Postperceptual effects and P300 latency

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Abstract
P300 latency is commonly thought to provide a chronometric index of the duration of perceptual processing. Because the evidence in favor of this assumption is controversial, we examined whether P300 latency is influenced by perceptual processes, response selection, and by motoric processes in two experiments using a two-choice spatial stimulus-response compatibility (SRC) task. Both experiments revealed additive effects of perceptual difficulty with spatial SRC in reaction time and P300 latency. In addition, Experiment 2 showed that P300 latency measured in average waveforms is insensitive to motoric processes. The influence of spatial SRC on P300 latency disagrees with the view that P300 latency is sensitive only to stimulus evaluation processes. However, P300 latency may be used to discriminate between influences on premotoric and motoric processing stages. A response conflict account for the SRC effect on P300 latency is suggested.

Descriptors: Event-related potentials, P300 latency, Mental chronometry, Spatial S-R compatibility, Stimulus evaluation, Motoric processes

The analysis of event-related brain potentials (ERPs) has significantly improved our understanding of the cognitive system (for review, see Coles, Smid, Scheffers, & Otten, 1995). ERPs provide on-line indices of some of the ongoing processes underlying human performance and complement behavioral measures in inferring the organization of information processing. One of the most popular chronometric ERP indices is the peak latency of the P300 component (cf. van der Molen, Bashore, Halliday, & Callaway, 1991). P300 latency is often used as an electrophysiological measure of perceptual processing duration (cf. Coles et al., 1995). We shall call this assumption the perceptual time marker (PTM) hypothesis of P300 latency.

In the present study, we distinguish between two versions of the PTM hypothesis. According to the strong PTM hypothesis, P300 latency is influenced only by perceptual variables but not by others. This hypothesis seems to be neither unequivocally supported by data (cf. Verleger, 1997) nor universally accepted (e.g., Sanders, 1990). The weak PTM hypothesis assumes that P300 latency is affected by perceptual and other processes to be specified. Because inferences in mental chronometry based on P300 latency may become more straightforward if our understanding of the mechanisms underlying P300 latency is improved, the present study was designed to test the PTM hypotheses and to reveal their possible limitations.

The P300 is a positive ERP component peaking 300 ms or later after stimulus onset and is characterized by a centroparietal scalp distribution. An influential theoretical model relates the P300 component to the revision of mental schemes (Donchin & Coles, 1988). Because this revision process is assumed to be elicited after the categorization of task-relevant events, on logical grounds, P300 latency has been held to index stimulus evaluation time (cf. Donchin & Coles, 1988). However, because the revision of mental plans may depend on the evaluation of stimulus–response (S-R) interactions (cf. Magliero, Bashore, Coles, & Donchin, 1984), according to the stimulus evaluation hypothesis, P300 latency may be sensitive to manipulations of stimulus–response compatibility (SRC) also (cf. Ragot & Renault, 1985).

Consistent with the view that P300 latency is sensitive to perceptual demands, initial studies have found P300 latency to be affected by stimulus discriminability and to covary with RT (e.g., Ritter, Simson, & Vaughan, 1972). That P300 latency often exceeds reaction time (RT) does not invalidate its use as a time marker for perceptual processing; this finding can be easily explained by assuming that P300 latency does not mark an event within information processing in an absolute sense but provides a relative index of stimulus evaluation time. For example, further processes not included in the S-R processing chain but time locked to perceptual processing may also contribute to absolute P300 latency.

Kutas, McCarthy, and Donchin (1977) first suggested that P300 latency may be used as a relative measure of stimulus evaluation time. In their study, P300 latency was found to increase with difficulty of stimulus classification and was found to be less sensitive than RT to different speed–accuracy instructions. Kutas et al. took the dissociation of P300 latency and RT with respect to speed–accuracy manipulations as evidence for the claim that P300 latency indicates the duration of stimulus evaluation, whereas RT seemed to be based on partial stimulus information.
The strongest support of P300 latency as a measure of perceptual processing time has been obtained with Sternberg’s (1969) additive-factor method (AFM). Sternberg assumed that the duration of particular processing stages could be influenced selectively by the appropriate manipulation of experimental factors. If processing occurs in distinct serially arranged stages, it would be possible to infer the structure of processing stages from experimental effects on RT. Thus, if experimental factors affect RT in an additive manner, effects on distinct processing stages could be assumed, whereas an interaction would indicate effects on at least one common stage. Applying this logic, at least six independent processing stages have been identified (Sanders, 1990), namely three perceptual stages (preprocessing, feature extraction, and identification), a central decision stage (response selection), and two motor stages (response programming and response adjustment).

According to the strong PTM hypothesis, P300 latency should be affected only by processing stages before response selection, whereas the weak PTM hypothesis and the stimulus evaluation hypothesis assume that P300 latency may be influenced by postperceptual processing stages.

Most AFM studies of P300 latency manipulated SRC in combination with perceptual factors. SRC refers to the fact that performance in perceptual-motor tasks strongly depends on the relationship between stimulus and response. Manipulations of SRC are taken to affect the duration of the central response selection stage. For present purposes, it is important to distinguish between different types of SRC effects (cf. Simon, Sly, & Vilapakkam, 1981), because studies of P300 latency have concentrated on particular variants of SRC. First, symbolic SRC refers to the observation that RT is shorter when a stimulus word signals a manual response with a key of the named location (e.g., LEFT → left R) than when it signals a different response (e.g., LEFT → right R). Second, spatial SRC effects denote the finding that, when stimulus location determines response location, spatially compatible responses are faster (e.g., left S → left R) than incompatible responses (e.g., left S → right R). Third, the Simon effect (for a review, see Simon, 1990) occurs with lateralized stimuli when a nonspatial stimulus attribute determines the spatially arranged response (e.g., green S → left R; red S → right R). As with the spatial SRC effect, responses ipsilateral to the stimulus (left S → left R, right S → right R) are faster than contralateral responses (left S → right R, right S → left R), although in this case stimulus location is task irrelevant.

McCarthy and Donchin (1981) first examined P300 latency within an AFM framework. They required choice responses with the left and right hand to the words RIGHT and LEFT. The words were embedded either in a matrix of either # symbols (high discriminability) or in a matrix of randomly chosen alphabetic characters (low discriminability). Symbolic SRC was manipulated by requiring responses either in accord with or opposite to the meaning of the presented word. Both discriminability and SRC varied at random from trial to trial and affected RTs in an additive fashion. However, in agreement with the strong PTM hypothesis, P300 latency was influenced by discriminability only.

