# The effect of attention on different features of the same stimuli on the P3 component in a Simon task
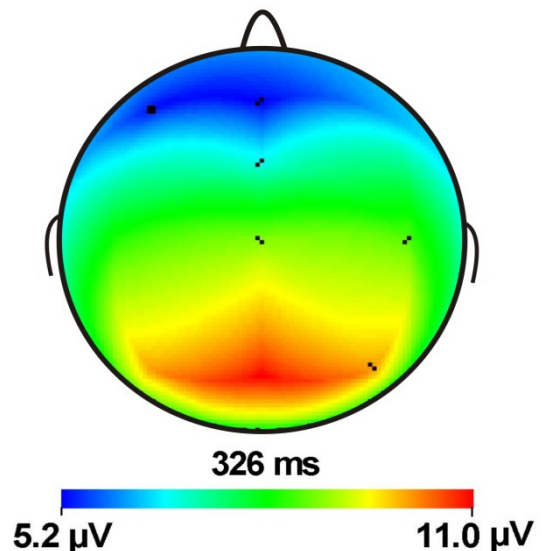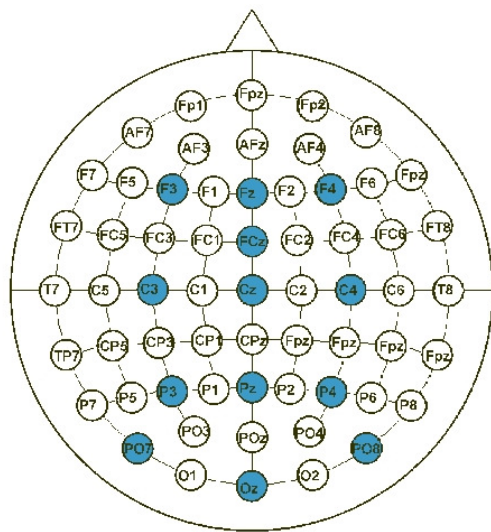
**Niet vertrouwlijk**

326 ms

5.2 µV    11.0 µV

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|---|---|
| Naam: | Bas Olthof |
| Opleiding: | Psychologie |
| Datum: | 21-12-2010 |
| 1e begeleider: | dr. R.H.J. van de Lubbe |
| 2e begeleider: | dr. E de Kleine |

# Content

**Samenvatting**

De huidige studie onderzocht of het letten op verschillende features van eenzelfde stimulus effect had op de latentie en de amplitude van de P3 component. Een event-related potential (ERP) component verkregen uit het elektro-encefalogram. 18 deelnemers namen deel aan het onderzoek en voerden een Simon taak, waarin zij reageerden op ofwel de kleur of op de vorm van de stimulus. Deze studie toont duidelijk aan dat de P3b component wordt beïnvloedt door het feature waar de respondenten op moeten reageren. Deze bevinding lijkt erop te duiden dat het idee van Polich's (2007) dat de P3b component een geheugenmechanisme representeert niet houdbaar is.

**Abstract**

The current study investigated whether attending to different features of the same stimuli had an influence on the latency and amplitude of the P3 component. An event related potential (ERP) component derived from the electroencephalogram. 18 participants took part in the study and performed a Simon task, in which they responded to either the colour or the shape of the stimulus. The current study clearly proves that the P3b waveform is mediated by the feature of the stimulus that the participants attend to. This finding seems to implicate that Polich's (2007) proposal about the P3b representing some kind of memory mechanism is no longer a valid one.

## 1. Introduction

Event-related potentials (ERPs) recorded on the scalp are used with great success in the studying of cognitive processes and the way these processes are implemented in the human brain. One of the most studied components is the P3 also called P300 and more recently divided in P3a and P3b (Nieuwenhuis, Aston-Jones, & Cohen, 2005; Polich, 2007). The P3 component was first described in 1965 (Debecker, Desmedt, & Manil, 1965; Sutton, Tueting, Zubin, & John, 1967) due to fast advancing computer technology it became possible to record and average signals/potentials generated by the brain and measured over the scalp after certain events. And since that day on many theories about the cognitive processes that the P3 might represent have been formulated and discarded again. Today, 40 years after the fist description of the P3 component, there is still uncertainty about how the P3 relates to information processing.

The P3 is a positive large amplitude potential which typically peaks between 300 and 400 ms after stimulus onset (Nieuwenhuis, et al., 2005), this component is typically seen in an ERP waveform, which is the result of an averaging process, but can be seen on a single trial especially when pain is involved (Bornhövd, et al., 2002; Nakata, Sakamoto, Inui, Hoshiyama, & Kakigi, 2009). A lot of factors have been reported to influence the P3, the most prominent one seems to be subjective probability but motivational significance and attention paid to the stimulus do play mediating roles too. That subjective expectancies are very hard to control for in experimental settings, was first recognized by Jarvik (1951) he noticed that participants expect more alterations then repetitions then actually occur in a truly random sequence (Jarvik, 1951). It is an often reported finding that the P3s amplitude is relatively insensitive to variables related to response generation and to physical properties of the stimulus (Nieuwenhuis, et al., 2005).

