Event-related brain potential correlates of identity negative priming from overlapping pictures

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Abstract

Event-related potentials (ERPs) were obtained from an identity priming task, where a green target had to be selected against a superimposed red distractor. Several priming conditions were realized in a mix of control (CO), negative priming (NP), and positive priming (PP) trials. PP and NP effects in reaction times (RTs) were significant. ERP results conceptually replicate earlier findings of left-posterior P300 reduction in PP and NP trials compared to CO. This ERP effect may reflect the detection of prime-probe similarity corresponding to the concept of a retrieval cue. A novel finding concerned amplitude increase of the frontal late positive complex (LPC) in the order NP, CO, and PP. NP therefore seemed to induce brain activity related to cognitive control and/or memory processes, with reduced LPC amplitude indicating effortful processing. Overall, retrieval-based explanations of identity NP are supported.

Descriptors: Negative priming, Identification, EEG, Event-related potentials, P300, Late positive complex, Episodic retrieval

Because of the limited capacity of the cognitive system, selective attention to the goal-relevant information is crucial for coherent behavior of individuals. Investigations applying the so-called negative-priming (NP) paradigm (Dalrymple-Alford & Budayr, 1966) showed that not only the process of extracting relevant information from the environment is important, but also the understanding of what happens to the ignored part of perceptual input. NP describes the phenomenon of prolonged reaction time (RT) and/or more errors when in a probe display subjects have to respond to a target that was the ignored distractor stimulus on a preceding prime display (i.e., the NP condition). The NP effect has been found in a wide variety of experimental tasks and can therefore be called quite a robust phenomenon (for reviews, see Fox, 1995; May, Kane, & Hasher, 1995; Tipper, 2001). In the present paper, we will particularly focus on visual identity prim-

ing tasks where the target is selected by means of a physical feature (e.g., color, location) and then responded to according to its identity.

Over the years, various theories have been developed to explain NP, but in spite of a lively theoretical discussion, a consistent explanatory account of all NP phenomena is still missing. Two major theoretical approaches can be distinguished: persisting-inhibition (Houghton & Tipper, 1998; Neill, 1977; Tipper, 1985) and episodic-retrieval (Milliken, Joordens, Merikle, & Seiffert, 1998; Neill, 1997) theories. Initially, inhibition-based theories (Tipper, 1985) postulated that NP is a behavioral index of an inhibitory component of selection. For instance, it has been suggested that cognitive representations of irrelevant stimuli are "deactivated" to support selection of the relevant target stimuli (Neill, 1977), or that the link between stimulus representations and the response mechanism is blocked (Tipper & Cranston, 1985). Inhibition is assumed to persist for some time, and when a former distractor becomes the relevant target in the probe display, responding is impaired. However, in the last few years a majority of researchers interpreted NP according to the episodic-retrieval view, that is, as a result of conflicting information caused by the automatic retrieval of prime information during probe processing (Neill, Valdes, Terry, & Gorfein, 1992). If the object information about the prime distractor from the retrieved episode is inconsistent with its current role as target object, a

conflict is elicited whose resolution is time-consuming. Rothermund, Wentura, and De Houwer (2005) proposed an alternative response-retrieval account, assuming that the NP effect results from conflict between the required probe response and the retrieved (incorrect) prime response.

There are findings in support of both inhibition and episodic-retrieval views, but the body of empirical evidence does not clearly favor one approach over the other. According to Tipper (2001), distractor-inhibition and episodic-retrieval theories are not mutually exclusive. Supposedly, in most tasks NP will be caused by a mixture of persisting inhibition and retrieval-interference, depending on context and other experimental factors (Kane, May, Hasher, Rahhal, & Stolzfus, 1997). Because these processes may sometimes oppose each other, it is difficult to distinguish them by means of behavioral measures like RTs and error rates (cf., Gibbons, 2006). In view of the complexity of the effect, it appears desirable to include other sources of information to elucidate the mechanisms of NP. Therefore, several researchers used event-related potentials (ERPs) to further investigate the processes underlying the NP effect, because of the excellent temporal resolution of ERPs.

Mayr, Niedeggen, Buchner, and Pietrowsky (2003) investigated RT and ERP effects of NP in the auditory domain. In this study, ERP analysis revealed an attenuation of the parietal late positive complex (LPC) for NP compared to control (CO). This LPC correlate of auditory NP was successfully replicated by Mayr, Niedeggen, Buchner, and Orgs (2006). The authors interpreted their results as support for episodic-retrieval accounts of NP, because the LPC is known to be sensitive to stimulus recognition and familiarity. In the following years, several ERP studies of identity NP in the visual domain have been published. A number of ERP components were discussed as candidates for correlates of behavioral NP, particularly the N200 and P300 potentials. Some results were interpreted as evidence for persisting inhibition; others seemed to support the episodic-retrieval view (for review, see Mayr & Buchner, 2007).

N200. In general, the N200 potential of the ERP has been interpreted to reflect early stimulus evaluation and especially active or passive discrimination processes subsequent to the perceptual identification of the stimulus features (cf., Ritter, Ford, Gaillard, Harter, Kutas, et al., 1984; Sams, Paavilainen, Alho, & Näätänen, 1985). Using a classical flanker paradigm, Frings and Groh-Bordin (2007) found larger frontal N200 for NP trials relative to CO; this N200 effect was more pronounced in participants with above-average behavioral NP. The authors concluded that ERPs in the N200 time range represent cognitive processes that caused their NP effect, and interpreted them as additional effort required in NP probes to select a previously inhibited stimulus against (non-inhibited) incompatible distractors. Also Daurignac, Houdè, and Jouvent (2006) observed enhanced N200 in NP trials and interpreted this ERP correlate of NP as evidence for effective inhibition mechanisms. Note, however, that their task was not typical for identity NP, because strategies rather than stimulus features were repeated from prime to probe.

P300. The most frequently observed ERP correlate of visual identity NP has been modulation of the P300 potential. The P300 is often interpreted as reflecting the updating of resources needed for stimulus evaluation within the context of a model of the environment (Donchin & Coles, 1988). Kathmann, Bogdahn, and Endrass (2006) found increased P300 amplitude in NP relative to control trials in a visual identification task with two overlapping black and grey digits. Kathmann et al. (2006) suggested that their P300 correlate of NP supports a response-retrieval account of NP. In contrast, Gibbons (2006) argued that P300 enhancement seems to be well in line with the inhibition view of NP. Inhibition theory assumes that the activation level of the internal representation of an NP target is below baseline at probe display onset (cf., Houghton & Tipper, 1994). Therefore, more activation is needed to reach a criterion threshold required for stimulus identification, which could well be reflected in increased P300 amplitude and/or latency. Based on similar considerations, one can expect reduced P300 amplitude and/or latency in a priming condition involving prime-probe target repetitions, due to above-baseline activation of the representation of the target at probe display onset (Stahl & Gibbons, 2007).