Importantly, the results of several studies are at variance with the strong PTM hypothesis. Magliero et al. (1984) reported a significant symbolic SRC effect in P300 latency of about 15 ms in a task similar to those used by McCarthy and Donchin (1981). Because the symbolic SRC effect on RT was several times larger, however, Magliero et al. concluded that P300 latency is largely unaffected by postperceptual processes. Later, Pfefferbaum, Christensen, Ford, and Kopell (1986) demonstrated that, when S-R mapping was consistent within a given block of trials, symbolic SRC influenced P300 latency additively to the perceptual effect of stimulus blurring. Similar effects of symbolic SRC on P300 latency for consistent S-R mapping conditions also has been demonstrated for young and old adults (Christensen, Ford, & Pfefferbaum, 1996; Ford & Pfefferbaum, 1985; Smulders, 1993).

Results obtained in the Simon paradigm led to a debate about the nature of P300 latency (Magliero et al., 1984; Ragot & Renault, 1985). Repeatedly, a Simon effect was found in P300 latency in the visual modality (Ragot, 1984; Ragot & Renault, 1981; Sommer, Leuthold, & Hermanutz, 1993; Smulders, 1993; Zeef & Kok, 1993), whereas the presence of a Simon effect on P300 latency may depend on task demands in the auditory modality. Thus, using a standard task, Leuthold and Sommer (1995) found an auditory Simon effect on P300 latency whereas Ragot and FIORI (1994), using a more complex RT task, did not. Because the Simon effect was thought to be located in the stage of response selection, Ragot initially claimed (Ragot, 1984; Ragot & Renault, 1981) that P300 latency is not a pure measure of stimulus evaluation time but is sensitive to the duration of response selection.

However, the locus of the Simon effect itself is currently under debate (cf. Leuthold, 1994). Whereas a perceptual locus of the Simon effect, as suggested by Hasbroucq and Guiard (1991), would be in accord with the strong PTM hypothesis of P300 latency, strong evidence now exists for a response-related locus of the Simon effect within information processing (cf. Hommel, 1995). Because both relevant stimulus information and task-irrelevant stimulus location influence the processing system in the Simon task, inferences about the underlying mechanisms are more problematic than in the spatial SRC paradigm, in which only task-relevant stimulus location is taken to influence performance.

It is therefore surprising that ERP studies have focused on the Simon task but barely have examined spatial SRC effects on P300 latency. Mulder, Glöerich, Broekhuis, van Dellen, and Mulder (1984) used a choice RT task in which participants were asked to discriminate between the length of simultaneously presented lines to determine the relevant stimulus location and to perform, as a function of this stimulus location, either a spatially compatible or incompatible response. They found P300 latency to be affected by stimulus discriminability but not by spatial SRC. Fitzpatrick, Klorman, Brumaghim, and Keeover (1988) used a memory scanning task in which participants were asked to detect a target within a row of four consonants. The mapping of target locations to finger responses changed between blocks and was either spatially compatible or not. They found P300 latency to be delayed for spatially incompatible when compared with compatible S-R mappings, but only in conditions of low memory load. In a four-choice pointing task with stimulus color determining response hand and stimulus location determining target position, FIORI, Ragot, and Renault (1992) found spatial SRC to influence RT but not P300 latency, whereas in a similar task RENAUT, FIORI, and GIANI (1988) did find a spatial SRC effect on P300 latency. Unfortunately, these studies are limited in their generalizability because they used complex RT tasks in which both a spatial and a nonspatial stimulus dimension were task relevant.

To our knowledge, there are no ERP studies testing the PTM hypothesis of P300 latency using a standard two-choice spatial SRC task. Therefore, a first goal of the two present experiments is to close this gap by examining whether P300 latency is affected by perceptual variables, by spatial SRC, and by motoric variables.

A second goal is to elucidate possible mechanisms underlying P300 latency’s sensitivity to response-related demands. On the one
hand, it has been suggested that perceptual and response-related variables may influence different parts of the P300 complex. Thus, Falkenstein, Hohnsbein, and Hornarm (1993, 1994) proposed that two P300 subcomponents are elicited in choice RT situations. Accordingly, a centrally distributed and modality-dependent P300 is sensitive to perceptual demands. This P300 subcomponent is called P-SR because it is identical with a positive component in simple reaction (SR) tasks. A second parietally distributed and modality-independent P300 subcomponent is influenced by response-related demands in choice reaction (CR) tasks. This additional late positive component is called P-CR.

On the other hand, Pfefferbaum et al. (1986) hypothesized that the organization of information processing may determine whether or not there are response-related influences on P300 latency. They assumed that P300 latency is affected by symbolic SRC if participants process stimulus and response in parallel. Verleger (1997) modified this account by proposing that parallel processing may affect P300 latency if response selection occurs simultaneously with the generation of P300. Verleger suggested that "... P3 should be more sensitive to delays of response selection the faster the responses are made in a given task" (p. 145). This sensitivity should hold true irrespective of the specific information processes involved in task accomplishment and also within task variations. We shall refer to this view as the base-level RT hypothesis of P300 latency. The sensitivity of P300 latency to response-related demands may decrease with increases in response latency because of a reduction of P300 subcomponent overlap because the response-related P-CR may gain less impact on the initial P300 peak (Verleger & Wascher, 1995).

Concerning present experiments, the base-level RT hypothesis predicts a clear effect of spatial SRC on P300 latency because, even for spatially incompatible mappings of stimulus to response locations, response speed is relatively high when compared with RT tasks using more arbitrary S-R mappings. Furthermore, the relationship between response speed and response-related P300 latency effects should hold even within a given RT task. To test this latter prediction, we examined the sensitivity of P300 latency to spatial SRC demands for different levels of response speed in Experiment 1. This analysis may also provide a means to examine whether two P300 subcomponents are elicited in choice RT tasks (Falkenstein et al., 1994) because the overlap of P300 subcomponents has been reported to be reduced for slow versus fast RT trials (cf. Falkenstein et al., 1993).

These present experiments attempted to test the validity and limitations of the strong PTM hypothesis of P300 latency. According to this hypothesis, P300 latency should be influenced by perceptual demands but not by manipulations of response selection demands. Furthermore, by analyzing response latency classified ERP waveforms, we tested the prediction derived from the base-level RT hypothesis that the influence of response-related demands on P300 latency decreases with increases in response latency.

**EXPERIMENT 1**

In Experiment 1, stimulus eccentricity and spatial S-R mapping were manipulated to influence the duration of perceptual and response selection stages, respectively. Visual and auditory stimulation was used to examine the generalizability of results. A further reason was to assess the overlap of P300 subcomponents that has been reported to be less pronounced in the auditory versus the visual modality (e.g., Falkenstein et al., 1993).

**Method**

**Participants**

Eight right-handed students (three women and five men, aged 24–31 years) with a mean handedness score of 89 (range = 65–100) in the Edinburgh Inventory for Handedness (Oldfield, 1971) participated. All participants reported normal hearing and had normal or corrected-to-normal vision.