As stated above many theories about what cognitive process or processes the P3 represents have been generated. A few rivalling but not mutually exclusive theories are still not explaining all finding on P3. Polich describes the P3 as a signifier of a context updating process. After basic processing of the incoming stimulus, a comparing mechanism compares the current stimulus to the previous stimulus which is assumed to be still present in working memory. If no change between the two stimuli is detected by this mechanism the already present representation is kept in working memory and no further processing is needed so only sensory evoked potentials (N100, P200, N200) are recorded (Polich, 2007). Polich divides the P300 in the more frontal orientated P3a and more central and parietal orientated waveform P3b. He relates the P3a to stimulus driven frontal attention mechanisms and the P3b to attention and subsequent memory components. The idea that the P300 is representing context updating is supported by the findings of first order interaction in two choice response tasks like the Simon task. In these sorts of tasks it is an often reported finding that participants respond faster to stimuli presented on the same side were the

response is being made, a so called congruent trial. First order interactions are the speeded responses when a congruent trial is being preceded by another congruent trial. Or put more formally The previous trial is having an influence on the current trial (Gratton, Coles, & Donchin, 1992). But not all theorists agree with Polich's view, one other idea of the meaning of the P3a comes from the conflict hypothesis. The conflict hypothesis states that when the stimulus is presented to the opposite side of the response (incongruent trial) this trial will cause more conflict then a congruent trial, which leads to more recruitment of cognitive control. The conflict hypothesis further states that this higher level of cognitive control is transferred to the next trial (Kerns, et al., 2004), depending on this next trial it can either facilitate the response on this trial if this happens to be an incongruent trial as well, or slow down the response when this trial happens to be a congruent one. This conflict monitoring system is believed to reside in the anterior cingulated cortex a mid-brain structure which has many crosslink's with the prefrontal cortex (Donkers & Van Boxtel, 2004). It is believed that the dorso-lateral prefrontal cortex is detecting the conflict and activates the ACC to overcome this conflict. The activation of the ACC is supposedly leading to an increase in cognitive control which in its turn leads towards attentional biasing of the information processes necessary to perform the specific task at hand. This process reduces the influences of task-irrelevant information. A dissociation is made between stimulus conflict and response conflict, where response conflict seems to be a good predictor of response time, stimulus conflict seems to predict the first order interactions better(Notebaert & Verguts, 2006). Mayr, Awn & laurey (2003) dubbed this interpretation of the congruency sequences "*conflict adaptation*". A problem here is that the P3 is not a sensitive tool to distinguish between stimulus and response conflict (Verleger, 1997). Wijers et al.(1989, p. 489) suggest that "*P3 latency reflects the duration of only certain subsystems of stimulus evaluation.*"(Wijers, et al., 1989) Verleger (2008) does also claim that if memory components have anything to do with the generation of the P3 these should be reflected by the P3a and

not the P3b(R. Verleger, 2008, 2010). According to Verleger the P3b is reflecting a decision process about what to do with the stimulus (Nieuwenhuis, et al., 2005; R. Verleger, 2008; R. Verleger, Jaśkowski, & Wascher, 2005) also called the stimulus evaluation theory (Verleger, 1997).

This leaves us with a few possible accounts:

- Polich claims that the P3a signifies a stimulus driven frontal attention mechanism.(One could regard the P3a, novelty P300 and no-go P300 as variations of the same potential (Polich, 2007; Spencer K & J., 1999), P3b in this view relates to memory operations(Polich, 2007).

- The P300 could also be the result of a conflict resolving mechanism residing in the ACC (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Kerns, et al., 2004; Notebaert & Verguts, 2006)

- Verleger claims that if P300 relates to memory component this is represented in the P3a, because areas that are known to contribute to this component have a relation with memory. Verleger about the P3a wrote: "*Speculatively, the link between memory and P3a might simply be that participants have to keep in mind what the target stimuli are and what the task is about, so any stimulus is classified, as reflected by P3a, with respect to these memorized categories.*" (R. Verleger, 2008)
The P3b in this view relates to a decision process about what the participant has to with the stimulus (Nieuwenhuis, et al., 2005; R. Verleger, 2008)


In this study a Simon task is conducted with two different conditions. In experiment one the participants focus on the colour of the stimulus and in experiment two the participants focus on the shape of the stimulus. The same stimuli and response buttons are used in both experiments (fig. 1), the stimulus input and response output are kept constant, no changes are made between the conditions. The only thing that changes is the feature of the stimulus the participants are focussing on (colour or shape). So if Polich's claim about the P3a being a

stimulus driven component and the P3b being a memory component is true we expect the P3a component to be small and relative unaffected by the experimental conditions. The P3b component is expected to follow the normal pattern as seen in other two choice response tasks. If the conflict adaption account is true, the experimental conditions are most likely going to impact on the P3a component, because this component is believed to be influenced by ACC activity. If Verleger's view is the right one we expect an impact on the normal P3a pattern as observed in other two choice response tasks and an impact from the experimental conditions on P3b because a decision has to be made on different accounts (either colour or shape).