In contrast to Kathmann et al.'s (2006) findings, Stahl and Gibbons (2007) found NP-related reduction of left-posterior P300 amplitude in a study of identity NP in the Eriksen flanker task (Eriksen & Eriksen, 1974). Stahl and Gibbons (2007) suggested that their P300 effect is better in line with episodic-retrieval than with inhibition view. For this conclusion, it was important that left-posterior P300 reduction was also observed in yet another priming condition, involving prime-probe target repetitions. Typical for this condition is the strong facilitation of responding known as positive priming (PP). If anything, there should be persisting activation for PP targets; consequently, reduced P300 amplitude in both PP and NP trials suggests persisting activation rather than persisting inhibition also in NP trials. Therefore, to explain the emergence of behavioral NP, a process operating at a later stage, which counteracts the presumed facilitatory NP effect during stimulus evaluation, has to be assumed. In a recent study, Gibbons (2009) provided a successful replication of NP-related left-posterior P300 reduction in the flanker task. In addition, a subsequent left-posterior N400 potential was specific for NP and was interpreted as a correlate of the effortful processing of the retrieved task-inappropriate information. An additional analysis in the study by Gibbons (2009) revealed that the N400 effect was restricted to the group of participants showing above-median behavioral NP, thus confirming the significance of this ERP effect for NP.

The divergent empirical findings of Kathmann et al. (2006) and Stahl and Gibbons (2007; see also Gibbons, 2009) concerning P300 amplitude may be accounted for by several methodological differences, which cannot be discussed here in detail (see Stahl & Gibbons, 2007). Briefly, it seems that Stahl and Gibbons (2007) provided conditions that encouraged episodic retrieval to become effective, while Kathmann et al.'s (2006) experimental setup favored the emergence of persisting inhibition.

Further ERP studies on visual identity NP have been published, but either there were no ERP effects of NP (Gibbons, 2006; Hinojosa, Villarino, Pozo, Elosua, Merino, et al., 2007), or the interpretation of the ERP correlates of NP was difficult because no NP effects were found at the behavioral level (Gibbons, Rammsayer, & Stahl, 2006). Two other studies using lexical decision tasks found small N400 amplitude reductions in the NP condition relative to control (Heil & Rolke, 2004; Wagner, Baving, Berg, Cohen, & Rockstroh, 2006). It has, however, been argued that this effect was a correlate of a detected prime-probe repetition, rather than a specific correlate of NP (cf., Heil & Rolke, 2004).

To summarize, on the basis of the relatively small number of existing studies and the heterogeneous results, it has not been possible to get a clear picture of the ERP correlates of visual identity NP up to now. Overall, the majority of studies seem to support an episodic-retrieval explanation of NP. Yet, the inconsistency of previous results and especially the lack of replication of the ERP correlates of NP have hitherto prevented significant contributions of ERP research to the theoretical debate on NP. Only the finding of left-posterior P300 reduction for both NP and PP conditions compared to control (Stahl & Gibbons, 2007) was replicated by Gibbons (2009) using the same flanker task. In a next step, showing that the P300 effect generalizes over different identification tasks would substantially add to the literature. However, it should also be emphasized that previous findings only indirectly support retrieval explanations; at least, a genuine functional late-range ERP correlate of NP which could reflect the conflict between retrieved prime information and information extracted from the probe is still missing.

The aim of the present study of identity-based NP was to test two predictions that can be derived from episodic-retrieval view. First, retrieval of prime information should only occur if the probe display in NP trials is *perceived as somehow similar* to the prime display. Second, because the retrieved prime information is inappropriate for the required probe response in NP trials, *late processing conflict* should emerge. For both processes ERP correlates should be found. The ERP reflection of perceived prime-probe similarity and/or the retrieval process itself should be largely the same for NP and PP trials (for both conditions, the probe target is a repeated prime stimulus). We therefore expect a conceptual replication of a repeatedly observed ERP correlate of visual NP, that is, P300 amplitude reduction in both PP and NP trials relative to CO (Gibbons, 2009; Stahl & Gibbons, 2007). By contrast, the second, late-range ERP correlate should distinguish NP from both PP and CO conditions, because only in NP trials should conflict emerge. Anterior predominance can be expected for this late-range ERP correlate of NP, given the crucial role of the frontal cortex in the processing of various types of conflict (see Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004, for review).

The relatively small behavioral NP effects (10–15 ms) found in previous ERP studies of visual NP (e.g., Frings & Groh-Bordin, 2007; Gibbons, 2009; Kathmann et al., 2006; Stahl & Gibbons, 2007) may be one reason why no late-range, conflict-related ERP effect of NP has been established until now. Therefore, in the present study a classical picture-naming task (cf., Tipper, 1985) is employed, which has not been used in ERP studies of NP so far but is known to produce relatively strong NP effects (30–50 ms; cf., Titz, Behrendt, Menge, & Hasselhorn, 2008). Obviously, this increases the chance to find a functional late-range ERP correlate of NP, if indeed a late conflict-related process is responsible for NP. Also, the facts that more complex stimuli are used and RT is generally larger than in the simple flanker task may increase the chance to find a late conflict-related ERP correlate of NP.

Method

Participants

Sixteen right-handed young adults (undergraduate students from the University of Göttingen, Germany), five males and eleven females with mean age of 23.3 years, $SD = 5.5$, took part in the study and received course credit or were paid 8€ (∼ $10). All participants had normal or corrected-to-normal vision and were naive about the aims of the experiment.

Materials and Apparatus

Seven line drawings of familiar objects were prepared in green and red color (RGB coordinates were 0, 255, 0 for green pictures; 255, 0, 0 for red pictures). To minimize the potential systematic error in naming latencies between stimuli originating from differential triggering of the microphone, all objects began with the same initial plosive letter. The objects were: ball (German: Ball), tree (Baum), bench (Bank), book (Buch), boat (Boot), bus (Bus), and box (Box). The experiment was run on an IBM-compatible computer using Presentation software (Version 9.20, www.neurobs.com). A microphone was used to record naming latencies. In each trial, two superimposed objects were presented in the middle of a 19" computer monitor. The participants sat in front of the monitor at a distance of approximately 80 cm. Each stimulus subtended a horizontal visual angle of 5.0° and a vertical visual angle of 4.3°. On the whole, every participant processed 840 successively presented displays (trials). The display sequences were portioned in 20 blocks containing 42 trials each. The first two trials in each block were not analyzed to exclude adaptation effects. The probability of presentation for the seven objects was balanced within each block.