**Apparatus and Stimuli**

Participants were tested in a dim sound-attenuated chamber with a constant noise level of 40 dB(A). Visual stimuli were presented on an Amiga 1024 color monitor, controlled by an Amiga 2000 microcomputer. A viewing distance of 1 m was controlled by a fixed chin rest. A gray rectangle (1.3 cd/m²) of 5.0° × 2.8° visual angle with a fixation point placed 0.15° below its center was visible throughout the experiment. The rectangle served as background for visual stimulation and allowed fixation in the auditory condition. Auditory stimuli were presented via two loudspeakers at ear level that could be placed at variable eccentricity on a horizontal bar orthogonal to the mid sagittal plane.

In both modalities, stimuli were presented at constant interstimulus intervals of 2 s, equi-probably to the left or right side. Responses were recorded with two keys mounted 20 cm apart on a horizontal response panel and located in front of the participant symmetrical to the mid sagittal plane. Switch closure required a 3-mm vertical displacement and a force of about 2 N. The index fingers of the left and right hand operated the left and right key, respectively. Eccentricities of the stimuli were selected on the basis of preliminary experiments.

Visual stimuli (square, diamond, circle, octagon) were of 2.1 cd/m², subtended visual angles of approximately 0.3°, and were presented for 100 ms. In the large and small eccentricity conditions, the stimuli appeared 1.2° and 0.15°, respectively, to the left or right of the central fixation point.

In the auditory condition, sinusoidal tones (600, 725, 775, 900 Hz; cf. Footnote 1) of 66–68-dB(A) intensity and 65-ms duration, including 8-ms rise/fall times were used. The stimuli in the large and small eccentricity conditions were presented to the left or right of the mid sagittal plane at angles of 40° and 5°, respectively.

**Procedure**

Written instructions about the experimental procedure were used. The participant’s task was to make choice responses as a function of stimulus location. In the compatible S-R mapping condition, participants responded with the left key (operated by the left index finger) to stimuli on the left side and with the right key (operated by the right index finger) to stimuli on the right side; in the incompatible condition, the mapping was reversed. S-R mapping changed between experimental sessions on consecutive days. Participants were encouraged to perform rapid but reasonably accurate responses.

For each participant one practice and two experimental sessions were conducted on consecutive days and at similar hours. The 1-hr practice session included vision testing and handedness assessment. During practice no electrophysiological data were recorded and only half as many trials were presented as in one of the 2.5-hr sessions.

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1 The different shapes (and pitches) were used to control for stimulus factors in comparison with a different experiment not reported here. They are neither relevant for the present task nor did they have any effects on the dependent variables.
experimental sessions. Both the visual and auditory choice RT task consisted of 16 blocks of 64 trials taking about 2.5 min each. After each block participants were given verbal feedback about their performance in terms of speed and accuracy. Visual and auditory conditions were separated by a break of about 5 min and counter-balanced across participants.

**Design**

Two arrangements of eccentricity conditions were used. Within the first four blocks eccentricity changed either after each block or after two blocks. In the next four blocks conditions were repeated in reversed order (LSLS-SLSL and LLSS-SSL; L for large and S for small eccentricity). The last eight blocks repeated the first eight blocks except that now the alternation rates of eccentricity conditions were exchanged (LLSS-SSL and LLS-SLAL). Four of the eight participants began with the large eccentricity condition and the other four participants began with the small eccentricity condition. S-R mapping was kept constant within a given experimental session and changed for the next session on the consecutive day. Ordering of S-R mapping and modality was balanced across participants.

**Electrophysiological Recording**

The electroencephalogram (EEG) was recorded from Fpz, Fz, Cz, Pz, and Oz according to the International 10–20 System (Jasper, 1958) and from the left mastoid. The electrooculogram (EOG) was recorded from electrodes affixed above and below the left eye and from the outer canthus of each eye. All electrodes were referenced to the right mastoid. Grass E5SH Ag/AgCl electrodes and Beckman Electrode Electrolyte paste were used and electrode impedance was kept below 10 kΩ.

All signals were amplified with time constants of 5.5 s and low-pass filters were set to 40 Hz (−3 dB attenuation, 12 dB rolloff/octave). The EEG and EOG were digitized at 100 points/s for 1,270 ms, starting 270 ms before stimulus onset. Off-line, all EEG channels were recalculated to an average mastoid reference, and the vertical and horizontal EOG channels were recalculated to bipolar derivations. From these digitized waveforms, ERPs were obtained by averaging according to the experimental conditions. Vertical and horizontal EOG (vEOG and hEOG) were averaged the same way.

**Data Analysis**

We discarded from data analysis the first four trials of each block, which were considered practice, and all trials with incorrect responses and trials immediately following an error. We also excluded trials with an RT of less than 100 ms and more than 1,000 ms and trials in which hEOG or vEOG activity exceeded a range of 50 μV. Thus, the analysis of behavioral (RTs) and electrophysiological data included only trials that passed these criteria. Dependent variables were subjected to repeated measures analyses of variance (ANOVAs) using conservative F tests (Huynh & Feldt, 1976).

The latencies of early visual ERP components (P130, N200, P265) were measured at the Oz electrode in average waveforms with a peak-picking procedure at the time point of maximal negativity or positivity between 100 and 320 ms. Visual and auditory P300 latencies were measured both in average and in single trial waveforms. In average (unfiltered) waveforms P300 peak latency was taken as the interval between stimulus onset and the time point of maximal positivity at the Pz electrode between 250 to 850 ms as determined by a computerized peak picking procedure. One problem with the latency measured in average ERP waveforms is that it does not necessarily equal the average of single trial latency (Callaway, Halliday, Naylor, & Thouvenin, 1984). Therefore, P300 latency was measured in single trials by applying the vector filter method (see Gratton, Coles, & Donchin, 1989). Stimulus-synchronized waveforms recorded from the Fz, Cz, and Pz electrodes were digitally low-pass filtered at 3.4 Hz and linearly combined with different weighting coefficients for each electrode (Fz = 0.15, Cz = −0.53, Pz = 0.83). P300 latency was then determined in the composite waveforms with a cross-correlation procedure. For each trial, a 2-Hz sine half-wave template was moved across the stimulus-synchronized composite ERP waveform during a poststimulus interval from 250 to 850 ms in increments of 10 ms. For each lag, the cross-products between template and composite ERP waveform were calculated. At the lag of the maximum cross-product, P300 latency was taken as the time point in the ERP corresponding to the center of the template.

To examine whether response-related P300 latency effects varied as a function of base-level RT, we classified all correct trials on the basis of RT into three bins of fast, medium, and slow trials for each experimental condition and participant. Single trial P300 latency was measured in composite waveforms as just described.