The P3 is often studied by making use of an oddball task, in which targets appear with a low frequency (oddball) in a train of non-target stimuli (standards). It is often found that the amplitude of the P3 is inversely correlated with the probability of the oddball event (Verleger, 1997). This effect is perhaps partly due to subjective expectancies and as mentioned before it is virtually impossible to control for, but by giving all stimulus-events the same probability in this study, we assume that all stimulus-events are affected by this phenomena in the same way. Instead of an oddball task, this experiment is using an adapted version of the Simon task, which in itself is known to be effected by attentional cueing effects (Abrahamse & Van der Lubbe, 2008), the previous trial could unintentionally serve as a cue for the forthcoming trial and influence the processing of that trial. To make sure that the measured effects on the P3 are not due to sequence effects caused by the influence of the previous trial the congruency level of the previous trial is considered in the analysis.

## 2.    Methods

### 2.1    Participants

Eighteen students (four male and fifteen female) of the University of Twente, aged between 18 and 27 years (mean 19,16 ± 2,06) were recruited. The participants took part in the

experiment as part of a curriculum requirement in their educational program. All participants were right-handed, had normal or corrected to normal vision and hearing capabilities and reported no history of neurological disorder. Two participant's datasets were rejected due to too many EEG artefacts. The experiments were conducted with the informed and written consent of each participant. The ethics committee of the University of Twente approved the study.

## 2.2    Stimuli and task procedure

The stimuli consisted of yellow or blue filled circles (5cm in diameter) and triangles (5cm high, 3.5 cm wide) (fig 1.) presented to either the left or right side of fixation with an eccentricity of 5°. Participants were instructed to keep their gaze fixated on a white cross (2 cm wide, 2 cm high) presented to the centre of the screen, which was visible throughout the entire block.
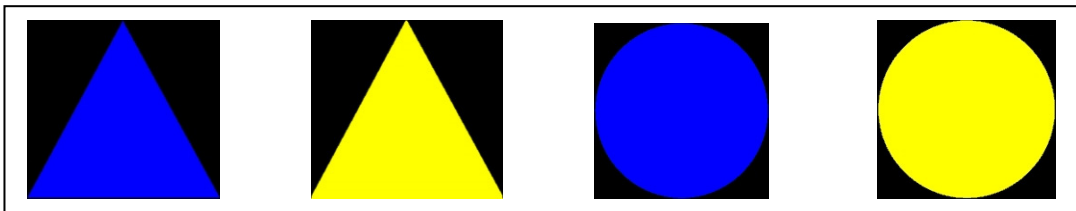


Figure 1:          The four possible stimuli used in the experiment.

Responses were recorded with a standard QWERTY keyboard, by pressing the left or right shift button. In the colour condition (fig. 2), participants were instructed to press the left shift key for a yellow stimulus no matter its location or shape and to press the right shift key in case of a blue stimulus.
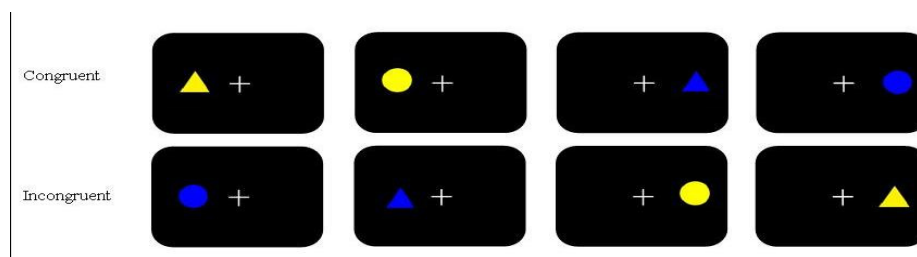