Each display contained a green target stimulus and a red distractor stimulus, or only one green target stimulus. Target and distractor were positioned in the center of the display. All line drawings appeared equally often as target and as distractor per experimental condition. By means of two successively presented displays, several priming conditions were realized (see Figure 1). In 16% of the prime-probe pairs, none of the prime stimuli were repeated in the probe display (control trials, CO). In 13% of the prime-probe pairs, the prime distractor reappeared as target in the probe display (NP). Thirteen percent of the trials realized the PP condition where the target from the prime repeated as the probe target. In addition to the above classical conditions, five single-target conditions were also realized, to investigate a research question not addressed by this paper. Three of these conditions showed only a target and no distractor in the probe trial (30% of all trials). The remaining trials were distractor-plus-target filler trials following single-target presentations (32% of all trials). These trials were excluded from analysis. All priming conditions were presented pseudo-randomized and in unpredictable order.

Procedure

Participants were tested individually in sessions that lasted no longer than 70 min. Prior to the main experiment, subjects were tested for their color discrimination abilities, by asking them to name different color patches printed on a card. The line drawings of the experimental stimuli along with their names printed in black were then shown to the subjects. They were told that they would see these objects overlapping one another, one drawn in green and the other in red. Participants were also instructed to name the green target object as quickly and correctly as possible while ignoring the superimposed red distractor object. To familiarize participants with the experimental procedure, a 30-trials practice session preceded the main session. Participants paced the succession of the instructions as well as the experimental blocks themselves by button presses.

In a single trial, subjects saw the following series of events: (a) a fixation cross, centered on the screen for 500 ms; (b) a display
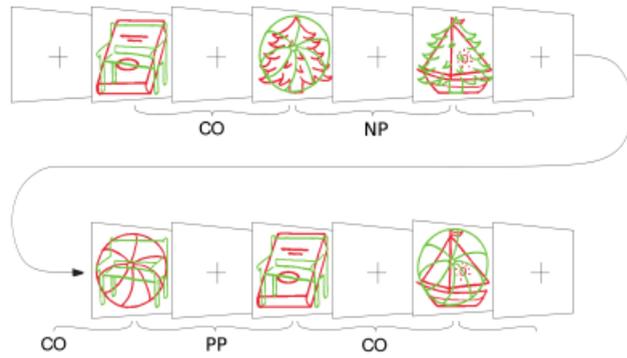
Figure 1. Example of a sequence of stimuli used in the identity priming task. In the actual experiment, the target was printed in green and the distractor was presented in red. Participants had to respond to a continuous stream of trials, where each display served as prime for the next one. A fixation cross was displayed for 500 ms before the presentation of every stimulus. The recurrence of prime objects in the probe defined the priming condition (meanings of the acronyms are introduced in Materials and Apparatus).

containing two superimposed (or a single) object(s) (until the subject responded, but no longer than 2 s); (c) a blank screen for a randomized duration between 0 and 1000 ms. The length of the response-to-stimulus interval (RSI) was thus randomized between 500 and 1500 ms (blank screen plus fixation cross), because this approach yielded good results in terms of strong NP effects in previous experiments. After each experimental block, subjects were allowed to take a short break.

Behavioral errors were noted when subjects accidentally named the distractor, used a wrong name identifier, stuttered, or failed to answer. Once the participants had completed all trials, they were asked to comment on the experimental procedure (e.g., difficulties in identifying the presented pictures) to exclude strong outliers.

Electrophysiological Recordings

EEG (electroencephalogram) was continuously recorded from 63 head electrodes (see Figure 2) arranged in an extended 10–20 system, using a 64-channel BrainAmp MR amplifier and an electrode cap (Brain Products Inc., Munich, Germany) with sintered Ag/AgCl electrodes. The sampling rate was 1,000 Hz and band-pass was set to 0.1–70 Hz. Vertical electro-oculogram (EOG) was monitored from an electrode positioned 1 cm below the right eye. FCz served as active reference electrode. All impedances were kept below 5 kΩ.

From continuous electroencephalogram, ERPs were derived separately for priming conditions (CO, NP, and PP) and participants, according to the following steps. First, EEG segmentation was performed, resulting in (− 100, 1500 ms) epochs, with zero indicating probe display onset. Epochs were then baseline-corrected with respect to the (− 100, 0 ms) interval, and an initial artifact rejection was performed to identify epochs with technical artifacts (i.e., amplitudes exceeding ± 1 mV). Afterwards, data were subjected to EOG correction according to Gratton, Coles, and Donchin (1983). A final, more sensitive artifact rejection eliminated all epochs containing amplitude values exceeding ± 100 µV. This resulted in a reduction of trials of less than 10% for each participant and priming condition. Epochs were then averaged separately for priming conditions and participants. In a final step, these individual averaged waveforms were re-referenced against algebraically linked mastoids (LM, RM).

Statistical Analysis of Behavioral Data

An analysis of variance (ANOVA) with a repeated-measures factor Priming Condition (CO, NP, and PP) was computed for RTs, employing correction of *p* values according to Geisser and Greenhouse (1958). One-tailed Bonferroni-corrected *t*-tests were applied to test differences to control for conditions NP and PP (expecting NP and PP effects, respectively).

ERP Analysis

First, major ERP potentials were determined from grand-averaged ERP waveforms computed across the three priming conditions (see Figure 2). Identified potentials included posterior P1 (mean peak latency 102 ms) and N1 (mean peak latency 174 ms). A subsequent P2 potential peaked at around 230 ms, followed by N2 (270 ms). At posterior electrodes, P300 was observed at around 360 ms. In addition, over frontal areas a LPC occurred at around 700 ms after probe display onset. Second, in an attempt to systematically investigate ERP priming effects, amplitudes and latencies of these ERP peaks were determined separately for priming conditions and individuals. Separately for electrodes, the P1 peak was found as the most positive amplitude value between 80 and 120 ms. The N1 peak was found as the most negative amplitude value between 140 and 200 ms, and the P2 peak as the most positive amplitude value between 220 and 250 ms. N2 was found as the most negative amplitude value between 250 and 300 ms. The P300 peak was determined as the most positive amplitude value between 300 and 500 ms, and the frontal LPC was found as the most positive peak between 400 and 900 ms.

Amplitudes and latencies of P1, N1, P2, N2, P300, and LPC potentials were subjected to separate ANOVAs, treating Priming Condition (CO, NP, and PP) and Electrode as repeated-measures factors, with levels of the latter factor depending on the potential of interest: For P1, N1, and P300, electrodes from the most posterior three rows (see Figure 2) were included in the analysis, whereas for P2 and N2, only electrodes from the most posterior two rows were considered. In the analysis of LPC, the most anterior four rows were included. Note that P300 amplitude was measured as mean voltage between 300 and 500 ms, to account for the broader temporal distribution of P300. Since analysis revealed a strong priming effect on LPC peak latency, LPC amplitude was not determined from a fixed time window. Rather, to assess priming effects on LPC amplitude and latency independently of each other, LPC amplitude was computed separately for participants, priming conditions and electrodes as mean voltage in 200-ms time windows adjusted for LPC peak latency. Intervals ranged from 500 to 700 ms in the PP condition, and from 550 to 750 ms in the NP and control conditions. Greenhouse-Geisser correction was applied when necessary (Geisser & Greenhouse, 1958) and significant effects were further explored using post-hoc Scheffe's test.

