gender in two prime phases. In a subsequent test phase, stimuli could be congruently primed with respect to the task during the prime phase, incongruently primed, or new.

(BioSemi, Amsterdam, Netherlands). Active, sintered Ag/AgCl electrodes were used, which were mounted in an elastic cap. Recording sites corresponded to the standard BioSemi 128-channel arrangement, with 16 additional electrodes sited below the standard positions at inferior occipito-temporal and temporal sites. EEG was recorded continuously with a 256-Hz sampling rate from DC to 75 Hz. Please note that BioSemi systems work with a "zero-Ref" setup with ground and reference electrodes replaced by a so-called CMS/DRL circuit (refer to http://www.biosemi.com/faq/cms&drl.htm for further information).

Contributions of blink artifacts were corrected using the algorithm implemented in BESA 5.1 (Berg & Scherg, 1994). EEG was segmented from 200 ms before until 1200 ms after stimulus presentation. All trials with nonocular artifacts, saccades, and incorrect responses were discarded. Artifact rejection was carried out using the BESA 5.1 tool, which sets an individual criterion of maximum amplitude difference within the chosen time segments for each participant. When appropriate, a more conservative criterion was chosen manually, which resulted in an average amplitude threshold of approximately 100 μV. In addition, a gradient criterion, rejecting all trials with more than a 75-μV difference between two consecutive data points was chosen. Remaining segments were averaged separately for each experimental condition in the test phases of the experiment (age categorization/congruently primed, age categorization/incongruently primed, age categorization/new, gender categorization/congruently primed, gender categorization/incongruently primed, gender categorization/new), digitally low-pass filtered (20 Hz, 24 dB/oct, zero phase shift), and recalculated to average reference. For statistical analysis, channels were pooled to 14 regions of interest (left frontal [FM], middle frontal [FM], right frontal [FR], left central [CL], middle central [CM], right central [CR], left parietal [PM], middle parietal [PM], right parietal [PR], middle occipital [OM], left occipito-temporal [OTL], right occipito-temporal [OTR], left temporal [TL], and right temporal [TR] regions; cf. Figure 2) on the basis of prior priming experiments (Neumann, Schweinberger, Wiese, & Burton, 2007).

For the P1 component, individual peak latency was calculated in a time range from 80 to 130 ms at the middle occipital ROI. N170 latency was determined between 120 and 200 ms at the right occipito-temporal ROI. P1 and N170 amplitudes were quantified as mean amplitude measures ranging 30 ms around the peak (for a similar approach, see, e.g., Rossion, Joyce, Cottrell, & Tarr, 2003). Whereas P1 amplitude was analyzed at OM, OTL, and OTR, analysis of N170 amplitude was restricted to OTL and OTR. For later ERP components, mean amplitudes over 100-ms time segments were analyzed until 600 ms after stimulus onset. Whereas analysis of the 200–300-ms time window (P2/N250) was restricted to the left and right occipito-temporal ROIs, later analyses (300–400, 400–500, 500–600 ms) were carried out including all 14 ROIs, because no a priori assumption about the topographical distribution of experimental effects in the P3/N400 time range were applied. Statistical analyses on these measures were carried out using repeated-measures analyses of variance (ANOVAs) with degrees of freedom Greenhouse–Geisser corrected where appropriate.

Results

Behavioral Data

For age categorizations, participants responded with a mean reaction time of 529.5 ms to congruently primed faces, of 529.3 ms to incongruently primed faces, and of 539.4 ms to new faces in the test phase. For gender categorizations, mean reaction times of 536.8 ms for congruently primed faces, of 552.9 ms for incongruently primed faces, and of 554.1 ms for new faces were measured (cf. Figure 3). Error rates were less than 5% in all conditions. Statistical analysis was therefore conducted for reaction times of correct responses only.

A repeated-measures ANOVA on reaction time (RT) data with the within-subjects factors task (age categorization, gender categorization) and prime type (congruent, incongruent, new) revealed significant main effects for both factors (task: $F[1,31] = 4.3$, $p < .05$; prime type: $F[2,62] = 8.3$, $p < .001$), as

