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The Effects of Temporal Preparation on Reaction Time

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by

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Abstract

When responding to external stimuli, preparation reduces Reaction Time (RT). One form of preparation known as temporal preparation results from advance knowledge about when a stimulus will appear. We used Event Related Potentials to investigate how increasing temporal preparation decreases RT during a speeded, choice RT task by manipulating temporal preparation within subjects. In order to determine which cognitive processes are speeded, the latencies of the Lateralized Readiness Potential (LRP) and P300 were examined across two levels of temporal preparation. In line with previous research the stimulus locked LRP, but not the response locked LRP, was speeded when temporal preparation was high. Using Principal Component Analysis, we also found that the P300 latency was reduced by nearly the same extent as RT was reduced. These findings suggest that temporal preparation speeds stimulus evaluation processing specifically, and this explains to a large extent how temporal preparation reduces RT.

Introduction

When responding to external stimuli, preparation leads to faster responses. Preparation can result from advance knowledge about *what stimulus will occur, where the stimulus will be presented,* or *when the stimulus will appear.* Also advance information can allow the participant to know in advance which would be the appropriate response. The effects of preparation on reaction time (RT) are robust, and the relationship between preparation and Reaction Time (RT) has been much studied (For reviews see: Coull & Nobre, 1998; Requin, Brener, & Ring, 1991; Posner, 1980). Preparation can be defined as "the process by which organisms are readied for perceiving future events and reacting to them" (Requin, et al., 1991). The most common paradigm in the literature used to study preparation employs warning stimuli in a choice-RT paradigm. Subjects are required to respond differentially, using either hand, to a specific imperative stimulus (IS). Prior to the IS a warning stimulus (WS) provides information about the upcoming IS. As with the types of preparation listed above, the WS can provide information about *what* the IS will be, *where* the IS will be presented, or *when* the IS will appear. As the degree to which the WS gives useful information increases, useful preparation may increase. For example, imagine an experiment in which the IS is either the letter 'L' or the letter 'R' presented visually, and the subject must respond with his left hand to the 'L' and with his right hand to 'R'. If the WS predicts which letter the IS will be on this particular trial, it allows preparation for *what* the IS will be. If the WS predicts the spatial location of the IS, it allows preparation for *where* the IS will be. Lastly, if the WS predicts the point in time at which the IS will be presented, it allows preparation for *when* then IS will be. Note that in the latter two cases, no information is given about which hand to prepare, but in all cases, to varying degrees, RT will decrease as preparation increases. The fundamental question being explored in this study is *how* does preparation decrease reaction time. Many processes occur from the time of stimulus onset to the execution of a response, as well as during the time leading up to an anticipated stimulus or response. These processes can be part of sensation, perception, decision-making, response selection, motor processing, or motor execution. Which subsets of these processes are speeded by preparation? The loci of the effect of preparation appear to differ depending on the type of preparation, but there is no consensus as to how knowing *when* an event will occur, or temporal preparation, results in decreased reaction time. Some view the effect as a result of more efficient perceptual processing, some as a result of speeded motor processing, and some as a combination of both (for reviews see Correa, Lupianez, Madrid, & Tudela 2006; Hackley & Valle-Inclán, 2003).

One way researchers explore this effect is through the use of Event Related Potentials (ERPs). ERPs display brain activity that is evoked by specific events. These events can be external, such as a flash of light, or internal, such as the recognition of semantic deviance. While the ERPs are small relative to the ongoing EEG, when they are time locked to the eliciting event they can be revealed by the use of signal-averaging. ERPs reveal distinct voltage deflections that are reliably elicited after a given event, and these deflections are called “components” of the ERP. Many components of the ERP are known to result from neural processing uniquely related to sensation, perception, motor processing, etc. The latency, amplitude, and morphology of a given component can vary depending on manipulated conditions, representing changes in the underlying processing. ERP components can thus be used as a dependent measures to assess the effects of manipulated variables, such as temporal preparation.