Results

Behavioral Data

Mean RTs in each priming condition, standard deviations, and difference effects for NP and PP trials compared with CO trials are shown in Table 1. Trials in which an error was committed (1.2 %) and subsequent trials were excluded from further RT analysis. Trials with response latencies below 250 ms or more than two standard deviations above the individual mean for each participant and priming condition were excluded as outliers (4.7%).
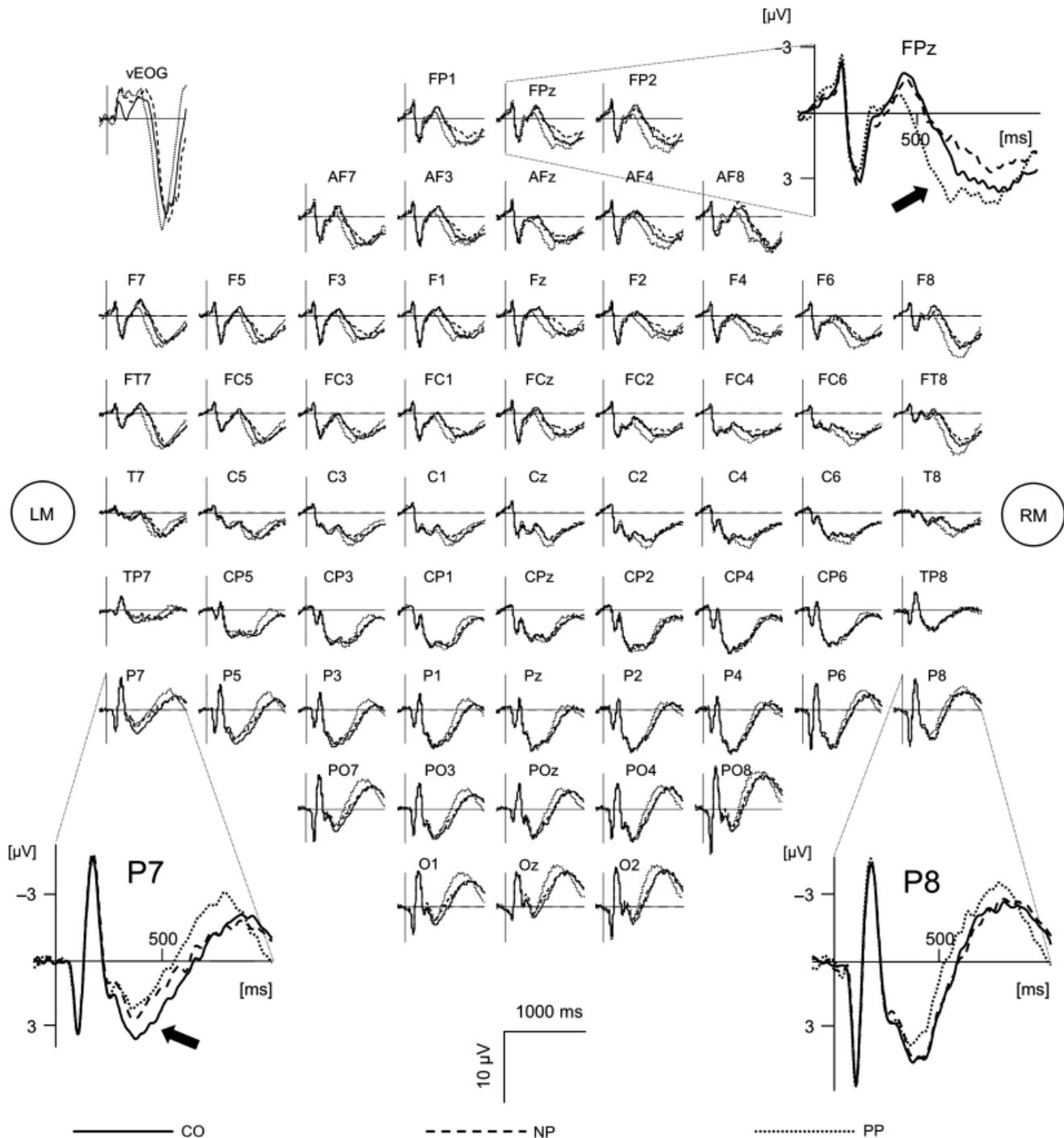
Figure 2. Grand-averaged ERP waveforms for each priming condition (CO = thick line, NP = dashed line, PP = dotted line). Negativity is plotted upwards. Note the reduced left-posterior P300 amplitude for the NP and the PP conditions as compared to CO trials (e.g., P7). Moreover, amplitude and latency of a frontal late positive complex (LPC) between 500 and 700 ms post-stimulus were found to be sensitive to the priming manipulation. NP trials showed significantly reduced LPC amplitude compared to CO trials, while PP trials produced significantly increased amplitude (see Discussion). In addition, the LPC peak occurred earlier for PP trials (e.g., FPz).

One-way ANOVA was used to analyze priming effects. The effect of Priming Condition (CO, NP, and PP) was significant $F(2,30) = 85.68$, $p < .001$; $\varepsilon = .85$. Planned comparisons showed that mean RT for NP trials was significantly increased compared to CO trials [CO vs. NP: $t(15) = -5.62$, $p < .001$]. As anticipated, RT for trials in the PP condition was significantly decreased [CO vs. PP: $t(15) = 8.57$, $p < .001$].

ERP Data
Figure 2 displays the grand-grand average ERP waveforms computed across priming conditions. Components P1 (mean peak latency 102 ms), N1 (174 ms), P2 (230 ms), N2 (270 ms), and P300 (360 ms) can be identified. In addition, a frontal/fronto-central LPC component can be seen at around 700 ms post-stimulus. Figure 2 suggests ERP priming effects on N2, P300,

Table 1. *Reaction Times (RTs) as a Function of Priming Condition (CO, NP, PP); RT Differences (Priming Effects)*

	Mean Response Latencies in ms
CO	765.8 (198.8)
NP	793.3 (214.2)
PP	632.9 (139.0)

	Priming Effects in ms
CO-NP[a]	− 27.5
CO-PP[a]	132.9

Note: Standard deviations in brackets. CO = control trials, NP = negative priming trials, PP = positive priming trials, CO-NP = negative priming effect, CO-PP = positive priming effect.
[a]RT differences between control condition and the respective prime condition.

and LPC. Posterior N2 was increased specifically in the NP condition. While P300 amplitude was reduced for both conditions PP and NP relative to CO, particularly over left posterior areas, amplitude of the anterior LPC increased in the order NP, CO, and PP. Moreover, LPC peaked earlier for PP compared to both NP and CO. By contrast, at first glance there seemed to be no priming effects on earlier ERP components P1, N1, and P2. To further investigate these findings, repeated-measures ANOVAs were carried out for peak amplitude and latency of components P1, N1, P2, N2, P300, and LPC, employing factors Priming Condition (CO, NP, and PP) and Electrode, with levels of the latter factor depending on analysis (see Method).