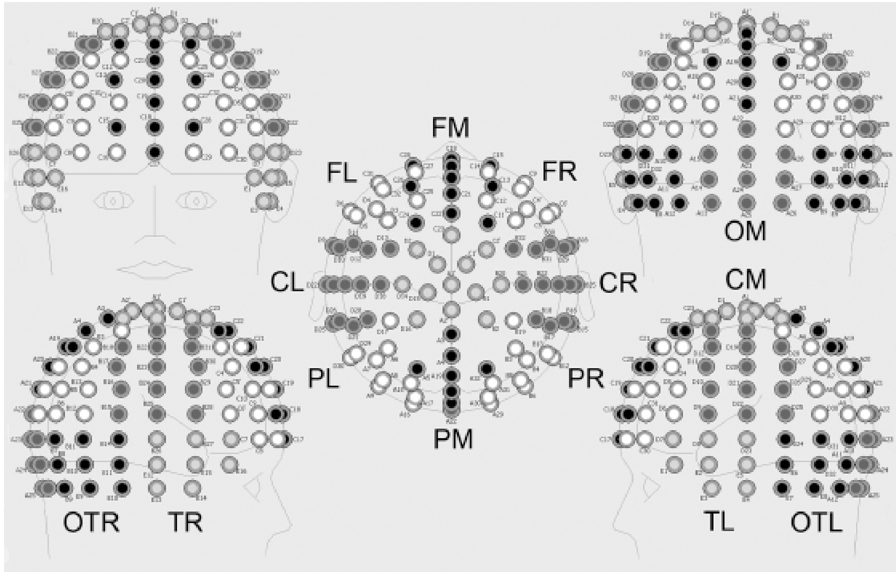

Figure 2. Illustration of the 144 electrode positions. Gray tones indicate the 14 regions of interest. FM: frontal middle, FL: frontal left, FR: frontal right, CM: central middle, CL: central left, CR: central right, PM: parietal middle, PL: parietal left, PR: parietal right, OM: occipital middle, OTL: occipito-temporal left, OTR: occipito-temporal right, TL: temporal left, TR: temporal right.

well as a significant interaction, $F(2,62) = 4.6$, $p < .05$).[1] To follow up this interaction, additional comparisons were calculated for both tasks separately. For the age categorization task, a repeated-measures ANOVA with the factor prime type yielded a significant main effect, $F(2,62) = 3.6$, $p < .05$. Contrast analysis, comparing the different factor levels, revealed significantly faster RTs both for the congruent compared to the new condition, $F(1,31) = 5.8$, $p < .05$, and for the incongruent compared to the new condition, $F(1,31) = 4.7$, $p < .05$. For the gender categorization task, the repeated-measures ANOVA yielded a significant main effect of prime type, $F(2,62) = 9.9$, $p < .001$. Contrast analysis revealed significantly faster RTs for the congruent compared to the new condition, $F(1,31) = 14.5$, $p < .001$, but no significant difference between the incongruent and the new condition ($F < 1$).

Event-Related Potentials

Event-related potentials averaged across tasks as well as for age and gender categorization tasks separately are illustrated in Figures 4, 5, and 6. ERPs were analyzed calculating repeated-measures ANOVAs with the factors task (age categorization, gender categorization), prime type (congruent, incongruent, new), and ROI (depending on the ERP component, see below). Table 1 summarizes the relevant latency and amplitude measures described in the following paragraphs.

P1. P1 amplitude was analyzed at OM, OTL, and OTR. A repeated-measures ANOVA yielded a significant main effect for the ROI factor, $F(2,62) = 18.8$, $p < .001$, with larger amplitudes at the middle compared to the more lateral ROIs. No further significant effects were detected (all $F < 1$, except for the ROI × Task interaction, $F[2,62] = 2.1$, $p > .05$, as well as the ROI × Prime Type interaction, $F[2,62] = 1.3$, $p > .05$, $\varepsilon = .72$). P1 latency was calculated at the region of largest amplitude (i.e., at the middle occipital ROI, OM) and peaked approximately 100 ms after stimulus onset (see Table 1). Repeated-measures ANOVA calculated at the middle occipital ROI did not reveal any significant effects.

N170. A repeated-measures ANOVA for N170 amplitude at left and right occipito-temporal ROIs revealed a significant three-way interaction of ROI × Task × Prime Type, $F(2,62) = 4.3$, $p < .05$. Subsequent ANOVAs for the age categorization task with the factor prime type revealed no significant effect at the right ROI ($F < 1$), but significantly more negative amplitudes for the primed compared to the new conditions at the left ROI, $F(2,62) = 5.5$, $p < .01$. Contrast analysis revealed significantly more negative amplitudes both for the congruent compared to the new condition, $F(1,31) = 16.2$, $p < .001$, and for the incongruent compared to the new condition, $F(1,31) = 4.3$, $p < .05$ (cf. also upper part of Figure 7). Analogous ANOVAs for the gender categorization task yielded no significant results (all $F < 1$).

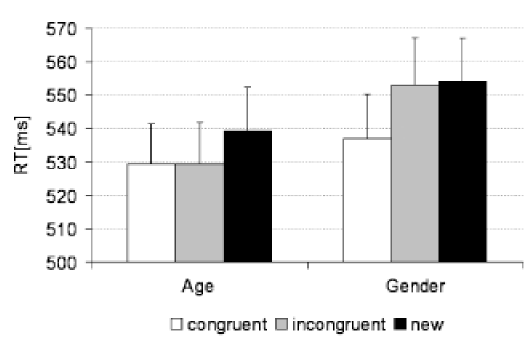

Figure 3. Mean reaction times (+ standard error of the mean) during age and gender categorization for congruently primed, incongruently primed, and new faces.

[1]In a post hoc analysis, we selected a subgroup of participants with equal RTs in the age and gender task, by excluding those 7 participants with the largest RT increase for the gender versus the age task. In this subgroup, although the main effect for task was eliminated, $F(1,24) = 0.003$, $p = .95$, the Prime Type × Task interaction remained present, $F(2,48) = 4.3$, $p < .05$.