Figure 2:          The congruent and incongruent trials for the colour condition

In the shape condition (fig. 3), participants were instructed to press the left shift key for a triangle no matter its location or colour, and to press the right shift key in case of a circle. The instructions were presented on screen and were followed by a series of twenty-eight practice trials.
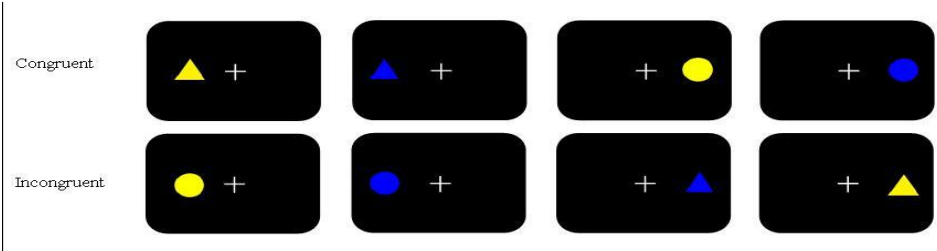


Figure 3:         The  congruent and incongruent trials for the shape condition

The stimuli were presented using 'presentation' software on a 17" computer screen placed approximately 60 cm in front of the participants. A complete trial period included a default screen in which only the fixation cross was visible for 100 ms, then a stimulus (Fig. 1) appeared left or right of fixation, lasting 1500 ms In this time the participant was expected to respond to the stimulus. Finally a 500 ms default screen was shown before the next trials started, resulting in a 2100 ms inter stimulus interval (ISI). Figure four and five represent a few possible two trial sequences for each condition. Blocks consisted of 64 trials after which
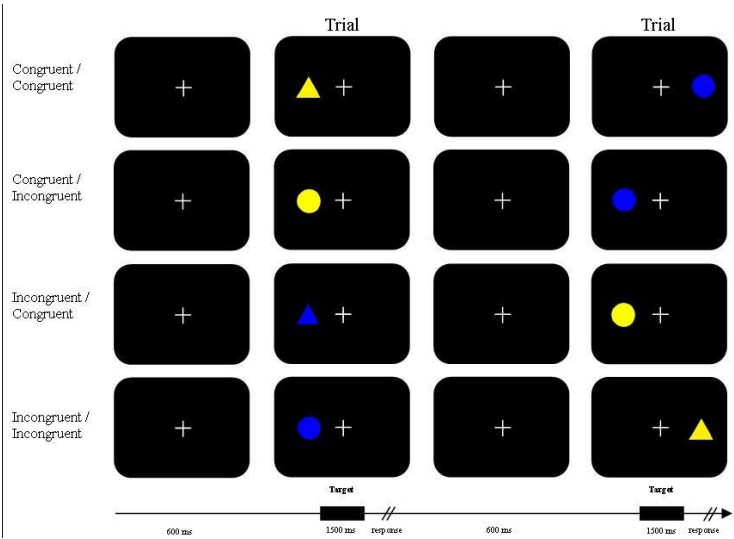


Figure 4:         Experiment 1: Colour condition. An example of the sequences per category is shown. Notice

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that not all possible options are show for each category. See figure 2 for all different trial options for each category (congruent / incongruent). The temporal sequence of stimulus presentation appears in the lower part of the figure.

the participants were granted a break as long as they saw fit. Participants performed all eight blocks of one condition before they moved on to the other set of eight blocks in the other condition. Starting conditions were counterbalanced between subjects. After the first eight blocks the new instructions were presented on the screen, immediately followed by another set of twenty-eight practice trials. Participants did not receive feedback on their performance during the experiment.
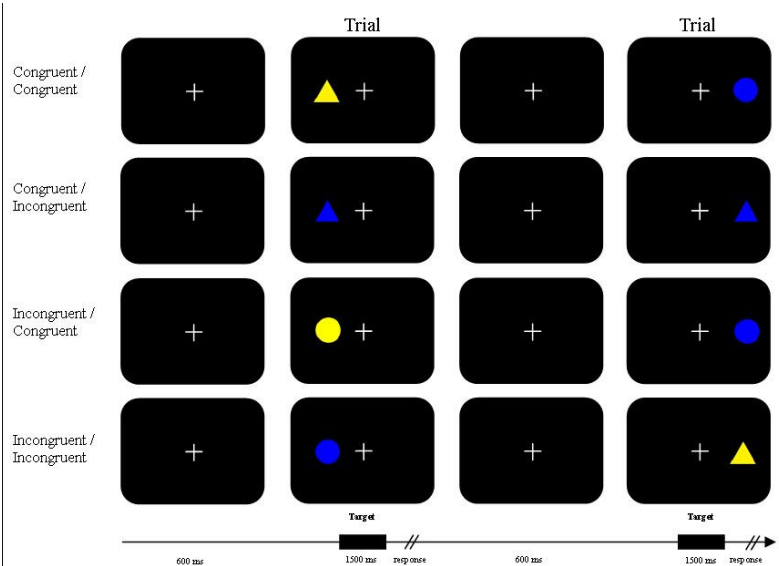


Figure 5: Experiment 2: Shape condition. An example of the sequences per category is shown. Notice that not all possible options are show for each category. See figure 3 for all different trial options for each category (congruent / incongruent). The temporal sequence of stimulus presentation appears in the lower part of the figure.