P1. In the analysis of P1 latency, only the main effect of Electrode was significant, $F(16,240) = 5.0$, $p < .01$; $\varepsilon = .25$. This effect was not further explored because it was irrelevant to priming. Neither the main effect of Priming Condition, $F(2,30) = 0.7$, $p = .47$; $\varepsilon = .80$, nor the interaction by Electrode, $F(32, 480) = 0.8$, $p = .51$; $\varepsilon = .13$, proved to be reliable. Also, the analysis of P1 amplitude did not yield any significant priming effects; main effect of Priming Condition, $F(2,30) = 1.7$, $p = .20$; $\varepsilon = .88$; interaction Priming Condition × Electrode, $F(32,480) = 0.4$, $p = .84$; $\varepsilon = .14$.

N1. There was a significant priming effect on N1 peak latency, $F(2,30) = 3.7$, $p < .05$; $\varepsilon = .97$. According to Scheffe's test, in the NP condition the N1 peak was reliably delayed compared to PP (176 and 172 ms, $p < .05$). N1 latency in the CO condition (174 ms) was not significantly different from NP and PP conditions ($p > .50$). Neither the main effect of Priming Condition on N1 amplitude, $F(2,30) = 1.5$, $p = .23$; $\varepsilon = .93$, nor the interaction by Electrode, $F(32,480) = 0.8$, $p = .56$; $\varepsilon = .19$, were significant.

P2. Also for P2 latency, a significant effect of Priming Condition could be established, $F(2,30) = 3.8$, $p < .05$; $\varepsilon = .79$, which was due to P2 peaking slightly *earlier* for NP than CO (237 and 241 ms, $p < .05$ according to Scheffe's test). P2 latency in the PP condition (239 ms) did not differ significantly from the other two conditions ($p > .50$). The interaction Priming Condition × Electrode was not significant, $F(14,210) = 1.1$, $p = .36$; $\varepsilon = .31$. Neither the main effect of Priming Condition on P2 amplitude, $F(2,30) = 0.4$, $p = .61$; $\varepsilon = .75$, nor the interaction by Electrode, $F(14,210) = 1.4$, $p = .24$; $\varepsilon = .36$, were significant.

N2. No reliable priming effects were observed for N2 latency; main effect of Priming Condition, $F(2,30) = 0.7$, $p = .50$; $\varepsilon = .85$; interaction by Electrode, $F(14,210) = 0.5$, $p = .67$; $\varepsilon = .33$. By contrast, a significant main effect of Priming Condition was established for N2 amplitude, $F(2,30) = 3.7$, $p < .05$; $\varepsilon = .91$. N2 was significantly larger in the NP condition than in the CO condition (− 0.8 µV and 0.0 µV; $p < .05$ according to Scheffe's test). Both the differences between NP and PP and between PP and CO were not significant ($p > .30$). The interaction by Electrode was not significant, $F(14,210) = 1.8$, $p = .14$; $\varepsilon = .31$.

P300. The analysis of P300 latency yielded a significant main effect of Priming Condition, $F(2,30) = 4.3$, $p < .05$; $\varepsilon = .74$. Scheffe's test revealed that the P300 peak occurred in the PP condition reliably earlier than in the NP condition (351 and 361 ms, $p < .05$). The difference between NP and CO was not significant ($p = .83$), nor was the difference between PP and CO ($p = .10$). The interaction by Electrode was not significant, $F(32,480) = 1.6$, $p = .16$; $\varepsilon = .20$. Also for P300 amplitude, the main effect of Priming Condition was significant, $F(2,30) = 4.3$, $p < .05$; $\varepsilon = .78$. As indicated by Scheffe's test, P300 amplitude was reliably larger in the CO condition (3.6 µV) than in both the PP condition (2.9 µV; $p < .05$) and the NP condition (3.0 µV; $p < .05$). PP and NP condition did not differ from each other ($p = .95$).

The main effect was further qualified by a significant interaction by Electrode, $F(32,480) = 4.5$, $p < .001$; $\varepsilon = .19$. Since an *a priori* hypothesis had been formulated based on the results by Stahl and Gibbons (2007) and Gibbons (2009), regarding left-parietal predominance of priming effects on P300 amplitude (see introduction), planned comparisons between priming conditions were performed for clusters of left-parietal (P1, P3, P5, P7) and homologous right-parietal electrodes (P2, P4, P6, P8). Over left-side parietal areas, P300 amplitude in the CO condition (4.3 µV) was significantly larger than in both the NP condition (3.6 µV, $t[15] = 4.1$, $p = .001$), and the PP condition (3.5 µV, $t[15] = 2.7$, $p < .05$). By contrast, right-parietal P300 amplitude did not differ significantly for NP and CO (4.6 and 4.8 µV, $t[15] = 1.3$, $p = .22$), and PP and CO (4.4 and 4.8 µV, $t[15] = 1.7$, $p = .11$).

LPC. For analysis of the frontal LPC at around 700 ms post-stimulus, the four most anterior rows of electrodes were considered (see Figure 2). The main effect of Priming Condition on LPC peak latency was significant, $F(2,30) = 10.1$, $p < .001$; $\varepsilon = .99$. According to Scheffe's test, LPC peaked significantly earlier in the PP condition (711 ms) than in both the CO condition (789 ms; $p < .01$) and the NP condition (769 ms; $p < .05$). The difference between NP and CO was not significant ($p > .50$). There was no reliable interaction between Priming Condition and Electrode, $F(50,750) = 1.3$, $p = .20$; $\varepsilon = .17$. Analysis of LPC amplitude determined as mean voltage in a 200-ms window centered around the condition-specific LPC peak (see Method) yielded a significant main effect of Priming Condition, $F(2,30) = 13.7$, $p < .001$; $\varepsilon = .71$. Scheffe's test revealed significantly larger LPC amplitude in the PP condition (3.6 µV) compared to both NP (2.1 µV; $p < .001$) and CO conditions (2.8 µV; $p < .05$). Also the difference between NP and CO was significant at $p = .05$. The interaction by Electrode was not significant, $F(50,750) = 0.6$, $p = .66$; $\varepsilon = .09$.

Given that there was substantial blink activity at around (or, immediately after) the overt response (see Figure 2, vEOG), it was necessary to ensure that the frontal LPC effects were not

merely due to differences in vertical EOG activity between priming conditions. Mean EOG activity in the 550–750 ms interval (which is exactly the time window used for LPC amplitude analysis) was compared for CO and NP conditions. No significant difference was found, $t(15) = 1.5$, $p = .16$. To compare CO and PP conditions, the time window had to be adjusted for the PP condition (500–700 ms) to compensate for LPC latency differences, thus exactly matching the time window chosen for the PP condition in the analysis of LPC amplitude. The t-test was also not significant, $t(15) = 0.4$, $p = .68$.

