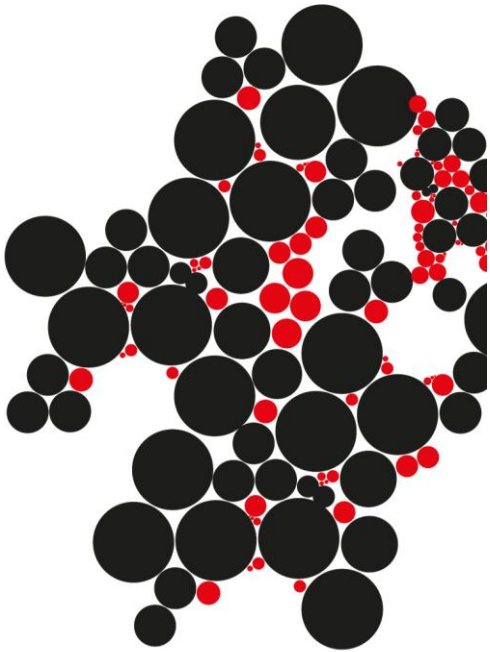


BACHELOR THESIS



DIFFERENCES IN POSTERIOR CONTRALATERAL NEGATIVITY (N2PC)

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Abstract

The N2pc component has become a popular tool in the study of attention. Its exact function however remains unclear. Using an altered Simon task involving a pre and postcue, Van der Lubbe, Abrahamse and de Kleine (2012) found differences in this component. The N2pc was more pronounced for postcues than for precues. The goal of this study was to evaluate this finding by reexamination of the data. Three accounts for the differences in N2pc were tested. First variability at the moment of orienting in case of precues, second an increased perception-action cycle for postcues and third, added attention to hands for postcues were investigated. The data did not replicate the more pronounced N2pc for postcues due to exclusion of participants. Enough evidence was gathered however to reject all proposed accounts for the differences in N2pc.

Samenvatting

De N2pc component is een populair middel geworden in het meten van aandacht. De exacte functie van de component blijft echter onduidelijk. Met een aangepaste Simon-taak, waarbij gebruik werd gemaakt van een pre- en een postcue, vonden Van der Lubbe, Abrahamse and de Kleine (2012) verschillen in de N2pc. Deze uitte zich sterker in het geval van postcues dan precues. Het doel van dit onderzoek was meer te weten te komen over dit verschil door de data opnieuw te onderzoeken. Drie verklaringen voor de verschillen in N2pc zijn getest. Ten eerste, variabiliteit in het moment van aandacht richten in het geval van precues, ten tweede een versterkte perceptie-actiekoppeling voor postcues en ten derde, extra aandacht gericht op de handen voor postcues werden onderzocht. De data repliceerde het verschil in N2pc niet. Wel werd er genoeg bewijs gevonden tegen alle drie de verklaringen voor de verschillen in N2pc.

1.1 Introduction

Many years of research have shown that in the brain, perceptual and motor systems seem to be heavily intertwined. Fuster (2003) first described the continuous interplay and outcome expectancy between perceptual and executive networks as the perception-action cycle. This means that humans continuously monitor and adjust their actions to make sure these actions are appropriate for the environment. In neurocognitive experiments a cue is often used to create an expectation about the location, features or relevance of the target. This converts the perception-action cycle into a more complex preparation-perception-action cycle. The latter is validated by consistent findings that show reaction times (RTs) are faster when a target is expected (validly cued targets) compared to when it is not (Posner, 1980). This difference in RTs has, at least partially, been appointed to the response preparation of the invalidly cued target (Eimer, 1993).

Another reminder of the connection between perception and action is the Simon effect. J. R. Simon himself described an innate tendency for humans to respond toward the source of stimulation and this effect refers to the observation that responses increase in both speed and accuracy when the location of stimulus and response correspond, compared to when they do not. Even if the stimulus' location is irrelevant to the task (Simon & Rudell, 1967). A Simon task traditionally requires two possible stimuli (left and right) and a response to be made with the left or the right hand. So a participant might be asked to make a right-handed response if an X appears on the screen and a left-handed response for an O, while X's and O's can appear on both left and right of the screen. Using this setup consistently yields the abovementioned results. The role of attention within the Simon effect is currently under debate. In his overview of research on the Simon effect, Hommel (2011) dismisses an attention orienting framework in favor of his Theory of Event Coding. This dismissal is disputed however (Van der Lubbe & Abrahamse, 2011). In order to support their view that the Simon effect can

indeed be explained in terms of attention, Van der Lubbe et al. (2012, Experiment 1) found that when attention was focused instead of only recently switched, a decrease in the Simon effect had taken place. This provides evidence that attention does indeed seem to play a role within the studied effect.