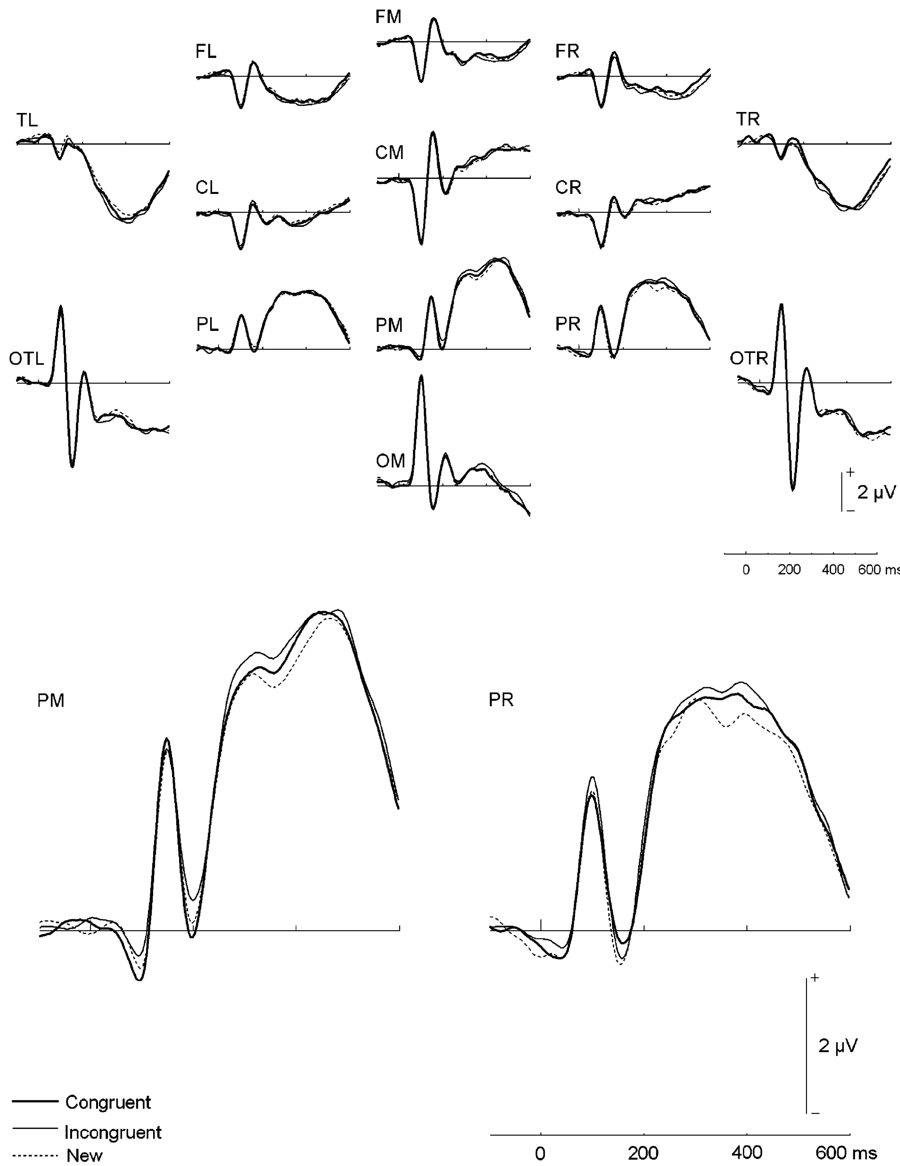

Figure 4. Grand mean ERPs of the 14 ROIs averaged over tasks. Note the more positive amplitudes in the N400 time range (300–400 ms) at the middle parietal ROI for incongruently primed faces.

N170 latency was measured at the region of largest amplitude (i.e., at the right occipito-temporal ROI; cf. Table 1). A repeated-measures ANOVA yielded a significant interaction of Task $\times$ Prime Type, $F(2,62) = 4.1$, $p < .05$, $\varepsilon = .72$. Whereas a subsequent ANOVA for the age categorization task revealed no significant effect of prime type, $F(2,62) = 1.5$, $p > .05$, $\varepsilon = .63$, a significant main effect of prime type was observed in the gender categorization task, $F(2,62) = 3.7$, $p < .05$. Contrast analysis revealed significantly earlier peak latencies in the congruent compared to the new condition, $F(1,31) = 5.0$, $p < .05$, but no significant difference between the incongruent and the new condition ($F < 1$).

P2/N250. A repeated-measures ANOVA on mean amplitude measures in the P2/N250 time range (200–300 ms) at left and right occipito-temporal ROIs yielded no significant effects (all $F < 1$, except for the Task $\times$ Prime Type interaction: $F[2,62] = 1.4$, $p > .05$). An additional analysis was performed on the P2 at OTR and OTL in a time window from 200 to 240 ms, which again revealed no significant effects (all $F < 1$, except for the Task $\times$ Prime Type interaction: $F[2,62] = 1.8$, $p > .05$).

Previous studies (e.g., Schweinberger, Pickering, Jentzsch et al., 2002) described effects in the N250 time range at frontal sites, which might reflect top-down influences on automatic processes and may accordingly be relevant for the present study. However, a repeated-measures ANOVA in the 200–300-ms time window at the left, middle, and right frontal ROIs did not result in significant effects (all $F < 1$, except for the main effect ROI, $F[2,62] = 3.0$, $p > .05$, $\varepsilon = .84$, the main effect prime type, $F[2,62] = 1.4$, $p > .05$, $\varepsilon = .95$, and the ROI $\times$ Prime Type interaction, $F[2,62] = 1.1$, $p > .05$, $\varepsilon = .68$).