Modalities were analyzed separately for two reasons. First, the comparability of the modality-specific ERP components in terms of underlying processing mechanisms is unclear. Second, stimulus eccentricity is unlikely to be completely equivalent in the two modalities, both in terms of processing requirements and magnitude of the experimental effects.

**Results and Discussion**

**Performance**

Data were analyzed by two-way ANOVAs with repeated measures on eccentricity (large or small) and mapping (compatible vs. incompatible). Figure 1 shows the effects of eccentricity and mapping on mean RT and error rate in visual and auditory modality.

![Figure 1. Mean reaction times and error rates (E) as a function of eccentricity (large vs. small), S-R mapping (compatible vs. incompatible), and modality (visual vs. auditory).](image-url)
In the visual modality fewer errors occurred for large than for small eccentricity \((M = 9.3\% \text{ vs. } 12.1\%\), \(F(1,7) = 16.6, p < .01\), and when S-R mapping was compatible versus incompatible \((9.8\% \text{ vs. } 11.5\%\), \(F(1,7) = 6.1, p < .05\). Similar results were obtained in the auditory modality for the effects of eccentricity \((\text{large vs. small: } 7.1\% \text{ vs. } 13.5\%\), \(F(1,7) = 21.8, p < .01\), and mapping \((\text{compatible vs. incompatible: } 9.0\% \text{ vs. } 11.7\%\), \(F(1,7) = 12.8, p < .01\).

Visual RTs were shorter for large than for small eccentricity \((261 \text{ ms vs. } 299 \text{ ms})\), \(F(1,7) = 93.7, p < .001\), and for compatible than for incompatible S-R mapping \((267 \text{ ms vs. } 292 \text{ ms})\), \(F(1,7) = 35.4, p < .001\). The mapping effect was not modulated by eccentricity, \(F = 2.7, p = .14\). In the auditory modality, the analysis showed additive main effects of eccentricity \((\text{small vs. large: } 263 \text{ ms vs. } 304 \text{ ms})\), \(F(1,7) = 39.8, p < .001\), and mapping \((\text{compatible vs. incompatible: } 260 \text{ ms vs. } 306 \text{ ms})\), \(F(1,7) = 38.8, p < .001\), but no interaction of these factors, \(F < 1\).

An explanation of RT effects in terms of a speed–accuracy trade-off can be excluded because conditions with shortest RTs were also the most accurate \(\text{(cf. Figure 1)}\). Additive effects of eccentricity and mapping on RTs in both modalities suggest that these factors influenced different stages of information processing \(\text{(cf., Sternberg, 1969)}\). This result is in accord with reports of additive effects of perceptual manipulations and SRC \(\text{(e.g., Biederman & Kaplan, 1970; Frowein & Sanders, 1978)}\). The eccentricity effect in both modalities may be interpreted in terms of discriminability rather than early sensory processing. When participants respond as a function of nonspatial stimulus information in the visual modality, RT usually increases with eccentricity because of the decrease of acuity from the central toward the peripheral visual field \(\text{(e.g., Nicoletti & Umiltà, 1989)}\). Because the present eccentricity effect is into the opposite direction, it appears to be located at a perceptual stage subsequent to early sensory processing.

**Electrophysiology**

Figure 2 \(\text{(left panel)}\) shows stimulus-synchronized averaged ERP waveforms from the visual condition. Early visual ERP components appeared most clearly at the Oz electrode, where a small positive deflection at about 150 ms \(\text{(P150)}\) was followed by a negativity around 200 ms \(\text{(N200)}\) and a subsequent positivity at 265 ms \(\text{(P265)}\). Most distinct was a positivity at the Cz and Pz electrode sites peaking between 300 and 400 ms \(\text{(P370)}\). We take this component to reflect the P300 or P3b component because of its scalp distribution, latency, and the apparent effect of perceptual difficulty on its amplitude \(\text{(cf. Johnson, 1988)}\).

Stimulus-synchronized ERP latencies were analyzed by two-way ANOVAs with repeated measures on eccentricity \(\text{(large or small)}\) and mapping \(\text{(compatible vs. incompatible)}\). In the visual modality, occipital P265 peaked earlier for small than for large eccentricity \((259 \text{ ms vs. } 273 \text{ ms})\), \(F(1,7) = 8.3, p < .05\). In contrast, P300 latency \(\text{(cf. Figure 3)}\) was shorter for large than for small eccentricity \((355 \text{ ms vs. } 397 \text{ ms})\), \(F(1,7) = 5.7, p < .05\), and earlier for compatible than for incompatible S-R mapping \((368 \text{ ms vs. } 384 \text{ ms})\), \(F(1,7) = 21.6, p < .01\); the Eccentricity × Mapping interaction was not significant, \(F < 1.3\). The analysis of single trial P300 latencies confirmed the previous results. Visual P300 latency occurred earlier when eccentricity was large \(\text{(large vs. small: } 355 \text{ ms vs. } 389 \text{ ms})\), \(F(1,7) = 36.4, p < .001\). The effect of mapping \(\text{(compatible vs. incompatible: } 366 \text{ ms vs. } 378 \text{ ms})\) re-

![Figure 2](image-url)
mained to be a trend, $F(1,7) = 3.7, p = .10$. The Eccentricity × Mapping interaction was still nonsignificant, $F < 1.5$.

According to these results, visual eccentricity presumably influenced two loci within the flow of information processing. The increase of P265 latency with retinal eccentricity indicates an effect on an early sensory preprocessing stage (cf. Sanders, 1990). The reversed effect of eccentricity in P300 latency agrees with that on RTs and suggests an influence on a stage where perceptual evidence is accumulated (e.g., Kutas et al., 1977; McCarthy & Donchin, 1981). Because of the opposite effects of eccentricity on early and late perceptual stages, visual RTs may slightly underestimate the total effect of eccentricity in the present experiment. Auditory ERPs (Figure 2, right panel) showed N100 and P200 components, followed around 270 ms by a negativity at fronto-central electrode sites (N270), and a subsequent centroparietal P300 component peaking between 300 and 400 ms (P350). In particular, the latency of the P300 component appeared to be affected by eccentricity and mapping.

In the auditory modality a comparable reversal of the eccentricity effect from early to late ERP components was not observed. In this case, only P300 latency was affected by experimental factors. P300 in averaged waveforms peaked earlier when eccentricity was large rather than small (325 ms vs. 350 ms), $F(1,7) = 8.6, p < .05$, and when responses were compatible rather than incompatible (326 ms vs. 351 ms), $F(1,7) = 10.3, p < .05$; eccentricity and mapping did not interact, $F = 1.2$. The analysis of single trial P300 latency confirmed the additive effects of eccentricity (large vs. small: 364 ms vs. 382 ms), $F(1,7) = 7.0, p < .05$, and mapping (compatible vs. incompatible: 362 ms vs. 385 ms), $F(1,7) = 11.9, p < .01$. The Eccentricity × Mapping interaction was again nonsignificant, $F < 1$.