The Lateralized Readiness Potential (LRP) is a component of the ERP that indexes specific motor preparation. In 1965 Kornhuber and Deecke discovered a ramp-like negativity, the Readiness Potential (RP), which leads up to a voluntary motor response (Kornhuber & Deecke, 1965). Kutas and Donchin (1974) then showed that the RP is lateralized – the RP is larger over the hemisphere contralateral to the responding hand. There is substantial evidence to indicate that the RP is produced in the motor cortex (Brunia, 1988), and that the lateralization of the RP is due to the functionally contralateral lateralization of the motor cortex (Eimer, 1998). The lateralization of the RP (i.e. the LRP), therefore indexes specific motor preparation, that is, preparation for the responding of a specific hand, and when the lateralization reaches a certain threshold the response is generated (Kutas & Donchin, 1980). Further, Kutas and Donchin (1980) have shown that the onset of the lateralization of the RP depends on the time at which the choice between the hands is indicated. Therefore, the time between the onset of the LRP and the actual response represents processing *subsequent to the* initial choice of the responding hand. The latency of the LRP can thus be used as a dependent measure when examining the effects of temporal preparation. Analyzing and interpreting the effects though must be done with caution as the different processes, including decision making, that take place before each response do not occur in a strictly serial manner. According to the continuous flow model (Eriksen & Schultz, 1979), different streams of information processing can proceed in parallel, and information can flow continuously between them. In fact, Coles et al. (1985) showed that information flows continuously between parallel evaluation and response systems. Further, Gehring et al. (1992) showed that not only is there continuous flow, but subjects often make initial, possibly unconscious, decisions about which response to prepare prior to obtaining any information about the event. However, recent work using the LRP to examine temporal preparation (for review see Hackley, 2009) seems to assume a serial model of information processing. When assuming a serial model, the decision (i.e. the LRP onset) is seen as necessarily representing processing *after* sensation, evaluation, and categorization of the stimulus. Using this logic the onset of the LRP has been used to dissect the S-R interval into two orthogonal parts. One part represents processes related to sensation, evaluation, and decision, and the other represents post decision, largely motor related activity. Changes in the length of these two segments (i.e. changes in the onset of stimulus-locked and response-locked LRP) are then assessed in order to narrow in on the locus of the temporal preparation effect. This approach though is not consistent with the continuous flow model, and interpretation of results obtained using this approach can therefore be misleading. First, the use of the LRP as tool for a clean dissection of the S-R interval is called into question, as its onset does not necessarily mark the end of processes such as stimulus evaluation. Second, averaging the LRP over all trials within conditions of varying temporal preparation might actually hide important differences in LRP onset and morphology. If subjects do lateralize prior to any information about the stimulus, *on average* that lateralization should occur in each direction an equal number of trials. So, when averaging over all trials, the onset of the LRP won't be visible until much later than the LRP onset for each individual trial. Interpretation of changes in the average LRP onset is therefore limited. Theoretically, temporal preparation could interact with pre-stimulus lateralization affecting RT in different ways. Imagine three different types of pre-stimulus lateralization: lateralization consistent with the upcoming stimulus information, lateralization inconsistent with the upcoming stimulus information, or no lateralization. With the occurrence of the stimulus the LRP will switch direction, continue in the same direction, or start from baseline. It is possible, for example, that preparation might only affect the switching of lateralization, while there is no effect on consistent lateralization. It is therefore important to group trials based on pre-IS lateralization and *then* examine the effects of temporal preparation on RT and the onset of the LRP. In the current study, the LRP was not only examined as a dependent measure, but pre-IS lateralization was used to group trials in order to examine the possibly interacting effects of temporal preparation and pre-stimulus lateralization on RT.

Another ERP component used as a dependent variable to investigate temporal preparation is the P300 (Sutton, Braren, Zubin, & John, 1965). The P300 is a positive deflection, with a primarily parietal scalp distribution, peaking 300 to 700ms after stimulus onset, generally elicited by events that violate the subject's expectancies. It results from processing involved in the updating of an environmental model. When an event is perceived to deviate from the current model of the context, the model must be updated, and the P300 will manifest. The latency of the P300 depends on the time it takes to categorize an event, such that faster evaluation results in shorter latency (Donchin 1981). Many studies have shown that the latency of the P300 decreases as preparation increases. However, this finding has generally been overlooked because it is purported that the P300 onset overlaps with the offset of the Contingent Negative Variation (CNV;

Walter, Cooper, Aldridge, McCAllum, & Winter, 1964) (e.g. Hackley, Schankin, Wohlschlaeger, & Wascher 2007). The CNV is a general negativity that develops prior to an expected stimulus, and its morphology differs across conditions in typical temporal preparation studies. It is thus claimed that, due to the overlap, differences in P300 latency between conditions can't be trusted. This argument, however, is unconvincing on two levels. Not only should amplitude differences prior to the P300 not affect the measurement of peak *latency*, but also the problem of overlapping components can be controlled for, using Principal Component Analysis (PCA; Spencer, Dien & Donchin, 1999). In fact, Donchin, Tueting, Ritter, Kutas, & Heffley (1975) have shown that PCA can be used to assess the P300 component independent of differences in CNV. However, to date no one has used PCA to separate overlapping components within the temporal preparation paradigm. The latency of the P300 can be a useful tool to asses the effect of temporal preparation, because the P300 latency is sensitive to stimulus evaluation processing, and insensitive to response selection and motor execution (McCarthy & Donchin, 1981). Therefore, if P300 latency varies across conditions (i.e. decreases as preparation increases), it can be said that temporal preparation affects stimulus evaluation processes specifically. Further, the degree to which P300 latency and RT co-vary can shed light on the relative contribution of speeded stimulus evaluation to the RT effect.