300–400ms. Because we had no clear a priori hypotheses about the scalp distribution of ERP effects in the N400 time range, all regions of interest were entered into the analysis in the following ANOVAs. Please note that in this case, only

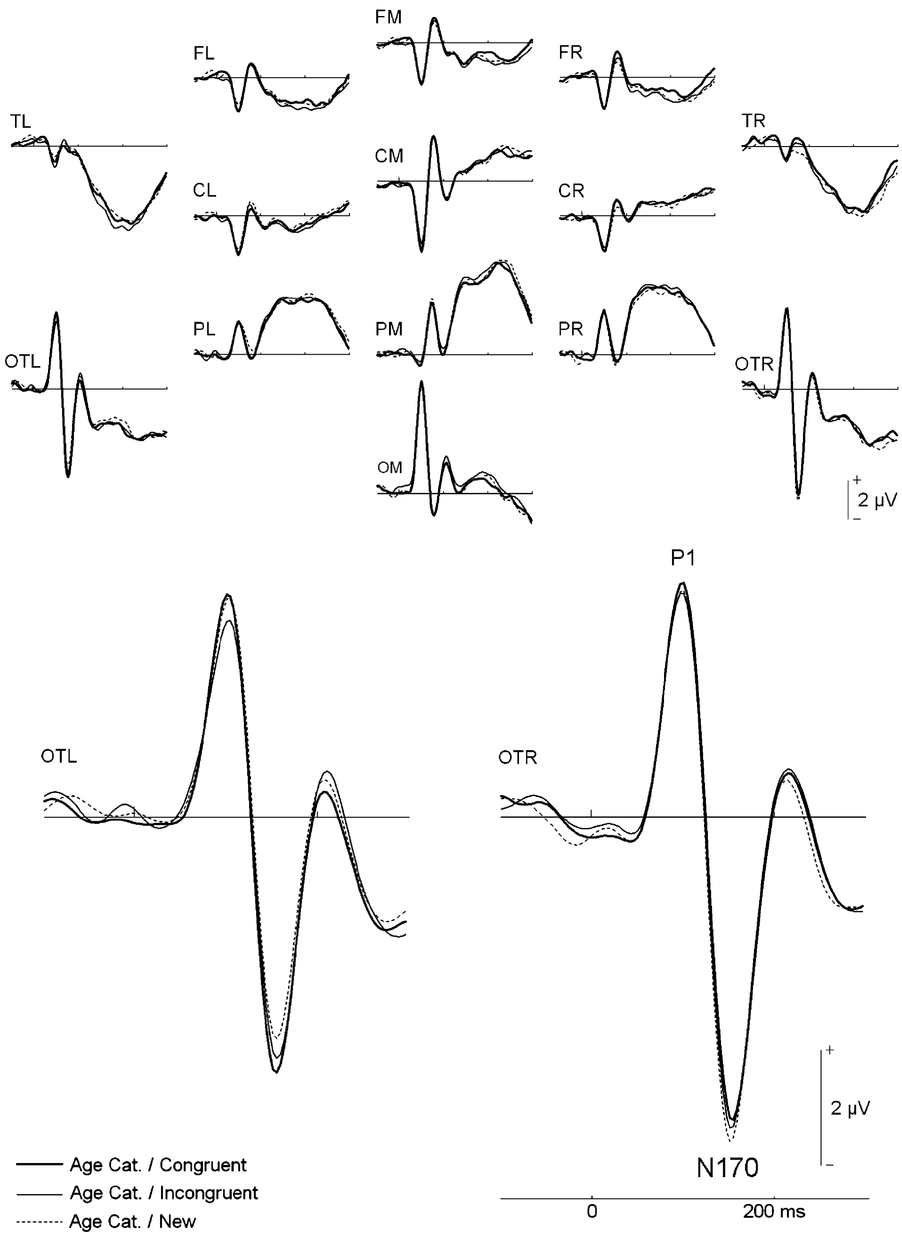

Figure 5. Upper part: Grand mean waveforms of the 14 ROIs for the age categorization task. Lower part: Left (OTL) and right (OTR) occipito-temporal ROIs. Note the repetition effects for congruently and incongruently primed unfamiliar faces in the N170 over the left hemisphere.

experimental effects involving the ROI factor are meaningful, as the average reference sets the signal over all scalp positions to zero. The corresponding ANOVA in the 300- to 400-ms time window yielded a significant interaction of ROI $\times$ Prime Type, $F(26,806) = 2.3$, $p < .05$, $\varepsilon = .23$. In the subsequent ANOVAs for all 14 ROIs with the factor prime type averaged over task, significant main effects were observed at the right, $F(2,62) = 6.5$, $p < .01$, and middle parietal ROIs, $F(2,62) = 6.7$, $p < .01$, as well as at the left temporal ROI, $F(2,62) = 4.8$, $p < .05$. At PR, contrast analysis revealed significantly more positive amplitudes for the congruent compared to the new condition, $F(1,31) = 5.0$, $p < .05$, as well as for the incongruent compared to the new condition, $F(1,31) = 11.2$, $p < .01$ (cf. also lower part of Figure 7). At PM, only the incongruent condition yielded significantly more positive amplitudes compared to the new condition, $F(1,31) = 13.5$, $p < .001$. Finally, at TL, incongruently primed faces elicited significantly more negative amplitudes in comparison to the new condition, $F(1,31) = 8.3$, $p < .01$.