Thus, the eccentricity effect in P300 latency indicates an influence on a supramodal perceptual processing stage. Whereas S-R mapping had no effect on the timing of early ERP components, its effect on P300 latency contradicts previous reports with negative findings (e.g., Fiori et al., 1992; Mulder et al., 1984). Our results indicate that response selection demands affect either the process that generates the P300 component or earlier processes. Previous studies have used either symbolic S-R tasks with variable S-R mappings (e.g., McCarthy & Donchin, 1981) or nonstandard spatial SRC tasks (e.g., Mulder et al., 1984). As to the significance of these findings for the interpretation of P300 latency, two alternative accounts are possible. Either P300 latency is in some cases sensitive to the duration of response selection, which is consistent with the stimulus evaluation interpretation and the weak PTM hypothesis, or spatially incompatible S-R mappings induce changes in perceptual processing time at least under the conditions of the present study.

To test the relationship between P300 latency’s sensitivity for response-related demands and base-level RT, we analyzed the influence of response selection demands on P300 latency for different levels of response speed. Dependent measures were analyzed by Huynh–Feldt corrected repeated measures ANOVAs with the factors eccentricity, compatibility, and RT-bin (fast or medium or slow). Results of this analysis are presented only if either previously reported effects changed or if effects including the factor RT-bin were obtained. For both modalities, we report results of the analysis of single trial P300 latencies. Largely equivalent results yielded from an analysis of P300 peak latencies in averaged ERP waveforms.

As can be seen in Figure 4, in stimulus-synchronized ERP waveforms the P300 component is clearly shifted in peak latency as a function of response speed, and the S-R mapping effect appears to increase with response latency. Statistical analyses confirmed that visual P300 latency increased with response latency, $F(2,14) = 24.3, p < .001, \epsilon = .92$, and this RT-bin effect was stronger for small than for large eccentricity conditions, $F(2,14) = 7.0, p < .05, \epsilon = 1$. However, the Mapping × RT-bin interaction was not significant, $F = 1.9, p = .19$, although there was a numerical tendency for the S-R mapping effect measured as the difference between RTs for incompatible and compatible conditions to increase with RT (fast vs. medium vs. slow: 3 vs. 14 vs. 19 ms). The same pattern of results was obtained for auditory P300 latency, which showed an increase with RT-bin, $F(2,14) = 30.6, p < .001, \epsilon = .66$, and an Eccentricity × RT-bin interaction, $F(2,14) = 6.5, p < .05, \epsilon = .76$. As for the visual modality, the mapping effect in P300 latency was not modulated by response speed (fast vs. medium vs. slow: 16 vs. 28 vs. 27 ms), $F = 0.7$.

The general increase of P300 latency with RT may be explained by a prolonged duration of perceptual processing stages in these trials. More interestingly, there was no significant change of the spatial SRC effect on P300 latency as a function of RT. If anything, there was a numerical trend in the opposite direction, that is, the compatibility effect on P300 latency tended to increase with RT. This result is at variance with the base-level RT hypothesis of P300 latency according to which the influence of the response selection stage on P300 latency should decrease with increasing response latency. Therefore, present analyses do not support the base-level RT hypothesis.

Concerning P300 overlap, in visual and auditory modality the present analysis showed no indication for the presence of two P300 subcomponents on slow RT trials. This result is in contrast with the finding by Falkenstein et al. (1993) that two P300 subcomponents can be differentiated in slow RT trials and even more clearly so in the auditory than in the visual modality. It is conceivable that the discrepancy between the present findings and those of Falkenstein et al. may relate to the particular tasks employed.

In summary, we have shown that spatial SRC may influence P300 latency and that the base-level RT hypothesis is inappropriate to account for the effect of response-related variables on P300 latency. However, before drawing such conclusions from a single experiment, replicating the spatial SRC effect on P300 latency in a second experiment appears to be necessary. Furthermore, a possible

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Figure 3. Mean P300 peak latencies as a function of eccentricity (large vs. small), S-R mapping (compatible vs. incompatible), and modality (visual vs. auditory).
influence of motor processes should be checked to demonstrate that P300 latency is sensitive only to a subset of the information processing stages going on between stimulus input and response output. Finally, the practice session of Experiment 1 could have included a parallel mode of information processing, as suggested by Pfefferbaum et al. (1986). Thus, it is important to show that a spatial SRC effect in visual P300 latency is found also when no practice before the experimental session is provided. Experiment 2 was designed to answer these questions.

EXPERIMENT 2

In Experiment 2, we manipulated stimulus brightness as a perceptual factor to demonstrate that P300 latency is affected by sensory processing demands and to extend the findings of Experiment 1. In RT research, Biederman and Kaplan (1970) reported additive effects of stimulus brightness and spatial SRC. Furthermore, Experiment 2 was designed to test whether P300 latency is influenced by the motoric portion of RT. To influence the duration of motoric processes, we manipulated hand placement. Several studies reported an increase of RT when crossed versus uncrossed hand placement was used. Usually, the hand placement effect is additive with SRC effects and, therefore, is attributed to an increase of motoric processing duration (e.g., Nicoletti, Anzola, Luppino, Rizzolatti, & Umiltà, 1982).

In agreement with this assumption, Ragot (1984) reported P300 latency to be unaffected by hand placement. Verleger (1997) accounted for this negative finding by suggesting that crossing the hands possibly complicates the mechanics of key pressing. In the present experiment we were able to examine this proposal by using force-sensitive keys as suggested by Verleger (1997). We reasoned that if crossing the hands exerted an influence on the peripheral system, the shape of the force curve should be affected, that is, the time from force onset to peak (time to peak, TTP) and the rate of force growth (cf. Ulrich, Rinkenauer, & Miller, 1996). In contrast, if hand placement affects central motor processes, we hypothesized that the onset (RT) but not the shape of the force impulse should be influenced. Taken together, we expected RT to reveal additive effects of stimulus brightness, spatial SRC, and hand placement given that these factors selectively influence perceptual, response selection, and central motor stages. In contrast, P300 latency should be influenced by stimulus brightness only if the strong PTM hypothesis is valid.

Method

Participants

Eight right-handed students (aged 27–36 years; \( M = 30.5 \) years) with a mean handedness score of +93 (range = +73 to +100) in the Edinburgh Inventory for Handedness (Oldfield, 1971) participated. All participants reported normal hearing and had normal or corrected-to-normal vision.

Apparatus and Stimuli

The square and diamond stimuli of Experiment 1 were used. Luminance of the dim and bright stimulus was 1.2 and 3.0 cd/m², respectively. All stimuli were presented 1° to the left or right of the fixation point.