Discussion

The present experiment was designed to investigate electrophysiological correlates of NP in a picture-naming task, striving for the main goal of finding evidence for two ERP correlates predicted from the episodic-retrieval view of NP. First, the finding of left-posterior P300 amplitude reduction for NP and PP conditions compared to control (Gibbons, 2009; Stahl & Gibbons, 2007), which may reflect the processing of prime-probe similarity, should be replicated in a completely different task. A second late conflict-related correlate of NP should be found that distinguishes the NP condition from both PP and CO conditions, and may reflect the NP-specific processing of conflict between retrieved prime information and information extracted from the probe. Only one such direct ERP correlate of visual identity-based NP has been reported before, in terms of NP-specific amplitude enhancement of a left-posterior, N400-like component (Gibbons, 2009). To find further evidence for a late-range ERP correlate of visual NP, we used a classical priming task with overlapping pictures (Tipper, 1985) that has not been used in ERP studies of NP so far, but is known to produce strong behavioral NP effects. Thereby, we aimed at broadening the empirical basis for the discussion of the mental processes and neuronal structures involved in NP effects.

Behavioral Effects

Relative to other ERP studies using digit-identification (Kathmann et al., 2006) or flanker tasks (Gibbons, 2009; Stahl & Gibbons, 2007), a strong advantage of the present picture-naming task is that it produces strong behavioral priming effects (cf., Titz et al., 2008). In the current study, mean RT was delayed by 28 ms in NP trials and accelerated by 133 ms in PP trials, compared to control. Because both effects, PP and NP, were sufficiently large, substantial differences in the corresponding ERPs can be expected, which should provide a good basis for valid interpretations of the obtained ERP correlates.

ERP Effects

The observed ERP correlates of NP mainly concerned two components, P300 and frontal LPC. Two other findings were not followed up further. The first was a small NP-related increase in N1 latency by 4 ms compared to the PP condition, which neither can account for the 28-ms behavioral NP effect nor for the 161-ms RT difference between NP and PP conditions. The second was a small N2 amplitude increase for the NP condition relative to control, which, however, did not distinguish the NP condition from the PP condition. Thus, in contrast to the studies by Daurignac et al. (2006) and Frings and Groh-Bordin (2007), no significant NP-specific effects on early ERP components were observed, and there seems to be little evidence in the present data that would support the inhibition view of NP. In the following, possible explanations for the present priming effects on P300 and

LPC amplitudes and their consequences for theories of NP are discussed in more detail.

Replication of the P300 ERP correlate of perceived prime-probe similarity. The present study provides a successful conceptual replication of earlier reports of priming effects on P300 amplitude. The finding of reduced left-posterior P300 in both NP and PP trials is well in line with the results obtained by Stahl and Gibbons (2007) and Gibbons (2009) in their Eriksen flanker tasks. Since these tasks are rather different from the present task employing overlapping objects, the convergent results regarding priming effects on P300, even with respect to the left-posterior scalp topography, are all the more remarkable. Note that the present left-posterior P300 effect was observed in a (300–500 ms) time window, whereas Gibbons (2009) and Stahl and Gibbons (2007) analyzed a somewhat earlier time window (300–400 ms). However, given the difference in mean RT between the present task using overlapping pictures (650–800 ms) and the two earlier studies using the flanker task (500–650 ms), it seems likely that functionally the same processes were involved in P300 reduction in both tasks. Therefore, in line with Gibbons (2009) we interpret PP- and NP-related reduction in P300 amplitude as reflecting processes related to perceived prime-probe similarity. Within the framework of episodic-retrieval view (Neill et al., 1992; Rothermund et al., 2005), this would correspond to the concept of a "retrieval cue."

One might argue that reduced P300 amplitude is at variance with the literature on (word) repetition effects on the ERP, usually reporting larger ERP positivity for repeated stimuli (see Rugg, 1995, for an early review). However, the ERP repetition effect typically has its maximum at around 600 ms, as opposed to the present joint PP/NP effect on P300 at around 400 ms. There are at least two other striking differences between the present priming task and the ERP repetition paradigm: First, in the present experiment all stimuli are repeated over and over, whereas in ERP repetitions studies first and second presentations of a stimulus are compared, with lags often ranging from many seconds to several minutes. Second, unlike the present task ERP repetition experiments do not involve selection; typically, on each trial one single stimulus is presented. The present P300 component, therefore, seems to be rather different from the late-range positive ERP components observed in ERP repetition studies.

It should be mentioned that we did not find differences in P300 peak latency between NP and CO conditions, suggesting similar speed of stimulus evaluation processes in these two priming conditions. When the relatively strong behavioral NP effect is considered, in line with Stahl and Gibbons (2007) it can be argued that at least one additional process in the post-P300 time range has to be assumed to explain behavioral NP.

A novel late conflict-related ERP correlate of visual NP. Two late-range ERP findings of the present study may provide a basis for a consistent explanation of the RT differences between priming conditions. These findings concern reduced amplitude and (qualitatively) delayed peak latency of the frontal LPC for the NP condition, as well as increased LPC amplitude and reduced LPC latency for the PP condition, both compared to control. The effects were widely distributed over the anterior scalp, including the first four rows of electrodes (fronto-polar to fronto-central). Note that LPC priming effects were analyzed between 500 and 700 ms, but frontal ERP differences-to-control already started at around 380 ms for PP and 520 ms for NP (see Figure 1). Given

that RTs ranged from 632 ms (PP condition) to 793 ms (NP condition), these LPC effects may well reflect processes that were responsible for priming effects on RT, and not merely consequences of the mean RT differences between conditions.

Frontal brain activity is known to be particularly necessary in situations where an individual's behavior is not simply controlled by stimulus-response relationships, but requires careful selection from different response options (see Ridderinkhof et al., 2004, for review). One possibility is to explain the present LPC differences in terms of the amount of cognitive control required. Processes related to cognitive control may become evident in late-range frontal ERP negativity, as it is often observed in situations of conflict processing (e.g., Krigolson & Holroyd, 2007; Lorist, Klein, Nieuwenhuis, De Jong, Mulder, & Meijman, 2000; West, Bowry, & McConville, 2004; Yeung, Botvinick, & Cohen, 2004). These processes should be strongest in the high-conflict NP condition, thereby reducing and/or delaying the ERP positivity that normally indicates the completion of trial processing. By contrast, in the low-conflict PP condition no strong cognitive control is required, causing earlier and stronger ERP positivity.

The response-retrieval theory introduced by Rothermund et al. (2005) may provide an especially good means of explaining NP in terms of late processing conflicts. This approach suggests that the prime response is automatically reactivated when prime stimuli are repeated in the probe. In case of PP trials, both prime response retrieval and probe processing converge at the same response, which causes behavioral PP and, moreover, should be accompanied by particularly low conflict. No (frontal) brain activity related to cognitive control is then required. This can explain why in the PP condition particularly strong and early frontal ERP positivity was observed, given that positive ERP deflections typically occur when mental resources can be updated because they are no longer needed for ongoing information processing.