400–500ms and 500–600 ms. In the two following time windows, repeated-measures ANOVAs revealed no significant interactions between ROIs and experimental conditions.

Discussion

Using a repetition priming approach the present study examined behavioral and ERP correlates of unfamiliar face categorization. Importantly, we found the behavioral pattern of priming to be strikingly different for age as compared to gender categorization. Moreover, our ERP results suggest that the activation of age and

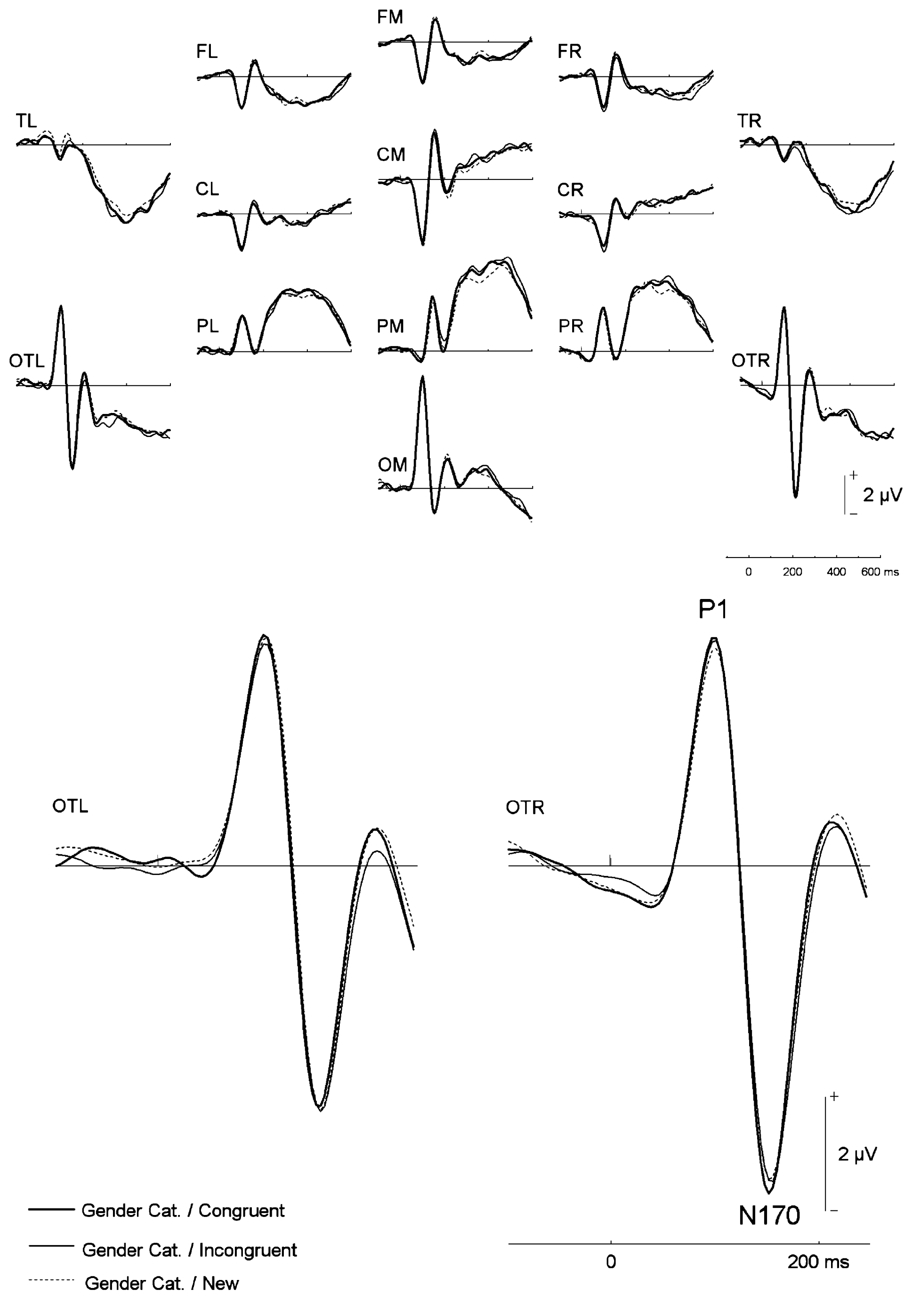

Figure 6. Upper part: Grand mean waveforms of the 14 ROIs for the gender categorization task. Lower part: Left (OTL) and right (OTR) occipito-temporal ROIs. Note the slightly earlier N170 peak at OTR in the congruent condition.

gender categories was accompanied by different neural correlates. Specifically, for age categorization both congruently and incongruently primed faces were classified faster than new faces, arguing for an implicit category activation process, independent of the task at hand. ERP results revealed a significant priming effect for both congruent and incongruent faces in the N170 at left occipito-temporal sites. By contrast, in the gender categorization task, behavioral priming was observed for congruently primed faces only, suggesting task-dependent activation of gender categories. ERPs revealed slightly but significantly shorter N170 latencies over the right hemisphere for primed compared to new faces in the congruent priming condition only. This pattern of results in the N170 time range parallels the effects observed in RT data. Finally, a parietal ERP priming effect in the N400 time range was detected, with more positive ERPs for primed compared to new faces. This effect was evident in both congruently and incongruently primed conditions, though it was somewhat more pronounced for incongruently primed faces. In the following paragraphs, we will discuss the behavioral results and the different ERP findings in turn, before we present the implications of these findings for mechanisms of person categorization.