Responses were measured by means of force-sensitive keys. A leaf spring (55 × 20 × 2 mm) was held by an adjustable clamp at one end, and the other end remained free. Strain gauges were attached near the fixed end of the leaf spring. Force keys were mounted on a horizontal response panel and were located in front of the participant 10 cm to the left and right of the body midline. Response force was recorded at 100 Hz without filtering for 1,270 ms starting 270 ms before stimulus onset. A response was registered as soon as force output exceeded a criterion of 60 cN (about 60 g) from the baseline force level. Baseline force was defined as the mean force level during a 100-ms interval before stimulus presentation.

Procedure

Participants were given written instructions. As in Experiment 1 the participant’s task was to make choice responses as a function of stimulus location. In the compatible S-R mapping condition, participants had to respond with the left key to stimuli on the left side and with the right key to stimuli on the right side; in the incompatible condition, the S-R mapping was reversed. Instructions always referred to the mapping of stimulus locations to response keys but not to the particular hands operating the keys. That
is, instructions about the S-R mapping did not change with hand placement conditions.

**Design**
Spatial S-R mapping (compatible vs. incompatible) and hand placement (uncrossed vs. crossed) changed between blocks. The ordering of these conditions was balanced via a Latin square. For the crossed hand placement condition, four participants had the left arm over the right arm and four had the opposite arm arrangement.

**Electrophysiological Recording and Data Analysis**
EEG and EOG recordings were the same as in Experiment 1 except that the EEG was recorded from Fz, Cz, Pz, O1, and O2. Furthermore, only trials that fulfilled the criteria of Experiment 1 for RT, EEG, and EOG were included in the analysis. Dependent variables were subjected to repeated measures ANOVAs using conservative F tests (Huynh & Feldt, 1976).

The latencies of early visual ERP components (P130, N180) were measured in average waveforms at the O2 electrode between 100 and 300 ms with a peak-picking procedure as in Experiment 1. P300 latency was determined both in average and single trial waveforms as described in the Data Analysis section of Experiment 1.

For each force pulse we determined the following measures within each trial (cf. Ulrich et al., 1996). Force onset (RT) was taken when force output exceeded a criterion of 60 cN and peak force (PF) when the force pulse reached its maximum. In addition, we determined the time from onset to peak force (TTP) and the force impulse (PF/TTP) as shape parameters of the force curve.

**Results and Discussion**

**Performance**
Error rates, RTs, peak force latency, and amplitude were analyzed by a four-way ANOVA with repeated measures on the factors brightness (bright or dim), mapping (compatible or incompatible), placement (uncrossed or crossed), and hand (left or right). Mean RTs and mean error rates are depicted in Figure 5.

Fewer errors occurred for right- than for left-hand responses (4.1% vs. 5.3%). For bright than for dim stimuli (2.2% vs. 7.2%), \(_{F(1,7)} = 22.6, p < .01\), and when hands were uncrossed rather than crossed (3.6% vs. 5.8%), \(_{F(1,7)} = 23.6, p < .01\). The effect of S-R mapping approached significance (3.9% vs. 5.5%), \(_{F(1,7)} = 4.8, p = .066\).

RTs were faster for bright than for dim stimuli (355 vs. 407 ms), \(_{F(1,7)} = 170.2, p < .001\). Mapping produced a similarly strong main effect, \(_{F(1,7)} = 26.3, p < .01\). RTs were faster for compatible than for incompatible S-R mapping (358 vs. 403 ms). Furthermore, a main effect of placement, \(_{F(1,7)} = 23.4, p < .01\), indicated faster RTs for uncrossed than for crossed hand conditions (357 vs. 404 ms). The hand factor approached significance, \(_{F(1,7)} = 5.4, p = .053\). Right-hand responses were faster than left-hand responses (376 vs. 385 ms). All these effects appeared to be additive because no interaction reached significance, \(F < 1, ps > .18\).

As in Experiment 1, an explanation of RT effects in terms of a speed–accuracy trade-off can be excluded (cf. Figure 5). The RT results are in accord with other reports of additive effects of spatial SRC with stimulus brightness (e.g., Biederman & Kaplan, 1970) and hand placement (e.g., Nicoletti et al., 1982; Simon, Hinrichs, & Craft, 1970). Present results extend the previous ones, however, in that we found additivity when brightness, spatial SRC, and hand placement were manipulated orthogonally within a single experiment. This additive RT pattern suggests that the experimental manipulation of stimulus brightness, S-R mapping, and hand placement selectively influenced perceptual, response selection, and motor stages, respectively.

As can be seen in Figure 6, the force pulse peaked (485 ms) about 100 ms after force onset. Neither TTP nor the force impulse were influenced by the experimental variables, \(F < 1\), with the exception that TTP was shorter (99 vs. 108 ms) and the rate of force production was higher for right- than for left-hand responses (9.3 vs. 8.3 cN/ms), \(_{F(1,7)} = 7.4, p < .05\) and \(_{F(1,7)} = 7.4, p < .05\), respectively. Peak force was higher for bright than for dim stimuli (906 vs. 888 cN), \(_{F(1,7)} = 17.7, p < .01\). The apparent difference in peak force as a function of hand placement (cf. Figure 6) was not significant, \(F < 1\).

**Figure 5.** Mean reaction times and error rates (E) as a function of stimulus brightness (bright vs. dim), S-R mapping (compatible vs. incompatible), and hand placement (uncrossed vs. crossed).

**Figure 6.** Stimulus-synchronized grand mean waveshapes of the force curves superimposed for hand placement (uncrossed vs. crossed).
The analysis of response force revealed a TTP of about 100 ms, thereby replicating previous results (Ulrich & Mattes, 1996) and indicating that the rate of force production in the current experiment attained its minimal value (Freund & Büdingen, 1978). That is, responses were very rapid. In contrast to force onset latency, that is, RT, shape parameters of the response curve were not influenced by hand placement. These results agree with the assumption that hand placement influences central motoric processing stages but not the peripheral mechanics of responding as was proposed by Verleger (in press) to account for the absence of a P300 latency effect of hand placement.²

Electrophysiology
Because of a technical problem, recordings of the O1 electrode were distorted and could not be analyzed. For the remaining electrodes, components of the visual evoked potential were most clear at the O2 electrode, where a positive deflection at about 130 ms (P130) was followed by an N180. The P300 was most distinct at the Pz electrode site (Figure 7).

Stimulus-synchronized ERP latencies were analyzed by a four-way ANOVA with repeated measures on the factors brightness (bright or dim), mapping (compatible or incompatible), placement (uncrossed or crossed), and hand (left or right). P130 peaked earlier for bright than for dim stimuli (117 ms vs. 133 ms), $F(1,7) = 49.4, p < .001$. The effect of stimulus brightness on N180 latency (167 ms vs. 176 ms) did not reach significance, $F(1,7) = 2.2, p = .18$. P130 and N180 latencies were not influenced by other experimental factors, $F_{s} < 1.9, ps > .21$. The effect on P130 latency is consistent with the assumption that stimulus brightness affects relatively early perceptual processes (Sanders, 1990).