## 2.3 Electrophysiological recording

EEG recordings where acquired from 13 Ag/AgCl ring electrodes attached to a standard 10/10 electro cap from the following locations: F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, PO7, Oz, PO8 and Fcz (fig. 6). Two additional electrodes (M1, M2) were placed on the left and right mastoid bones. Horizontal eye movements (hEOG) were recorded through two Ag/AgCl ring

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electrodes placed at approximately one centimetre from the outer canthi of the eyes. Vertical eye movements (vEOG) and blinking were also measured using two Ag/AgCl ring electrodes placed approximately one centimetre above and below the left eye.

The ground electrode was placed in front of the Fz electrode. Impedance was kept below 10 kΩ at all times during the recording sessions. The recordings were referenced to the average of all electrodes. EEG and EOG data were amplified by a Quick-Amp (BrainProducts GmbH) amplifier and recorded at a sample rate of 1000 Hz and stored digitally in BrainVisionRecorder (Version 1.05.0001) for later off-line analysis.



Figure 6: electrode sides used
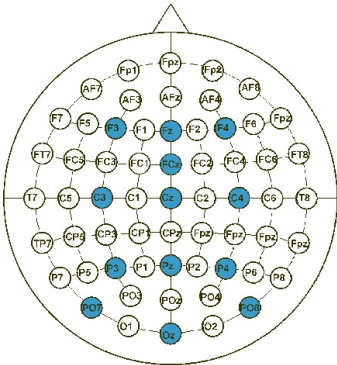
### 2.4    Data and statistical analysis

### 2.4.1   Behavioural measures

Incorrect responses and those faster than 100 ms, slower than 800 ms or missed at all were excluded from the dataset. To assess the influence of the congruency of the previous trial on the current trial, both current congruent and incongruent trials were divided into whether they were preceded by a congruent or incongruent trial. Repeated measures analysis of variance (ANOVA) were performed on RTs, percentage correct trials and percentage missed trials including relevant feature (colour (c) or shape(s)), congruency type of the previous trial (congruent (C) or incongruent(I)) and congruency type of the current trial (congruent (C) or incongruent(I)) as within subjects variables. Contrasts were made when necessary *post-hoc* by using a two tailed T-test procedure.

### 2.4.2   Event related potentials

The digital stored data was analysed by BrainVisionAnalyzer (version 1.05.0001) software. The data was re-referenced offline to the combined activity measured over the electrodes placed on the left and right mastoid bones. A Butterworth zero phase filter was applied with

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a band pass from 0.5 Hz (down 12db/oct) to 20 Hz (down 12 db/oct). The ERP epoch began 100 ms before and ended 1500 ms after stimulus presentation.

An artefact rejection protocol based on voltage amplitude was applied, all epoch for which the EEG exceeded 75 microvolt's in any channel were discarded for ERP analysis; 91.25% of cCC trials, 90.73% of cIC trials, 92.31% of cCI trials, 89.87% of cII trials, 90.62% of sCC trials, 92.41% of sIC trials, 88.79% of sCI trials and 90.56% of sII trials were accepted for analysis. Note that the first trial of every block had to be rejected because there was no preceding trial. The ocular correction based on the Gratton & Coles algorithm was applied, the baseline was set at the 100-0 ms pre-stimulus interval. A semi automatic peak detection procedure was used to determine the P3 peak amplitude and Latency. Amplitude ($\mu V$) is defined as the difference between the mean pre-stimulus baseline voltage and the largest positive –going peak of the ERP waveform within the 250-450 ms time window. Latency is defined as the time from stimulus onset to time of maximum positive amplitude within the aforementioned time window.

The P-values were calculated using the repeated measures ANOVA with the same within-subject variables as were used in the behavioural analysis. A two tailed T-test was used as a *post-hoc* test when necessary. For the P3 component, analyses were restricted to the sites Fcz and Pz , although information from other scalp sites is represented in topographic maps. To find out whether the P3 waveform differed significantly on the electrodes Pz and Fcz another repeated measures ANOVA was done with the two electrodes as another within subject variable added to the other factors.

## 3   Results

### *3.1   Behavioural measures*

A first analysis of the behavioural data showed that no responses were made before the 100 ms boundary, meaning that none of the trials were responded to prematurely. On the other

hand however 25,8% of all trials were either responded to, to slow or missed at all and were classified as a miss. The repeated measures ANOVA on the 'percentages missed' with the factors relevant feature, congruency previous trials and congruency current trial, revealed a significant interaction between relevant feature and congruency on the current trial $F(1,17)=5.953$, $P<0.028$. The *post-hoc* tests indicated that when colour is the relevant feature fewer misses were recorded in the congruent trials. In the shape condition the opposite was true. The trials classified as missed were discarded for further analysis. The main effect of relevant feature was not significant for the 'percentage missed'.