Behavioral Priming Effects

In the present study, priming effects were observed in both age and gender categorization tasks, at least for congruent trials. First, we should like to note that this result is at some variance with previous results on priming for unfamiliar faces. In behavioral experiments using familiar and unfamiliar faces, Ellis,

Table 1. *Mean ERP Latency (in Milliseconds) and Amplitude (in Microvolts) Measures ± Standard Deviation*

			N170					
	P1 (at OM)		OTL		OTR		N400 (300–400 ms)	
	Latency	Mean amplitude	Latency	Mean amplitude	Latency	Mean amplitude	PM	PR
Age categorization								
Congruent	102.4 (± 8.1)	5.1 (± 2.2)	157.0 (± 12.1)	3.8 (± 3.3)	155.3 (± 10.5)	4.6 (± 3.7)	3.7 (± 2.5)	3.4 (± 2.4)
Incongruent	102.7 (± 9.0)	5.0 (± 2.3)	157.4 (± 12.5)	3.6 (± 3.3)	154.4 (± 11.2)	4.6 (± 3.4)	4.1 (± 2.2)	3.6 (± 2.3)
New	103.2 (± 9.6)	5.0 (± 2.2)	157.8 (± 12.0)	3.2 (± 3.2)	152.9 (± 7.4)	4.8 (± 3.2)	3.9 (± 2.5)	3.3 (± 2.3)
Gender categorization								
Congruent	101.8 (± 8.4)	5.0 (± 2.1)	156.1 (± 11.9)	3.6 (± 3.4)	152.3 (± 8.3)	4.9 (± 3.5)	4.1 (± 2.4)	3.5 (± 2.5)
Incongruent	102.9 (± 8.6)	5.2 (± 2.3)	159.9 (± 14.1)	3.6 (± 3.2)	154.3 (± 9.9)	4.8 (± 3.5)	4.3 (± 2.5)	3.7 (± 2.5)
New	103.0 (± 8.8)	5.1 (± 2.2)	157.3 (± 12.4)	3.6 (± 3.5)	154.2 (± 9.6)	4.8 (± 4.0)	3.7 (± 2.6)	3.2 (± 2.3)
Averaged across tasks								
Congruent	—	—	—	—	—	—	3.9 (± 2.3)	3.5 (± 2.4)
Incongruent	—	—	—	—	—	—	4.2 (± 2.3)	3.7 (± 2.4)
New	—	—	—	—	—	—	3.8 (± 2.5)	3.3 (± 2.3)

Young, and Flude (1990) concluded that decisions involving a face's gender or expression were not susceptible to repetition priming. In their study, significant repetition priming only occurred in tasks that required the identification of a familiar face. They therefore concluded that repetition priming only occurred within the system that responds to the identity of familiar faces. Despite this conclusion, one may note that some trend toward faster processing of repeated unfamiliar faces in a gender categorization task could be seen in their Experiment 3. A more recent study by Goshen-Gottstein and Ganel (2000) did report a significant though small effect of repetition priming in a gender task, and the present finding of behavioral repetition priming in gender categorization is in line with this latter study.

Whereas facilitated processing of both congruently and incongruently primed faces was observed during age categorization, only congruent priming occurred in the gender categorization task. Although the reason for this difference is not immediately obvious, we suggest that age and gender categorizations are based on different types of diagnostic information in the stimulus. Specifically, in age categorization it might be more efficient to base the category decision on one specific feature, such as skin texture, existence of wrinkles in the picture, and so forth, rather than on a holistic analysis of the facial configuration. This idea is in accordance with other findings suggesting that age perception can be based on surface cues alone, in the absence of subtle three-dimensional configural information (George & Hole, 2000). By contrast, efficient gender categorization appears to require a configuration of features, including the jaw line, eyes and eyebrows, chin, and nose (Brown & Perrett, 1993). All these features are covered with or surrounded by skin, which is a cue for age. Accordingly, as Quinn and Macrae (2005) point out, when participants are attending to gender-relevant information, they invariably attend to age-related information as well. By contrast, gender-related information is not necessarily processed when participants attend to features relevant for age categorization. Taking these considerations into account, the behavioral results of the present study can be explained within the framework of transfer appropriate processing (Roediger, 1990). This theoretical approach assumes that the performance in a given explicit or implicit memory task benefits from the amount of overlap between the cognitive operations conducted during study and test. Accordingly, the transfer from the gender task in the prime phase to age categorization at test may be greater than in the opposite direction, which in turn may have caused priming of incongruent stimuli in the age but not in the gender categorization task.

This interpretation, however, also leads to the conclusion that task independence and dependence is nothing absolute but related to the specific selection of prime and test tasks. If, for instance, in an incongruent priming condition, face features that are not relevant for age categorization have to be attended to, age categorization during test may not occur implicitly. In contrast, for an incongruent prime task, which probes configural information, priming in the gender categorization task during test might appear task independent.