Experimental effects on P300 latency are depicted in Figure 8. P300 peaked earlier for bright than for dim stimuli (348 ms vs. 420 ms), $F(1,7) = 49.4, p < .001$. Furthermore, S-R mapping produced a significant main effect, $F(1,7) = 16.5, p < .01$, with shorter latencies for compatible than for incompatible conditions (369 vs. 400 ms). Hand placement (uncrossed vs. crossed: 383 vs. 385 ms) had no significant effect, $F < 1$. Interactions between the experimental factors did not reach significance, $F_{s} < 3.2, ps > .12$.

The analysis of single trial P300 latency confirmed the additive effects of intensity (bright vs. dim: 400 ms vs. 442 ms), $F(1,7) = 67.7, p < .001$, and mapping (compatible vs. incompatible: 406 ms vs. 437 ms), $F(1,7) = 26.5, p < .01$. In addition, there was a hand placement effect (uncrossed vs. crossed: 412 ms vs. 430 ms), $F(1,7) = 12.3, p < .05$. No interactions were significant, $F < 1$.

A first conclusion to be drawn from the present results concerns the finding that P300 latency was affected by the manipulation of stimulus brightness. This result is in agreement with the strong PTM hypothesis and with results reported by other studies (e.g., Smulders, Kok, Kenemans, & Bashore, 1995). A perceptual locus of the stimulus brightness effect is also indicated by the influence on P130 latency.

Second, there was a spatial SRC effect on P300 latency measured in averaged and single trial waveforms, thus replicating the finding of Experiment 1. This replication demonstrates that P300 latency is affected by spatial SRC when a standard two-choice RT task is used. Furthermore, unlike in Experiment 1, participants in Experiment 2 started the experiment without prior practice. Therefore, keeping the S-R mapping consistent within a block of trials seems to be sufficient to produce a spatial SRC effect in P300 latency. Importantly, the present finding again disagrees with the strong PTM hypothesis of P300 latency.

Finally, as in the study of Ragot (1984), P300 latency measured in averaged ERP waveforms was not influenced by hand placement. This result indicates that P300 latency is uninfluenced by motoric processing demands. However, this inference is not supported by the analysis of single trial P300 latency, which revealed a significant hand placement effect of about 16 ms. This inconsistency in results may be accounted for by assuming that single trial latency measures were more sensitive to the influence of hand placement on information processing than average ERP waveforms. For example, a delay of P300 because of prolonged motoric processing might have occurred only on a portion of trials and, therefore, may have remained concealed in average ERP waveforms.

Figure 7. Stimulus-synchronized grand mean waveshapes of the vertical electrooculogram (vEOG) and of the event-related brain potential at electrode sites Fz, Cz, Pz, and O2 superimposed for (bright vs. dim), S-R mapping (compatible vs. incompatible). Left panel: uncrossed hand placement. Right panel: crossed hand placement.

² A finding worth mentioning is the influence of task-irrelevant stimulus brightness on peak force. This result is interesting because most previous studies have reported intensity effects on peak force in the auditory modality (cf. Miller, Franz, & Ulrich, 1996). Recently, Ulrich and Mattes (1996) suggested an SRC hypothesis to account for the intensity effect of visual warning signals on response force in a simple RT task because the use of weak stimulus intensities excluded an arousing effect on the motor system. Accordingly, there is a tendency to assimilate the output to the input similar to other domains of SRC as described in the introduction. The present study lends further support to the SRC hypothesis of force coding proposed by Ulrich and Mattes (1996; see also Romaiguère, Hasbroucq, Possamaï, & Seal, 1993) and extends its validity to a choice RT situation.
forms (cf. Verleger & Wascher, 1995). Thus, on the basis of present results, it is difficult to determine whether or not P300 latency is sensitive to motoric processing demands.

**GENERAL DISCUSSION**

The main conclusion of the present article concerns the issue of whether P300 latency is exclusively sensitive to perceptual variables as postulated by the strong PTM hypothesis. The present experiments clearly provide strong additional evidence that the P300 latency is sensitive to the duration of perceptual processing. This result is in agreement with the strong PTM hypothesis of P300 latency. However, in two experiments we found P300 latency to be affected also by response selection demands in a standard two-choice spatial SRC task. This result clearly contradicts the strong PTM hypothesis of P300 latency. Hence, present findings extend previous reports about effects of symbolic SRC on P300 latency when consistent S-R mappings are used (e.g., Pfefferbaum et al., 1986; Smulders, 1993) to the spatial domain. As a consequence, it is not unambiguously possible to discriminate between perceptual and postperceptual loci of experimental effects on the basis of P300 latency. Thus, only a weak version of the PTM hypothesis of P300 latency seems to be valid.

In comparing the size of the experimental effects on RT with those obtained for P300 latency, inferring that P300 latency and RT are influenced differently by response selection demands is tempting. Thus, perceptual effects on P300 latency were similar or even larger in magnitude than those on RT, whereas in both experiments spatial SRC effects appeared to be smaller in P300 latency than on RT. However, such a comparison of effect magnitudes across measures is problematic. On the one hand, P300 latency obtained in average ERP waveforms may be a biased measure for the true effect (Callaway et al., 1984), whereas single trial P300 latency measures may be less reliable due to a low signal-to-noise ratio (cf. Verleger, 1997). On the other hand, stronger effects on RT than P300 peak latency may be because P300 latency does not reflect the termination but some earlier time point of processing within the response selection stage suppressing that SRC influences the rate of evidence accumulation within this stage (cf. Meyer, Osman, Irwin, & Yantis, 1988). Therefore, we prefer to refrain from drawing further conclusions concerning the size of experimental effects on RT and P300 latency.

Despite the problems with the strong PTM hypothesis, P300 latency may still be used to distinguish between premotor and motor effects on RT. Thus, P300 latency obtained in average ERP waveforms was not affected by motoric processes, thus replicating the results of Ragot (1984). Because Smulders et al. (1995) showed that P300 latency measured in average ERP waveforms is not influenced when motor stages are manipulated via response complexity, there is evidence for the assumption that P300 latency measured in average ERP waveforms taps only premotor processing demands. However, there is still some uncertainty concerning those postperceptual processes to which P300 latency is sensitive because in the present Experiment 2 single trial analysis revealed an influence of motoric processing demands.