The primary goal of the present study was to investigate how reduced uncertainty about the timing of an event optimizes responding to that event, using the LRP and P300 as tools within a temporal preparation paradigm. The first objective was to replicate the most recent literature by examining changes in the onset latencies of the stimulus locked LRP (S-LRP) and response locked LRP (R-LRP). Two prior studies have examined both the S-LRP and R-LRP while manipulating temporal preparation, and both found reduced S-LRP latency as temporal preparation increased and no effect on the R-LRP (Muller-Gethman, Ulrich, & Rinkenauer, 2003; Hackley et al., 2007). Replication of this pattern would suggest that early processes related to sensation, perception or early motor processing may be affected by temporal preparation and that late motor processing and motor execution are not. However, because processing does not necessarily occur in a serial manner these results can only be interpreted tentatively. The second objective was to examine the latency of the P300 using, for the first time within the temporal preparation paradigm, spatial PCA to disentangle overlapping components. A change in P300 latency across conditions would suggest that temporal preparation affects stimulus evaluation processes per se. If the P300 latency is not affected then stimulus evaluation is not effected by temporal preparation. The third objective was to examine the behavioral and ERP effects as a function of pre-stimulus lateralization. When pre-stimulus lateralization is consistent with stimulus information – that is, the correct motor response is being activated early- lateralization should reach the response threshold more quickly and RT should thus be reduced. When pre-stimulus lateralization is inconsistent with stimulus information, a reversal of lateralization is required before an accurate response and RT should thus be increased. Therefore both temporal preparation and pre-stimulus lateralization were expected to affect RT and potentially interact. The final objective was to discuss the relative efficacies of the LRP and P300 as tools for investigating temporal preparation and similar phenomena.

Method

Participants

Seventeen healthy undergraduate students from the University of South Florida participated in the study and obtained class credit through SONA for participation. A total of five participants were excluded from analysis: two due to equipment failure, two due to incompliance with instructions, and one due to excessive artifacts in the ERP data. Thus, twelve participants were used in the current analysis.

Task

In a choice RT task participants responded to a visual imperative stimulus (IS) using left and right hand key presses. Prior to the IS, a warning stimulus (WS) indicated that the IS would occur after a fixed time interval. The key manipulation was the difference in length of that interval, or stimulus onset asynchrony (SOA), across blocks, yielding short and long SOA conditions. Two experimental blocks with 90 trials each had a fixed, short SOA (600ms) while three experimental blocks with 60 trials each had a fixed, long SOA (3000ms). The ability to estimate time decreases as the time interval increases. Therefore, the ability to estimate the timing of IS onset in the long SOA blocks is poor relative the short SOA blocks. Thus, temporal preparation is higher in the short SOA condition (Requin, Brener, & Ring, 1991).

Each trial began with a fixation-cross presented in the center of the screen for a randomly varying interval between 2200 and 2800ms. At the end of the interval a WS, the letter "O", replaced the fixation-cross for 200ms signaling the upcoming IS. The IS consisted of a 2x3 matrix of characters (see figure 1) presented in the center of the screen. One of the two characters in the middle column of the matrix always contained the target character, either an "A" or "B" which varied randomly between trials. The rest of the characters were letters from the alphabet, chosen randomly on each trial, serving as distractors. These distractors were added to increase the difficulty of the task and in turn reduce the likelihood of floor effects for RT. The participant was required to respond differentially based on the whether the target was an "A" or a "B". The target character location varied randomly between the top and bottom row, and the location had no implications for the necessary response. The participants were instructed to respond as quickly as possible while maintaining reasonable accuracy. The trial ended with visual feedback in the form of the word "correct", "incorrect", or "too slow" depending on whether or not the subject responded with the correct hand within 550ms after IS onset. Feedback remained visible for 250ms and the next trial started immediately after. See figure 1 for a visual representation of the trial events.

In addition to the five experimental blocks, four control blocks, two for each SOA type, with 32 trials each were presented. The control blocks were identical to the experimental blocks except that instead of an "O", the WS was either an "A" or "B" which predicted with the IS target with 80% accuracy. Trials from the control block were not used in the analysis.

EEG Recording and Analysis

EEG was recorded with a 128-electrode Electrical Geodesics system (EGI, Eugene, OR) at the University of South Florida. The EEG data was digitized at a sampling rate of 250Hz and referenced to the central electrode (Cz) during recording.

Offline, the EEG data were processed separately for P300 and LRP analyses, because the analyses require different filtering settings. For the P300 analysis the EEG data were low-pass filtered at 20Hz and segmented at 200ms prior to, and 800ms after, the IS. For the LRP analysis the EEG data were low-pass filtered at 4Hz. For obtaining the S-LRP, long SOA trials were segmented at 3500ms prior to, and 800ms after, the IS; short SOA trials were segmented at 1100ms prior to, and 800ms after, the IS. For the R-LRP, long SOA trials were segmented at 2950ms before, and 800 after, the response; short SOA trials were segmented at 550ms before, and 800 after, the response. For all data, trials were baseline corrected, eye blink artifacts were removed using independent component analysis, bad segments were excluded, and the data was mathematically re-referenced to linked mastoids. Offline analysis was done using Netstation (EGI) software and MATLAB, including Joe Dien's EP toolkit (Dien, 2010).