The same repeated measures ANOVA was performed on the percentages of trials that were responded to correctly, this test revealed a significant interaction between relevant feature and the current trial $F(1,15)=9.996$, $P<0.006$, as well as a interaction between the previous and the current trial $F(1,15)=30.484$, $P<0.0001$. The *post hoc* test revealed that when colour was the relevant feature fewer mistakes were made for congruent trials. The lowest percentage correct was obtained for congruent trials when the relevant feature was shape. The *post hoc* test on the previous x current trial interaction effect revealed that CC and II sequences were answered better compared to IC and CI sequences.

The repeated measures ANOVA on the RTs data revealed an effect for the relevant feature $F(1,15)=11.261$, $P< 0.004$, the congruency of the current trial $(F1,15)= 21.081$, $P<0.0001$ and the congruency of the previous trial $F(1,15)=8.224,P<0.012$.

Next to these three main effects a significant interaction effect between the previous and the current trial type $F(1,15)=118.836$, $P<0.0001$ was observed *Post-hoc* contrasts were made for all the main effects and the interaction effect. When colour was the relevant feature responses were made faster (mean 26.38 ms). When the current trial was a congruent on, this would result in a faster response (mean 14.00 ms) compared to incongruent trials.

The *post-hoc* test on the interaction effect showed as has been reported many times in literature that II sequences compared to CC sequences were responded to slower (mean RT difference = 23.96 ms), IC sequences compared to CC sequences were also responded to slower (mean RT difference = 53.31 ms) as were CI sequences compared to II sequences (mean RT difference = 33.40 ms).

### 3.2    Event related potentials (ERP's)

The repeated measures ANOVA on electrode Fcz with the above mentioned within subject variables on the P3 amplitude revealed a main effect for the relevant feature F(1,16)= 7.601, P<0.0014. A two tailed T-test showed that when colour was the relevant feature of the stimulus the main amplitude of the P3 component on electrode Fcz was significant higher when compared to the trials where shape was the relevant stimulus feature.

The same repeated measures ANOVA on P3 latency on electrode Fcz revealed a main effect for relevant feature F(1,16) = 7.785, P<0.0013 and a main effect for the congruency of the current trial F(1,16) = 8.891, P<0.009.The post hoc two tailed T-tests revealed that when colour was the relevant feature the P3 wave peaked 15,61 ms earlier compared to the shape condition. The effect for congruency of the current trial was half this size, congruent trials peaked 8,41 ms earlier then incongruent trials.



A.        Time in ms -100-500

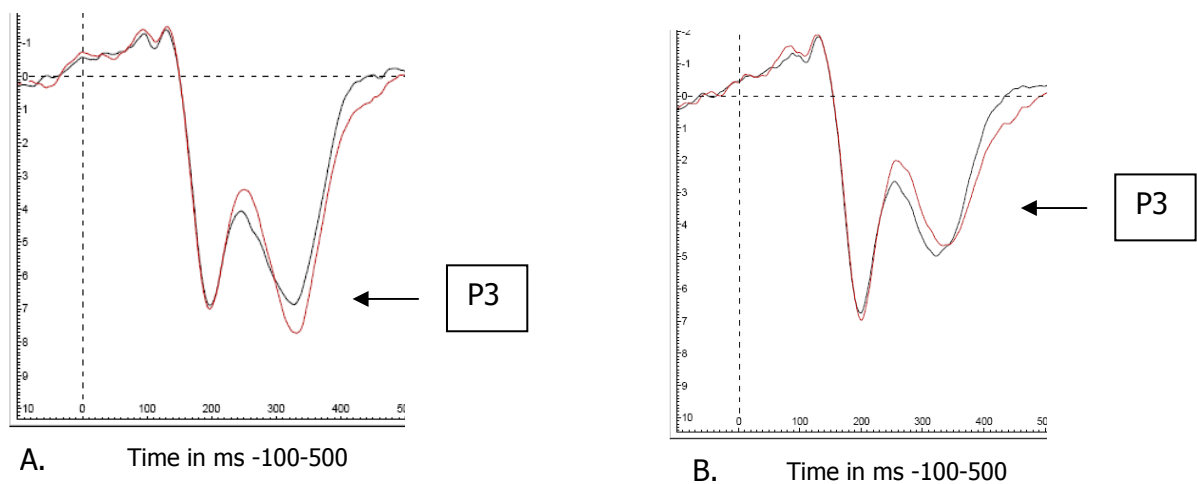B.        Time in ms -100-500

Figure 7              ERPs obtained on electrode Fcz are presented for the CC sequences (black) and IC sequences (red). A displays the ERPs obtained in the colour condition and B displays the ERPs obtained in the Shape condition.