ERP Effects: N170

Two effects of face repetition were observed in the N170 time range. First, in the age categorization task, there were more negative N170 peaks in the congruently and incongruently primed condition compared to new faces over the left occipito-temporal ROI. Second, in the gender categorization task, a small but significant latency effect was observed, in terms of slightly shorter N170 latencies over right occipito-temporal locations for the congruently primed compared to new faces only. These findings parallel the effects observed in the reaction times.

As described in the Introduction, the N170 for face stimuli is usually larger over the right scalp, which was also observed in the present study. It may therefore seem surprising that the amplitude effect during age categorization was strictly lateralized to the left hemisphere. Of particular relevance, a recent study demonstrated larger N170 components over the left hemisphere for the processing of featural changes, whereas configural changes led to larger N170 effects over the right hemisphere (Scott & Nelson, 2006). Moreover, Ito and Urland (2005) found larger N170 amplitudes over the left hemisphere for faces of White people compared to faces of Black people in an ethnicity categorization task (but see Stahl, Wiese, & Schweinberger, 2008), which can easily be handled by judging one specific feature, namely skin tone. These findings are in general agreement with functional imaging studies, demonstrating more pronounced activity of cortical face processing areas in the left hemisphere when participants analyzed face parts, whereas right hemisphere regions were more active when participants perceived whole faces (Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001; see also Lobmaier, Klaver, Loenneker, Martin, & Mast, 2008). If feature processing is of outstanding relevance for age categorization, the latter may

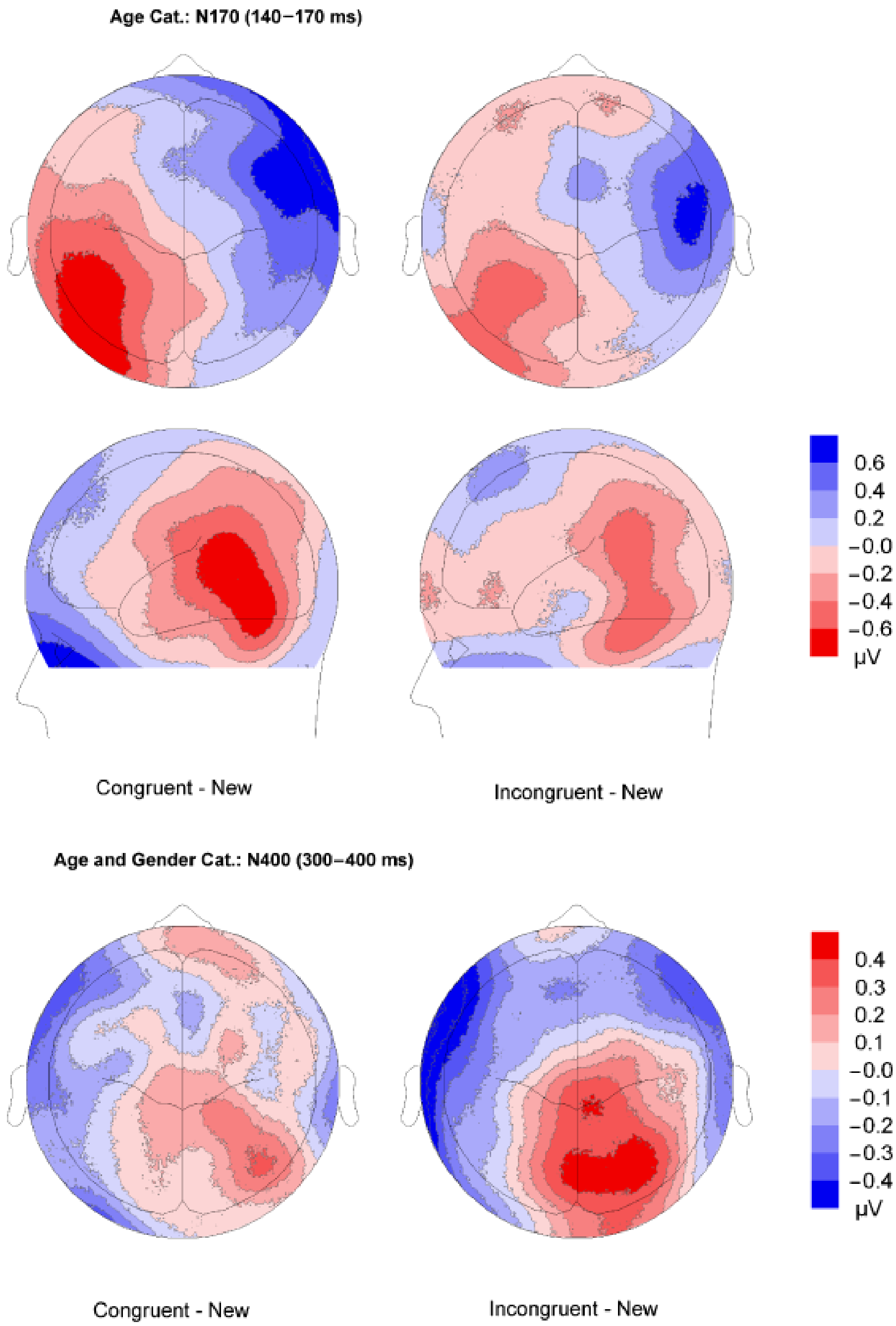

Figure 7. Scalp topographical voltage maps (spherical spline interpolation, 110° equidistant projection) for difference curves of congruently and incongruently primed minus new faces.

be expected to depend on left hemisphere regions as well. On that account, the left lateralization of the N170 repetition effect during age categorization supports the idea that the effect is brought about by a facilitation of featural processing.