All statistical tests, unless otherwise stated, were conducted using 2x3, SOA by pre-IS lateralization, repeated measures ANOVAs.

Pre-Stimulus Response Preparation

In order to analyze the behavioral, S-LRP, R-LRP, and P300 data as a function of both SOA and pre-stimulus lateralization, trials were first sorted based on pre-IS lateralization into one of three categories: "consistent", "inconsistent", and "neutral" in relation to the required response. The sorting procedure followed the method used in Gratton, Coles, Sirevaag, Eriksen, & Donchin (1988). At each time point during a trial the voltage at C3 was subtracted from C4 for trials requiring right-hand responses, and vise versa for left-handed trials. Next, the average amplitude over the 100ms preceding the IS was computed on the difference waveform for each trial. Then, the average amplitudes of the trials were converted into Z scores for each subject separately. Finally, trials with a Z score below -0.5 were labeled as "consistent", trials with a Z score above 0.5 were labeled as "inconsistent", and trials in between these bounds were labeled as "neutral". Recall that the LRP is negative over the hemisphere contralateral to the responding hand, so negative values prior to the IS onset may represent lateralization that is consistent with the upcoming stimulus information, while positivity in this time window may represent inconsistent lateralization (Gratton et al., 1988). Trials were then averaged for each subject and each category separately. The grand average pre-IS LRPs for each category are shown in figure 2.

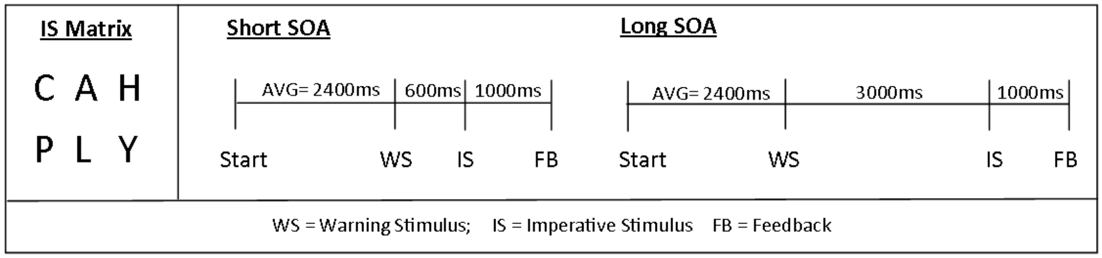

Figure 1. Imperative Stimulus Matrix and Trial Events.

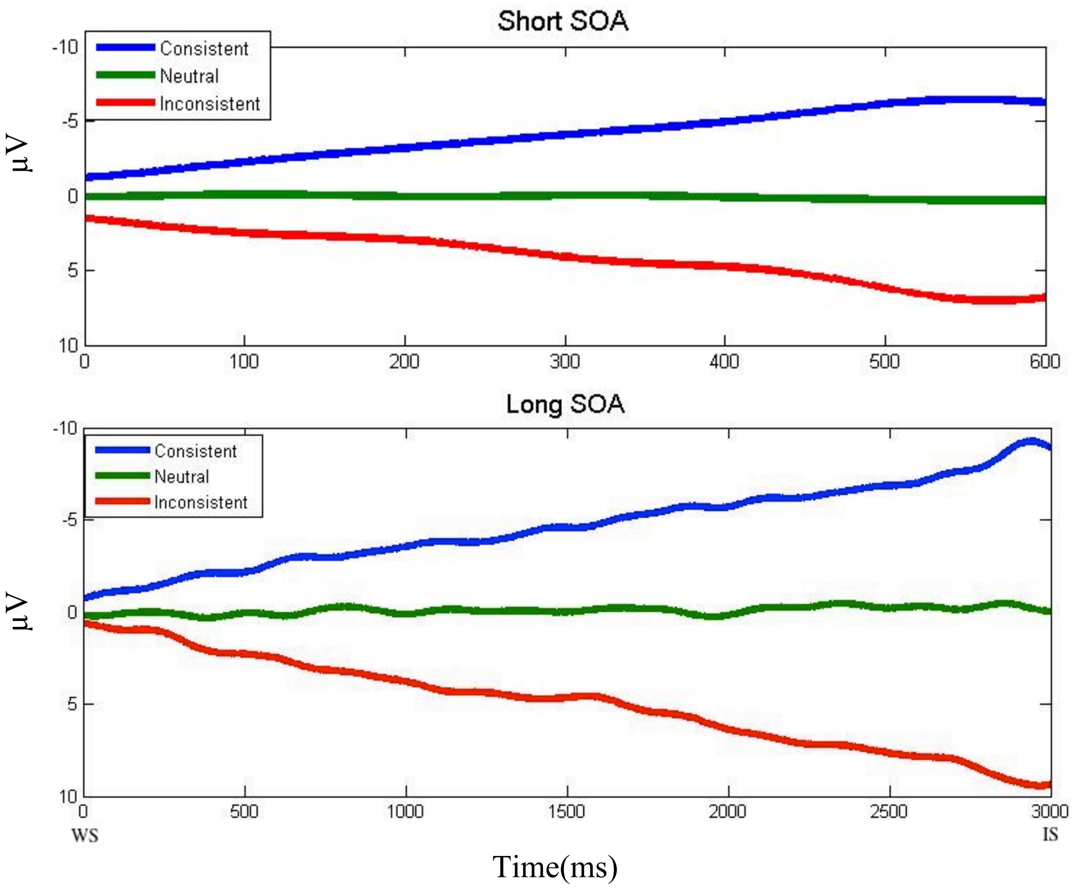

Figure 2. Pre-Stimulus Lateralization.
Note. WS = Warning Stimulus; IS = Imperative Stimulus