In contrast, in the NP condition retrieval of the prime response and algorithmic probe processing activate different responses, which may necessitate cognitive control processes reflected in late-range frontal brain activation. This type of brain activity typically manifests in ERP negativity. It may then be superimposed on positive components indicating the completion of stimulus analysis, thereby causing amplitude reduction and/or delayed latency of these positive components (see Kok, 2001, for the general argumentation). In sum, the observed differences in frontal LPC amplitude between NP, CO, and PP conditions are well in line with the prime-response retrieval account of NP (Rothermund et al., 2005).

A second explanation for the present LPC priming effects may directly refer to memory processes. Mayr et al. (2003, 2006) observed NP-related reduction of (posterior) LPC amplitude in the auditory domain. The authors interpreted their finding as support for episodic-retrieval mechanisms and argued as follows: In ERP repetition studies, familiarity of a stimulus is reflected in larger posterior LPC, compared to novel stimuli. If, however, NP is accompanied by reduced LPC amplitude, this may indicate that former distractor stimuli, when repeating as targets in the NP condition, are in some sense "less familiar" than the novel targets in the CO condition. This below-baseline reduced familiarity of NP targets may then result in less efficient processing of these stimuli, causing the NP effect. In principle, a similar mechanism related to memory processes may also be responsible for the present NP-related frontal LPC reduction. The different topographies of the present LPC effect and the LPC effect by Mayr

et al. (2003, 2006) might be explained in terms of modality differences (visual vs. auditory) and/or differences in task demands (naming a visual object vs. classifying a sound by means of a button press). Note that there is evidence in the literature that visual memory tasks indeed may involve frontal LPC effects (e.g., Hayama, Johnson, & Rugg, 2008; Wilding & Rugg, 1996). Ullsperger, Mecklinger, and Müller (2000) distinguished between a frontal LPC effect reflecting stimulus familiarity and a posterior LPC effect related to conscious recollection. The present priming effects on frontal LPC are, therefore, well in line with the assumption that familiarity of the probe target in the PP condition is particularly high (here, the largest LPC amplitude was observed). By contrast, in the NP condition showing smaller frontal LPC than control, familiarity of a recently ignored target seems to be below baseline.

Theoretical Implications

In sum, there seems to be little evidence in the present data for an interpretation in favor of the inhibition view of NP. In this respect, besides the fact that there were no significant NP correlates in the N200 time range, where according to the literature persisting inhibition can be expected to operate (Daurignac et al., 2006; Frings & Groh-Bordin, 2007), the finding of reduced left-posterior P300 amplitude for both PP and NP conditions relative to control has to be emphasized. P300 amplitude is often understood as an index of mental effort (e.g., Ullsperger, Metz, & Gille, 1988; see also Kok, 2001). Thus, a persisting-activation/inhibition view of PP/NP would predict larger P300 amplitude for NP compared to PP trials. Reduced P300 amplitude in PP trials would reflect facilitation of processing due to persisting activation of internal representations of the (repeated) target stimulus. Increased P300 amplitude in NP trials would reflect greater mental effort, as the activation of NP targets is still below baseline, due to persisting inhibition. As noted earlier, however, this pattern of P300 amplitudes was not found in the present study.

Episodic-retrieval view, therefore, seems most appropriate to interpret our ERP correlates of NP in a picture-naming task, because it can explain both reduced P300 amplitudes in both conditions NP and PP and the "parametric" modulation of LPC amplitude by priming. Regarding P300, recognized prime-probe similarity (cf., Fox & de Fockert, 1998), which is reflected in smaller P300 amplitude, may serve as a retrieval cue that triggers the retrieval of prime information (Neill et al., 1992). As explained above, the retrieved prime information then has opponent effects on further processing in PP and NP trials (beneficial vs. conflicting, respectively). This is consistent with our observation that up to the P300 time range ERPs did not reveal any major differences in the processing of NP and PP trials. Hence, the present NP effect seems to originate at a later, post-P300 stage of processing.

Conclusion

One of the two major results of our study, that is, smaller left-posterior P300 amplitude for NP and PP trials compared to the CO condition, represents a conceptual replication of the results by Stahl and Gibbons (2007) and Gibbons (2009) in a classical picture-naming priming task. Thus, the processing of prime-probe similarity seems to be important for visual NP in general and is not restricted to a certain task. In addition, the reduced LPC amplitude in NP trials suggests more effortful processes

related to cognitive control and/or memory retrieval. The present NP effect on frontal LPC amplitude has been observed for the first time, which may point to a specific advantage of the picture-naming task. This task is more difficult than typical visual NP tasks (e.g., the flanker) and produces long RTs and strong behavioral NP effects. Both these aspects may provide good conditions to identify late-range ERP correlates of NP. Overall, our results seem to favor a retrieval-based explanation of the present NP effect.

A cautionary note concerns the fact that the three priming conditions relevant to the present study (PP, NP, and CO) were randomly presented among other trial types not containing distractor objects. These trials were included to answer a separate research question not relevant to the present study. Their presence, however, may have affected possible strategies used by the participants and, thereby, processes related to NP. For example, the frequent inclusion of single-target trials may have increased the difficulty participants had when, on another trial, a distractor actually appeared. Insofar as this may have strengthened the NP effect, it is consistent with the aim of the present study, i.e., to increase the chance of finding ERP correlates of NP by employing a task known to produce strong NP. However, the present results may encourage further ERP studies with the overlapping-pictures task, which then should be composed only of the most relevant conditions PP, NP, and CO.

Furthermore, future studies should go beyond mere attempts to find ERP correlates of NP. Rather, the size of the behavioral NP effect should be experimentally manipulated, and corresponding changes in the ERP should be determined. For example, by using a larger temporal interval between the probe and the next prime than between the prime and the probe, conditions favoring episodic retrieval processes can be realized (cf. Neill et al., 1992; Allport, Tipper, & Chmiel, 1985). If differences in behavioral NP are found and, moreover, certain ERP correlates of NP are sensitive to this manipulation, this would strongly increase our understanding of the exact mental processes that are tapped by these ERP correlates.

REFERENCES

Allport, D. A., Tipper, S. P., & Chmiel, N. R. J. (1985). Perceptual integration and postcategorial filtering. In M. I. Posner & O. S. M. Marin (Eds.), *Attention and performance XI* (pp. 107–132). Hillsdale, NJ: Erlbaum.

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of some aspects of the Stroop color–word test. *Perceptual & Motor Skills, 23*, 1211–1214.