A key finding in N170 research is a delayed peak for inverted compared to upright faces (Bentin et al., 1996; Eimer, 2000b; Itier & Taylor, 2002; Latinus & Taylor, 2006; Rossion et al., 1999, 2000, 2003), which has been interpreted to result from disrupted configural processing. Moreover, a recent study associated the right-hemisphere N170 with configural and the left N170 with feature processing (Scott & Nelson, 2006). Accordingly, the present finding of small but significant differences in the right-hemisphere N170 latency for gender categorization might represent slightly faster analysis of facial configurations for faces that have previously been processed with this task. By contrast, because age categorization in the prime phase might have resulted in a smaller degree of configural processing, incongruently primed and new faces did not enjoy this advantage.

Finally, it should be noted that repetition priming led to differences in N170 amplitude for age categorization but to N170 latency effects for gender categorization. On a theoretical level, different types of neural stimulus repetition effects were recently discussed by Grill-Spector, Henson, and Martin (2006). In particular, these authors distinguished what they referred to as effects of neural fatigue, neural sharpening, and facilitation. On that account, it would be tempting to speculate that latency effects of priming in the congruent condition of the gender task caused facilitation in terms of faster neural processing. By contrast, amplitude effects of priming appear to be more consistent with the idea of more efficient processing at a predefined time. However, a direct interpretation of the present results along the neural mechanisms outlined above is complicated by the fact that decreased rather than increased amplitudes for primed stimuli would be implicated both by neural fatigue and neural sharpening explanations of priming. Although repetition priming has been shown to cause increased neural activity in some circumstances (Henson, Shallice, & Dolan, 2000), a direct relationship of those findings to the present results is not completely clear either. In sum, although the present results do provide some evidence for qualitatively different types of neural priming effects for age and gender priming, a delineation of the precise mechanisms underlying these effects requires further research.

ERP Effects: N250r

In the present study, neither age nor gender categorization resulted in a significant ERP effect in the N250r time range. When considering that we investigated long-term repetition effects across many intervening *unfamiliar* faces, this is well in line with earlier findings (Begleiter et al., 1995; Herzmann et al., 2004; Pfütze et al., 2002; Schweinberger et al., 1995; Schweinberger, Pickering, Burton et al., 2002). It may be noted that Tanaka, Curran, Porterfield and Collins (2006) recently reported the N250 to increase in the course of learning initially unfamiliar faces. However, that study used a huge number of repetitions, whereas in the present study repeated faces occurred only twice in the course of the experiment, which may not be sufficient for the acquisition of a robust structural representation.

ERP Effects: N400

The current study found more positive ERPs to repeated compared to new faces between 300 and 400 ms after stimulus onset for both age and gender categorization. This finding is reminiscent of similar earlier results (Schweinberger, Pickering, Jentzsch, et al., 2002), and, together with the timing and topography of this effect, we suggest that it may be related to a modulation of the N400. Priming effects in the N400 time range are usually interpreted as representing the facilitated access to semantic information (Kiefer, 2002, 2005; Schweinberger, 1996). Because several studies observed more positive ERPs for familiar compared to unfamiliar faces in a comparable time range (Bentin & Deouell, 2000; Eimer, 2000b), larger amplitudes for repeated faces in the present study might reflect processes of individuation rather than early perceptual categorization. Interestingly, in the present study N400 priming effects were seen for both congruent and incongruent priming but tended to be larger and more widespread for incongruent priming. A tentative explanation of this difference could be based on the idea that those faces that are more easily categorized (those in the congruent condition) may not be processed further, whereas those more difficult to categorize (those in the incongruent condition) are more likely to be processed at an individual level (for related ideas on ethnicity categorization, see Levin, 1996, 2000).

Two other studies observed ERP modulations in a broadly similar time range, using age or gender categorization tasks. Ito and Urland (2003) found larger P300s when a target individual's social category membership (being male vs. female or being White vs. Black) differed from preceding individuals on task-relevant dimensions. In general agreement with the present findings, P300 amplitude was also increased when a target picture differed along a task-irrelevant dimension. By contrast, Mouchetant-Rostaing and Giard (2003) found ERP effects between 215 and 400 ms at occipito-parietal scalp sites, but only for intentional discrimination of age and gender. As a limitation, a more direct comparison to the present results appears difficult when considering differences in experimental design and task used in these studies and the current experiment.

Conclusions

Quinn and Macrae (2005) concluded from a priming experiment that the activation of gender and age categories for unfamiliar faces is not automatic but task dependent. Their interpretation, however, was based on reaction time data that did not consider gender and age categorization tasks as separate. The present study observed differential effects for age and gender categorization and therefore qualifies previous findings by demonstrating task-irrelevant processing of age, but task-dependent gender categorization. In line with these behavioral results, ERP priming effects in the N170 time range suggest a task-irrelevant facilitation of age processing, but only task-dependent facilitation of gender processing. The present pattern of N170 lateralization provided some evidence with respect to the underlying mechanisms and suggests that age and gender processing tend to rely on featural and configural information, respectively.

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(Received January 18, 2008; Accepted March 14, 2008)