Results

Behavioral Data

Table 1 provides the average RT for each condition. Figure 3 shows the group RT distributions, represented as cumulative curves, for each condition. As expected, there was a main effect of SOA on RT, such that RT was longer in the long SOA by 25ms, $F(1,11)=18.17$, $p<.05$.The effect remained when using median RT (in fact it grew to a 28ms difference), suggesting that the mean RT difference is not driven by outliers. This is further confirmed by examining the distribution of RTs shown in figure 3. The number of errors between these conditions did not differ (7.5 and 8.1 mean errors for short and long SOAs, respectively; $F(1,11)=.36$, $p=.56$), so it is unlikely that the effect is due to speed accuracy trade off. This finding replicates the common effect of temporal preparation on RT and allows for investigation into the loci of the effect. Surprisingly, though there was a pattern for increased RT from "consistent" trials (382.2ms) to "neutral" trials (384.2ms) to "inconsistent trails (386.7ms), the effect of pre-IS lateralization was very small and only approached significance, $F(2,22)=3.08$, $p=.07$. Crucially, there was also no significant interaction with SOA, $F(2,22)=1.22$, $p=.32$. Further, there was no difference in the number of errors between inconsistent (6.8) and consistent (7.6) trials, $F(1,11)=1.24$, $p=.29$, and no interaction with SOA, $F(1,11)$, $p=.52$ (For this analysis the "neutral" level was removed due to a greater number of overall trials in that category, resulting in a 2x2 ANOVA). These null findings are difficult to explain given the large differences observed in the LRP prior to the IS as shown in figure 2, but a possible explanation is offered in the discussion section. Regardless of the reason, given that there were no significant effects of pre-stimulus lateralization on speed or accuracy of responses, subsequent analyses focus on trials collapsed across pre-IS lateralization.

LRP

To use the LRP as a tool in determining how temporal preparation affects RT, in accordance with the current literature, the latencies of the *onset* of the S-LRP and R-LRP were examined between SOA conditions. The S-LRP and R-LRP can be seen in figure 4. Inspecting the waveforms visually, it can be seen that that the S-LRP begins slightly earlier in the short SOA condition. In the R-LRPs however, there appears to be no latency difference. In order to test the differences statistically a jackknife-based method described by Miller, Patterson, & Ulrich (1998) and Ulrich & Miller (2001) was used. Because the LRP is a small component and determining something as subtle as its onset for each participant is difficult when any degree of noise is present, Ulrich & Miller (2001) recommend determining LRP onset using a jackknife-based method on the grand average LRPs for each condition. To conduct this analysis, first grand average waveforms for each condition are created iteratively while temporarily excluding each participant once, resulting in n waveforms where n is the number of participants (in this case n=12). Next an absolute voltage criterion, in µV compared to baseline, is set; the point in time that each waveform crosses that voltage criterion is determined to be the latency of onset. The onset latency for each jackknifed waveform is then treated as a participant value for a traditional ANOVA. But because using the jackknife technique artificially reduces the standard error, the F-values have to be adjusted by $F_c = F/(n-1)^2$, where F_c is the corrected F-value, n is the number of participants, and F is the F-value given by the

ANOVA. For the present analysis, the criterion for the R-LRP was set at -.38μV from baseline (corresponding to 25% of the overall R-LRP peak amplitude), and for the S-LRP at -.35μV from baseline (corresponding to 40% of the overall S-LRP peak amplitude) according to the recommendations my Miller et al., (1998).

Results from this analysis confirmed an earlier onset in the S-LRP in the short SOA condition (244ms) compared to the long SOA condition (284ms), $F(1,11)=9.1$, $p <.05$, and no significant difference in the R-LRP onsets $F(1,11)=2.4$, $p =.15$. There were no significant effects on the peak to peak amplitude of the S-LRP $F(1,11)=1.97$, $p =.19$, but there was a trend for larger peak to peak amplitude in the R-LRP, $F(1,11)=4.51$, $p =.06$, such that the peak was .34μV larger in the short SOA condition.