Our second research interest was concerned with possible mechanisms underlying P300 latency’s sensitivity to response-related demands. Falkenstein et al. (1993, 1994) proposed that, in choice RT situations, two P300 subcomponents are elicited, a frontocentral P-SR and a centroparietal P-CR being sensitive to perceptual and response selection demands, respectively. In agreement with this assumption, a spatial SRC effect was observed on the latency of the present centroparietal P300 component that may correspond to the P-CR findings by Falkenstein et al. However, the assumption of a separate P-SR subcomponent was not supported in the present data sets because only one centroparietal P300 component appeared in the analysis of response latency-classified ERP waveforms in Experiment 1. This was the case even for slow RT trials in which P-SR is assumed to overlap less with P-CR; therefore, separate P-SR and P-CR subcomponents should become more clearly visible (Falkenstein et al., 1993). It is conceivable that the presence of a P-SR depends on the particular task demands. For example, the presently used stimulus-to-location choice RT task might have been less demanding than the letter identification task used by Falkenstein et al. (1993, 1994) in which visual and auditory stimuli had to be attended to simultaneously within a block of trials.

We also examined the base-level RT hypothesis of P300 latency according to which the influence of the response selection stage on P300 latency decreases with increasing RT. In Experiment 1 the spatial SRC effect on P300 latency did not decrease with increases in RT as revealed by the analysis of response speed classified trials. Furthermore, the observation that in the visual modality the spatial SRC effect on P300 latency was weaker in Experiment 1 than in Experiment 2 (16 vs. 31 ms), although RTs were faster by about 100 ms, does not fit into the base-level RT account. The reduced spatial SRC effect may be explained by the extended practice participants received in Experiment 1 that also produced an apparently smaller effect on RT (25 vs. 45 ms). Therefore, further studies are needed to delineate the validity and the limits of the base-level RT hypothesis.

In contrast to the more general accounts of Falkenstein et al. (1993, 1994) and Verleger (1997) of postperceptual effects on P300 latency, we suggest a more specific explanation. Our suggestion is based on the influential dimensional overlap model of SRC by Kornblum, Hasbroucq, and Osman (1990). According to this model, stimulus location automatically primes a spatially corresponding response in parallel to the response selection process. The outcome of these two processes is compared in a separate verification stage. In case of incompatible S-R mappings, there is
a mismatch between the incorrectly primed response and the selected correct response. As a result, the primed response is aborted and a new response program is retrieved from memory before the correct response can be executed. The assumption of parallel response priming and response selection receives support from electrophysiological studies measuring the lateralized readiness potential (LRP) (e.g., De Jong, Liang, & Lauber, 1994; Leuthold, 1994; Zeef & Kok, 1993) as an index of specific response preparation (cf. Coles, 1989). In these studies, the LRP revealed the presence of two temporally separated response activation components, that is, early and late response activation. Early response activation appeared to be triggered automatically by stimulus location. In particular, the finding of an early incorrect LRP activity when stimulus and response locations did not correspond even when overt responses were correct indicated the priming of a spatially corresponding response. In the context of this framework, we suggest that P300 latency is delayed when an automatically primed response conflicts with a response selected via a controlled route.

As to the possible mechanisms underlying the modulation of P300 latency by response conflicts, we suggest that this modulation relates to the requirement of either additional response monitoring or response program retrieval. According to the first proposal, P300 latency is sensitive to changes in the duration of an ancillary cognitive monitoring process not directly involved in the S-R pathway. This assumption is consistent with the suggestion that P300 is invoked in the revision of a mental schema or plan (cf. Donchin & Coles, 1988). Thus, the monitoring process may be sensitive to plan violations, that is, it might be prolonged if task-relevant S-R associations as defined by the instructions and information about currently activated responses are in conflict. Accordingly, a delay of P300 latency in case of response mismatch indicates the working of a cognitive monitoring process evaluating the automatically activated response with the selected responses as implied by the dimensional overlap model (Kornblum et al., 1990).

Alternatively, P300 latency might be sensitive to the response program retrieval process after the abortion of an incorrectly activated response as postulated by the dimensional overlap model. Accordingly, P300 latency indicates the duration of short-term memory processes concerned with the retrieval of an appropriate response program. It is a well-established finding in the Sternberg task that P300 latency is influenced by memory set size, indicating the duration of short-term memory search (cf. Verleger, 1997). Although the set-size effect on P300 latency seems to be stimulus-related (e.g., Ford, Roth, Mohs, Hopkins, & Kopell, 1979; Strayer, Wickens, & Braune, 1987), to our knowledge, no studies have examined the influence of response-related memory search demands on P300 latency. Therefore, examining the motor program retrieval account in further SRC situations known to induce response conflicts may be worthwhile.

According to both the response monitoring and the response program retrieval hypotheses, a response conflict may underlie the observed SRC effect on P300 latency. The response conflict account of P300 latency is consistent with most experimental findings in the literature. First, P300 latency is delayed in the Simon tasks in conditions in which the LRP reveals an initial incorrect response activation, that is, when irrelevant stimulus location and response location do not correspond (e.g., De Jong et al., 1994; Sommer et al., 1993). Second, response conflict may account for the presence of a symbolic S-R compatibility effect on P300 latency if symbolic S-R mapping is consistent across a block of trials (e.g., Pfefferbaum et al., 1986; Smulders, 1993). Consistent S-R mapping may induce an automatic response priming effect and thus response conflict. Although proposed post hoc, this suggestion can be tested by recording the LRP in a symbolic SRC situation to assess automatic response activation. Third, in the Eriksen paradigm P300 latency is influenced by the so-called flanker effect that is taken to depend, at least in part, on a response conflict (e.g., Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Smid, Mulder, & Mulder, 1990). That is, P300 latency is delayed when irrelevant flanker stimuli prime a response different from that required to the central target stimulus versus when the same response is primed (e.g., Coles et al., 1985; Smid et al., 1990).

In accounting for existing experimental findings in P300 latency, there appears to be one major problem for the response conflict account, that is, the absence of a P300 latency effect in the Stroop paradigm (Duncan-Johnson & Kopell, 1981). Because the Stroop effect is usually attributed to response-related mechanisms (cf. MacLeod, 1991), the absence of a P300 latency effect in the Stroop paradigm is inconsistent with the response conflict explanation, whereas the absence is consistent with the strong PTM hypothesis. However, as long as the mechanisms underlying the Stroop effect itself are not fully understood, it is difficult to speculate about the reasons for this apparent inconsistency.

The present study has demonstrated that P300 latency is influenced by perceptual demands and by response selection demands as manipulated by spatial SRC. The latter result is at variance with the strong PTM hypothesis according to which P300 latency indicates perceptual processing time only. However, P300 latency may be used to distinguish between experimental effects on the premotoric and the motoric portion of RT, although further evidence is needed to rule out the possibility that P300 latency is sensitive to motoric processing demands. We suggest that a response conflict may account for most but not all cases when response-related variables affect P300 latency.

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