The same analysis was done on electrode Pz where the repeated measures ANOVA on mean amplitude of the P3 component showed a main effect for the relevant feature $F(1,15)= 8.417$, $P<0.011$ and the congruency of the current trial $F(1,15)= 24.86$, $P< 0.0001$. The *Post-hoc* test showed that, as was observed on electrode Fcz, when colour was the relevant stimulus feature the mean amplitude of the P3 wave was considerable higher. On this electrode however there is a main effect on P3 amplitude to be observed for the congruency of the current trial, the two tailed T-test revealed that congruent trials resulted in higher P3 amplitudes compared to incongruent trials.

The repeated measures ANOVA on the P3 latencies on electrode Pz revealed a main effect for the congruency of the current trial $F(1,15)= 4.854$ $P<0.044$. The *Post-hoc* test showed a peaking difference of 7.18 ms between congruent en incongruent trials. This main effect is so small and it only reached significance marginally that for the purpose of this study it can be ignored. The repeated measures ANOVA with the electrodes added as an extra factor on the peak amplitude revealed that there was a significant main effect on the electrodes visible $F(1,15) = 53.34$, $P<0.0001$, the *post-hoc* test revealed that the P3 peak had a higher amplitude on electrode Pz when compared to electrode Fcz. The latencies between the peaks obtained on those electrodes did not differ.



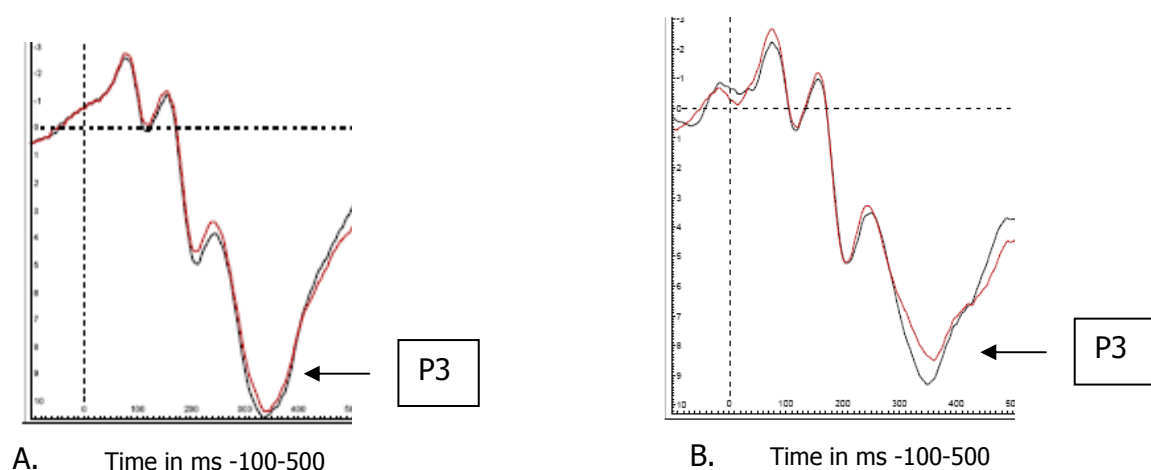A.   Time in ms -100-500

B.   Time in ms -100-500

Figure 8        ERPs obtained on electrode Pz are presented for the CC sequences (black) and IC sequences (red). A displays the ERPs obtained in the colour condition and B displays the ERPs obtained in the Shape condition.

## 4. Discussion

### 4.1 Behavioural measures

An unexpected result obtained in the current study were the many trials that were completely missed by the participants even though the ISI was 2100 ms. One explanation is the use of the Shift keys as response buttons. Frequent pressing of these buttons can result in errors in the operating system which may have resulted in faulty response recording, although if this were the case one would expect this effect to be randomly distributed over the trials and not to result in the patterns observed in this dataset. The many mistakes however are a cause for concern. The results of the current study clearly confirm the previous obtained results from other studies(Donkers & Van Boxtel, 2004; Enriquez-Geppert, Konrad, Pantev, & Huster, 2010; Gómez, Flores, Digiacomo, & Vázquez-Marrufo, 2009; Nieuwenhuis, et al., 2005; Smith, Johnstone, & Barry, 2007; Smith, Smith, Provost, & Heathcote, 2010; Verleger, 1997) that first order interactions result into higher accuracy and faster response times for CC and II sequences when compared to IC and CI sequences.

 CC and II sequences resulted into fewer misses and higher percentages correct responses compared to IC en CI sequences. CC sequences resulted into fewer misses and more correct responses compared to II sequences. The fact that the behavioural data follows the normal first order interaction pattern does seem to proof that the many missed trials are not due to faulty recordings but to some unknown factor in the experiment. Not only sequence effects were found in the behavioural data but also an effect for relevant feature. It was found that when participants had to respond to the colour instead of the shape of the stimulus they were able to do so faster and more accurate. This does seem logical because the stimulus's colour is more salient as its shape.