P300

To examine the P300 latency, subject averages of ERPs for all conditions were first submitted to a spatial PCA. Ten factors, accounting for 94.5% of the original variance, were rotated using the Promax rotation method. The second spatial factor (see figure 5), which accounted for 30.7% of the total variance, matched the centro-pariatel spatial distribution of the P300. Therefore, P300 analyses were conducted on the "virtual ERPs" derived from the factor scores of spatial factor 2. The "Virtual ERPs" representing the P300 are plotted in figure 5. Visual inspection of these waveforms reveals earlier P300 latency in the short SOA condition. Note also that there is no visible difference in the latency of components leading up to the P300, further confirming that the CNV offset has no effect on latency of the P300 "Virtual ERPs". In order to test the P300 latency differences statistically, the time point of the P300 peak for each subject and each condition was submitted to an analysis of variance. This analysis revealed a significant effect of SOA, $F(1,11)=9.69$, $p<.05$, such that latency was shorter in the short SOA condition (502.9ms) compared to the long SOA conditions (533.9ms). There were no effects of pre-IS lateralization on latency the P300 latency $F(1,22)=.17$, $p=.85$ and no interactions, $F(1,22)=.56$, $p=.58$.

Table 1. Reaction Time: Pre-Stimulus Lateralization by SOA Means

	Short SOA	**Long SOA**	***Marginal Mean***
Consistent	370.6ms	393.9ms	382.2ms
Neutral	373.3ms	395.1ms	384.2ms
Inconsistent	371.8ms	401.5ms	386.7ms
Marginal Mean	371.9ms	396.8ms	384.6ms

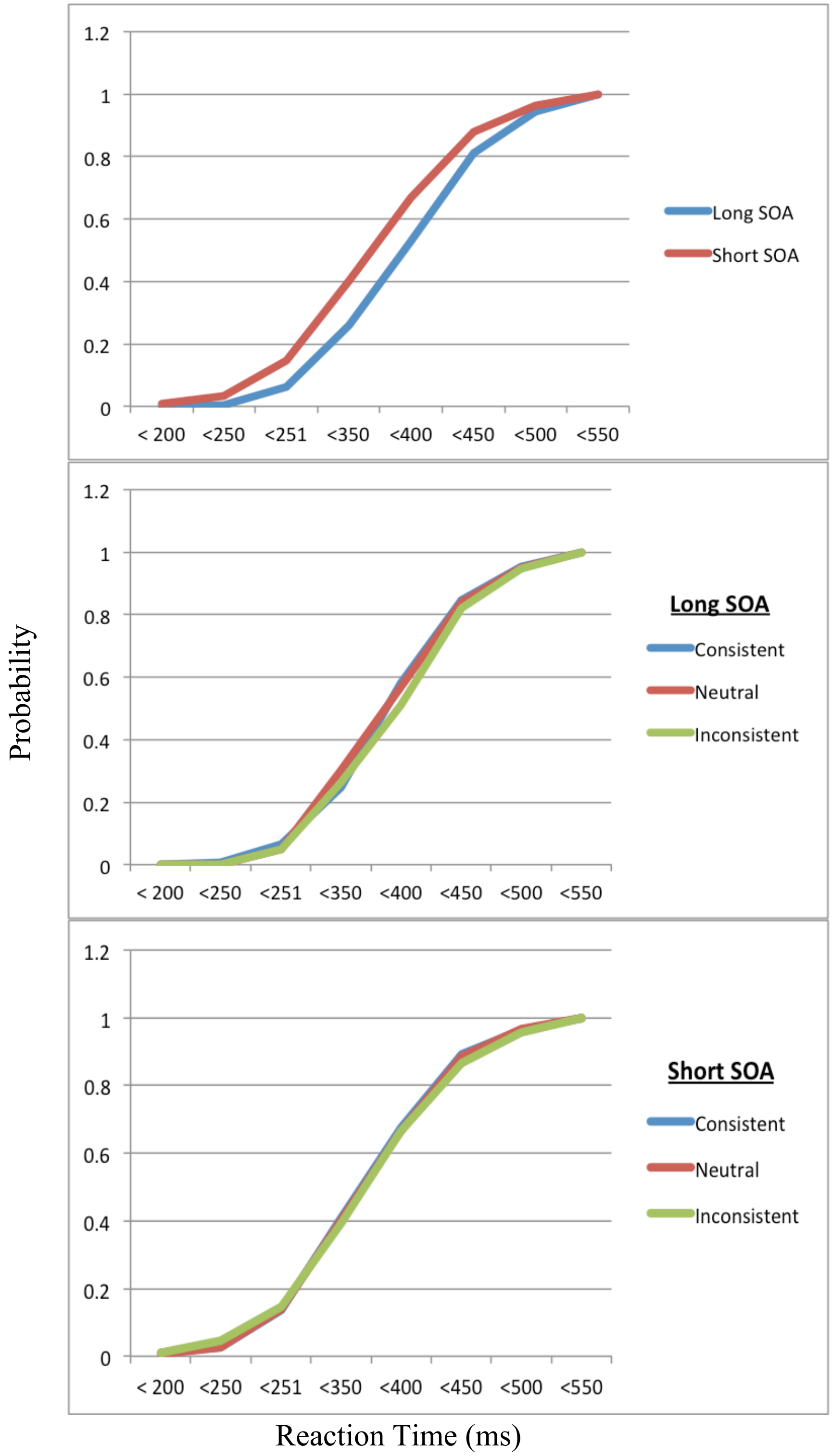

Figure 3. Reaction Time Distributions as Cumulative Curves
Note. Single trial reaction times were sorted into 50ms bins for each subject. Next the probability of a trial falling into, or below, each bin was calculated. The average probability per RT bin is displayed here for each condition across all participants.