Daurignac, E., Houdè, O., & Jouvent, R. (2006). Negative priming in a numerical Piaget-like task as evidenced by ERP. *Journal of Cognitive Neuroscience, 18*, 730–736.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*, 357–374.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of target letters in a nonsearch task. *Perception & Psychophysics, 16*, 155–160.

Fox, E. (1995). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review, 2*, 145–173.

Fox, E., & de Fockert, J. W. (1998). Negative priming depends on prime-probe similarity: Evidence for episodic retrieval. *Psychonomic Bulletin & Review, 5*, 107–113.

Frings, C., & Groh-Bordin, C. (2007). Electrophysiological correlates of visual identity negative priming. *Brain Research, 1176*, 82–91.

Geisser, S., & Greenhouse, S. W. (1958). An extension of Box's results on the use of the F distribution in multivariate analysis. *Annals of Mathematical Statistics, 29*, 885–891.

Gibbons, H. (2006). An event-related potential investigation of varieties of negative priming. *Journal of Psychophysiology, 20*, 170–185.

Gibbons, H. (2009). Functional brain-electrical correlates of negative priming in the flanker task: Evidence for episodic retrieval. *Psychophysiology, 46*, 807–817.

Gibbons, H., Rammsayer, T. H., & Stahl, J. (2006). Multiple sources of positive and negative priming effects: An evoked-potential study. *Memory & Cognition, 34*, 172–186.

Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*, 468–484.

Hayama, H. R., Johnson, J. D., & Rugg, M. D. (2008). The relationship between the right frontal old/new effect and post-retrieval monitoring: Specific or non-specific? *Neuropsychologia, 46*, 1211–1223.

Heil, M., & Rolke, B. (2004). Unattended distractor-induced priming in a visual selective attention task: N400 effects in the absence of rt effects. *Journal of Psychophysiology, 18*, 164–169.

Hinojosa, J. A., Villarino, A., Pozo, M. A., Elosua, R. M., Merino, J. M., Moreno, E., & Luna, D. (2007). An event-related potential study of identity positive and negative priming. *International Journal of Psychophysiology, 66*, 48–55.

Houghton, G., & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 53–112). San Diego, CA: Academic Press.

Houghton, G., & Tipper, S. P. (1998). A model of selective attention as a mechanism of cognitive control. In J. Grainger & A. M. Jacobs (Eds.), *Localist connectionist approaches to human cognition. Scientific psychology series* (pp. 39–74). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kane, M. J., May, C. P., Hasher, L., Rahhal, T., & Stolzfus, E. R. (1997). Dual mechanisms of negative priming. *Journal of Experimental Psychology: Human Perception & Performance, 23*, 632–650.

Kathmann, N., Bogdahn, B., & Endrass, T. (2006). Event-related brain potential variations during location and identity negative priming. *Neuroscience Letters, 394*, 53–56.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology, 38*, 557–577.

Krigolson, O. E., & Holroyd, C. B. (2007). Predictive information and error processing: The role of medial-frontal cortex during motor control. *Psychophysiology, 44*, 586–595.

Lorist, M. M., Klein, M., Nieuwenhuis, S., De Jong, R., Mulder, G., & Meijman, T. F. (2000). Mental fatigue and task control: Planning and Preparation. *Psychophysiology, 37*, 614–625.

May, C. P., Kane, M. J., & Hasher, L. (1995). Determinants of negative priming. *Psychological Bulletin, 118*, 35–54.

Mayr, S., & Buchner, A. (2007). Negative priming as a memory phenomenon: A review of 20 years of negative priming research. *Journal of Psychology, 215*, 35–51.

Mayr, S., Niedeggen, M., Buchner, A., & Orgs, G. (2006). The level of reaction time determines the ERP correlates of auditory negative priming. *Journal of Psychophysiology, 20*, 186–194.

Mayr, S., Niedeggen, M., Buchner, A., & Pietrowsky, R. (2003). ERP correlates of auditory negative priming. *Cognition, 90*, B11–B21.

Milliken, B., Joordens, S., Merikle, P. M., & Seiffert, A. E. (1998). Selective attention: A reevaluation of the implications of negative priming. *Psychological Review, 105*, 203–229.

Neill, W. T. (1977). Inhibition and facilitation processes in selective attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 3*, 444–450.

Neill, W. T. (1997). Episodic retrieval in negative priming and repetition priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 1291–3105.

Neill, W. T., Valdes, L. A., Terry, K. M., & Gorfein, D. S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 993–1000.

Ridderinkhof, K. R., van den Wildenberg, W. P. M., Segalowitz, S. J., & Carter, C. S. (2004). Neurocognitive mechanisms of cognitive control: The role of prefrontal cortex in action selection, response inhibition, performance monitoring, and reward-based learning. *Brain and Cognition, 56*, 129–140.

Ritter, W., Ford, J., Gaillard, A., Harter, M., Kutas, M., Näätänen, R., et al. (1984). I. The Relation of Negative Potentials and Cognitive Processes. *Annals of the New York Academy of Sciences, 425*, 24–38.

Rothermund, K., Wentura, D., & De Houwer, J. (2005). Retrieval of incidental stimulus-response associations as a source of negative priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*, 482–495.

Rugg, M. D. (1995). ERP studies of memory. In: M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind* (pp. 132–170). University Press, Oxford.

Sams, M., Paavilainen, P., Alho, K., & Näätänen, R. (1985). Auditory frequency discrimination and event-related potentials. *Electroencephalography and clinical Neurophysiology, 62*, 437–448.

Stahl, J., & Gibbons, H. (2007). Event-related brain potentials support episodic-retrieval explanations of flanker negative priming. *Experimental Brain Research, 181*, 595–606.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology, 37A*, 571–590.

Tipper, S. P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 54*, 321–343.

Tipper, S. P., & Cranston, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 37A*, 591–611.

Titz, C., Behrendt, J., Menge, U., & Hasselhorn, M. (2008). A reassessment of negative priming within the inhibition framework of cognitive aging: There is more in it than previously believed. *Experimental Aging Research, 34*, 340–366.

Ullsperger, P., Metz, A.-M., & Gille, H.-G. (1988). The P300 component of the event-related brain potential and mental effort. *Ergonomics, 31*, 1127–1137.

Ullsperger, M., Mecklinger, A., & Müller, U. (2000). An electrophysiological test of directed forgetting: The role of retrieval inhibition. *Journal of Cognitive Neuroscience, 12*, 924–940.

Wagner, M., Baving, L., Berg, P., Cohen, R., & Rockstroh, B. (2006). An ERP investigation of semantic priming, repetition priming, and negative priming in schizophrenic patients. *Journal of Psychophysiology, 20*, 195–211.

West, R., Bowry, R., & McConville, C. (2004). Sensitivity of medial frontal cortex to response and nonresponse conflict. *Psychophysiology, 41*, 739–748.

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of context: An event-related potential study. *Brain, 119*, 889–906.

Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: Conflict monitoring and the error-related negativity. *Psychological Review, 111*, 931–959.