## 4.2    Event related potentials

Figure nine and ten display the scalp topographies obtained in the colour and shape condition on the moment that the P3 peaked. These figures justify the choice to limit the data analysis to the Fcz and Pz electrodes, although arguments could be made for including electrode Oz in the analysis.
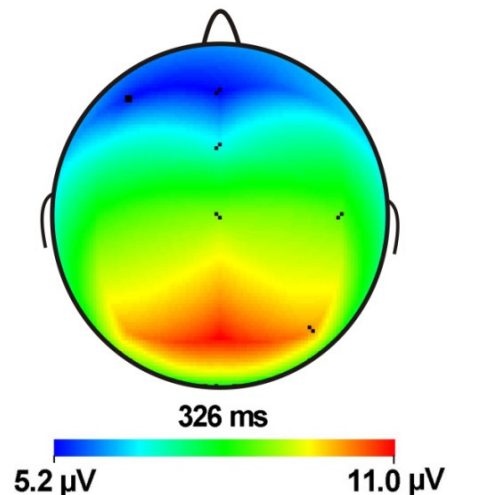


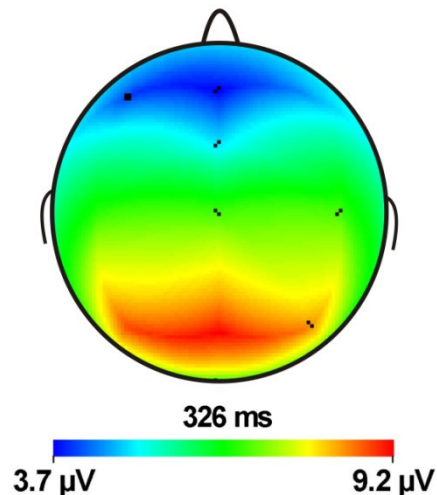| Figure 9: | Topographic map obtained in the colour condition |



| Figure 10: | Topographic map obtained in the shape condition |

The P3a which is often observed on electrode Fcz turned out to be rather small compared to the P3b observed on electrode Pz. This can easily be seen when comparing the ERPs as displayed in figures seven and eight. Notice that although the P3 amplitudes differ quite a bit between the two electrodes their latencies don't. Given the relative late peaking time it is questionable whether the current experiment was able to summon a P3a wave.

The aim of the current study was to test whether attending to different features of the same stimuli resulted in different P3 amplitudes and latencies. As it turned out when all factors are kept constant but the feature to attend to is different, not only response time and accuracy are effected but the P300 amplitude is to. The effect was more noticeable on electrode Pz, where the amplitude was nearly twice the amplitude obtained on Fcz, but the effect was

significant on both electrodes. A recent study showed that semantic colour categories can top-down effect the perception of colour in the pre-attentive period (Clifford, Holmes, Davies, & Franklin, 2010) suggesting that top-down processes can influence very early stages of stimulus processing. The fact that both P3a and P3b are affected by the feature the participant is responding to, tells us that both components do not solely reflect input processing or response selection.

The fact that the P3a was hardly noticeable and not distinguishable from the P3b component in latency is compatible with the view that the P3a is some sort of an orienting response. This component is often observed in oddball paradigms, where the oddballs have a much lower occurrence compared to the standards, in the current task each stimulus had the same occurrence rate and the disappearance of the P3a is consistent with the orienting or novelty P300 view advocated by Polich. But the P3a is not a solely stimulus driven component either, it is modulated by attention for a relevant feature. The fact that the P3a is sensitive to attentional modulation is known for a long time. Active tasks do create P3 components, observational task usually don't. Attending to the colour of the stimulus does also result in higher amplitude then attending on its shape does. This is consistent with the conflict hypothesis; colour is easier to discriminate resulting in higher conflict. Polich's view on the P3b is not supported either by this study; there is no logical reason for differences in memory mechanisms when attending to the stimulus's colour or shape. The view advocated by Verleger that the P3b is somehow connected to a decision process is supported by the findings of this study, probably because top-down processes can affect colour discrimination in the pre-attentive period this feature is much easier to detect then the stimulus's shape.

## 5  Conclusion

The current study clearly proves that the P3 waveform is mediated by the feature of the stimulus that the participants attend to. The findings indicate that the P3a is consistent with

the novelty P300 view but can also be accounted for by the conflict hypothesis. Polich's view on the P3b component as a memory reflecting component is hard to defend with the current findings. The view advocated by Verleger seems the most plausible one; the P3b seems to be a reflection from some sort of decision making process.

**Acknowledgments**

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