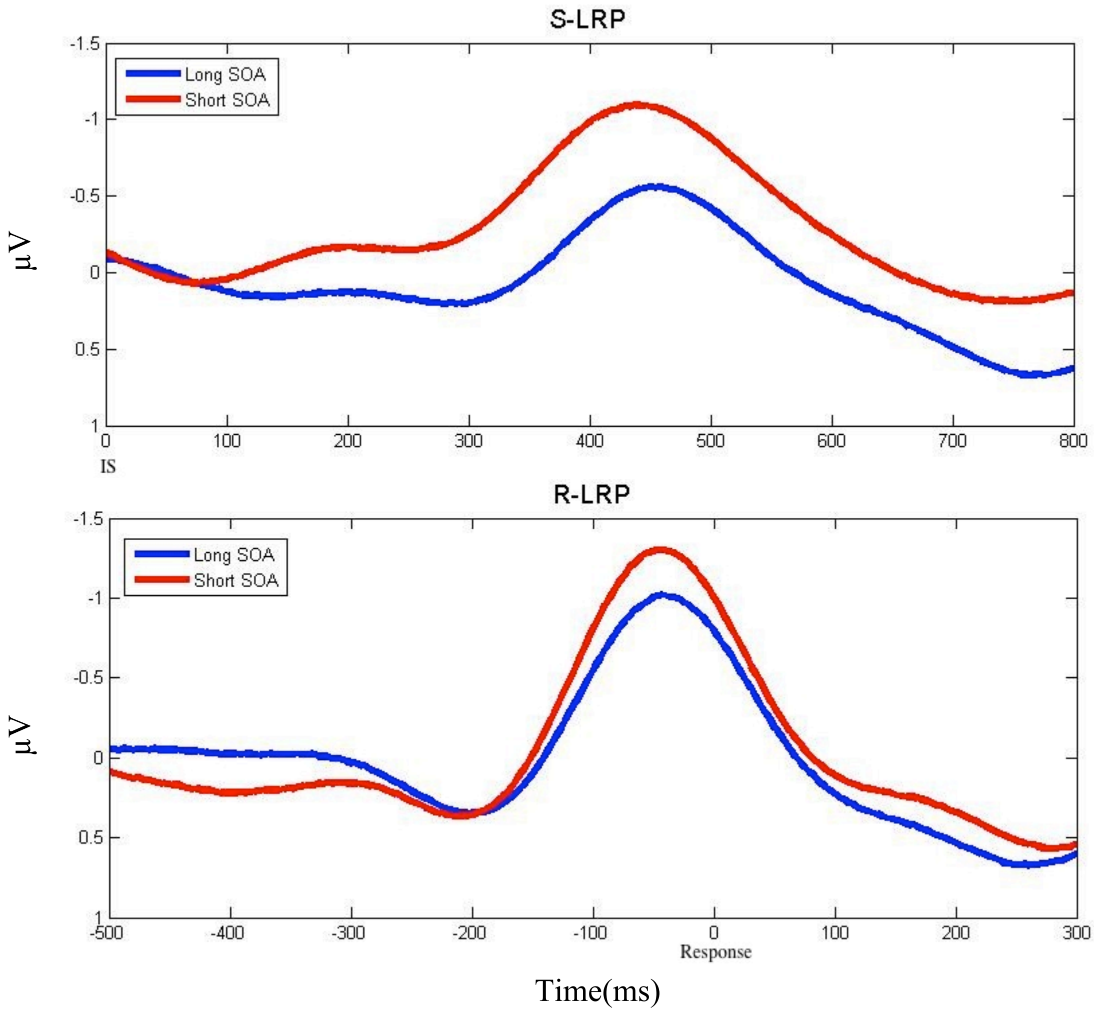

Figure 4. S-LRP and R-LRP.

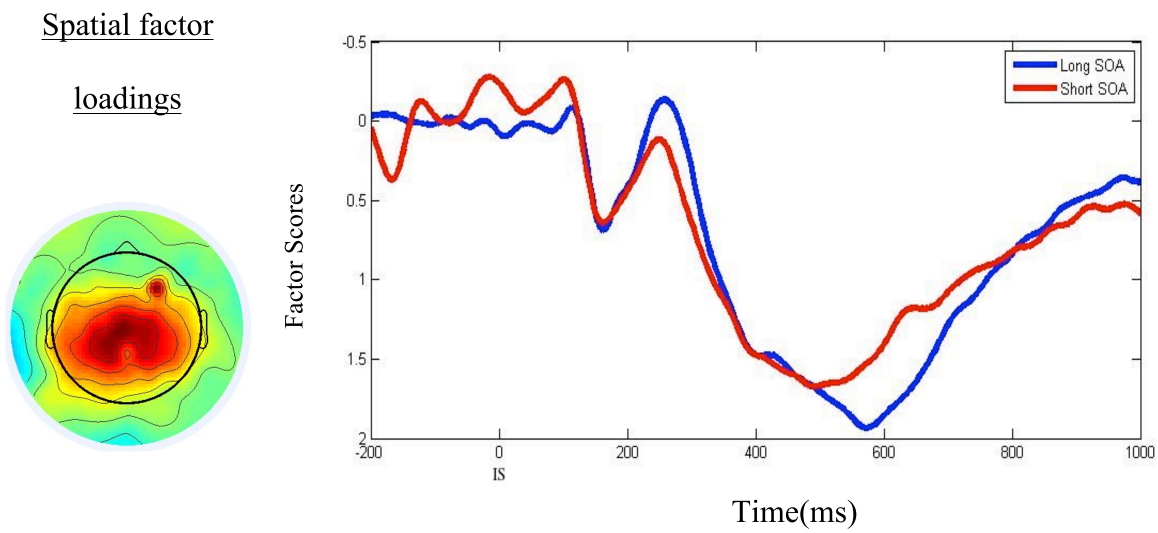

Figure 5. The P300 “Virtual ERP” at Spatial Factor 2.

Discussion

The effect of temporal preparation on RT was replicated in this study as a 25ms difference between the long and short SOA conditions. There were however no significant effects of pre-stimulus lateralization on RT or accuracy. These findings were surprising given the large differences in lateralization prior to the IS. One possible explanation is that despite varying degrees of pre-stimulus lateralization, participants waited until sufficient processing of the IS before initiating a response in most trials – a figurative "resetting" to baseline at IS onset. Indirect evidence for this interpretation comes from the observation that error rate was low overall (14.8%). This indicates that participants may have focused on accuracy at some cost of speed, which may have rendered the effect of pre-stimulus lateralization negligible. Despite the null findings of pre-stimulus lateralization in this study, given the trend for increased RT when lateralization was inconsistent with the upcoming stimulus, this sorting procedure should be used in future studies. It seems likely that as the degree to which speed is prioritized increases, the importance of pre-stimulus lateralization will also increase.

The LRP and P300 were measured to investigate which processes were speeded by temporal preparation. As expected, an earlier onset of the S-LRP, but not of the R-LRP, with increased temporal preparation was found. This dissociation has been reported previously (Muller-Gethman at al., 2003; Hackley et al., 2007), and has been interpreted as evidence that temporal preparation speeds processes related to stimulus evaluation, response selection, or early motor processing. However, the P300 appears be a more robust and discriminating instrument for this paradigm. Examination of the P300 latency in this study narrows the effect to stimulus evaluation processes specifically. The P300 latency was shorter with increased temporal preparation and the P300 has been shown to be sensitive to stimulus evaluation and insensitive to response selection and motor processing (McCarthy & Donchin, 1981). This alone does not preclude the possibility that response selection and motor processing are also speeded. It does however suggest that stimulus evaluation *is* speeded by temporal preparation - a conclusion that cannot be arrived upon by examining only the LRP latency. Further, the P300 and RT varied as function of temporal preparation to nearly the same extent – the P300 increased by 30ms as RT increased by 25ms – signifying that speeded stimulus evaluation processing is likely the primary explanation for the temporal preparation effect (Kutas, McCarthy, & Donchin 1977). However, further research is needed to strengthen this claim. First, multiple levels of SOA are needed to fully examine the covariance between P300 latency and RT as a function of temporal preparation. Also, it is important to examine the covariance of P300 latency and RT in this paradigm while manipulating the focus between speed and accuracy. Kutas et al (1977) showed that the relationship between the P300 latency and RT varies as a function of accuracy – responses that are closely tied to stimulus evaluation are far more likely to be accurate while responses that do not depend on sufficient stimulus evaluation are more likely to be fast and inaccurate. Findings from the current study suggest that increased temporal preparation caused speeded stimulus evaluation that in turn reduced RT. However, participants in this study seemed to prioritize accuracy. Therefore it would be informative to examine RT as more emphasis is placed on speed. If the effect of temporal preparation on RT is primarily due to speeded stimulus evaluation, then as speed is emphasized over accuracy the effect on RT should be reduced because responses will be less affected by speeded stimulus evaluation. If however the difference in RT between the temporal preparation conditions remains when more emphasis is placed on speed, then changes in stimulus evaluation speed cannot fully explain the RT effect. Further study using the P300 latency can therefore be used to shed even more light on the effect of temporal preparation

In conclusion, increased temporal preparation speeds the processing needed to evaluate an event, which appears to explain to a large extent why temporal preparation reduces reaction time. However, more research is needed to determine the degree to which the effect of temporal preparation can be explained by speeded stimulus evaluation.

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