Interestingly, it was also found that when attention was recently switched this resulted in a more pronounced negative event-related potential (ERP) lateralization at posterior sites compared to when attention was focused. A discovery, not shared by the precursor of their study. In this precursor, Van der Lubbe, Jaskowski, and Verleger (2005) used a precue,

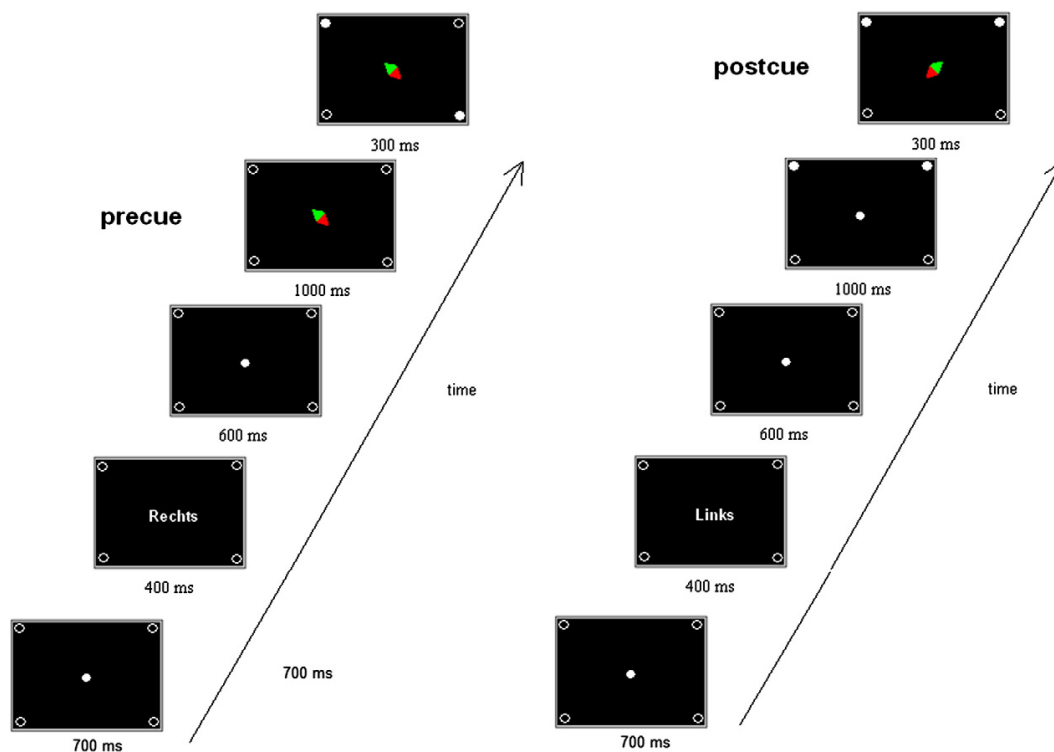


Fig.1. An example of the sequence of events used in the Van der Lubbe, Abrahamse, and De Kleine (2012) study. Both conditions, precue (left) and postcue (right) started with a central fixation dot followed by the word indicating with what hand to respond ('rechts' for right and 'links' for left). A rhomb consisting of a green and red triangle (one of which was marked as relevant) indicated the circle to attend for the precue condition. Consequently, two circles were filled. When the attended circle was filled, a response was to be made (Go) or when unfilled, action was to be withheld (Nogo). In the postcue condition presenting the rhomb and filling the circle was reversed.

simultaneous cue and postcue to find a Simon effect in all conditions and no significant differences regarding lateralized negativity amplitude at posterior sites between conditions.

Argued was however, that a second switch of attention might have taken place and

consequently the experiment was altered on several points (see Fig.1). First, the task was converted in a Go/Nogo task to enable better separation of processes. Second, symmetrical arrows were used to eliminate automatic response side effects and finally the time interval between cue and target was increased to ensure participants directed their attention before appearance of the target.

One explanation for the observed differences in amplitude between conditions is given by the authors of the 2012 study and it involves the way EEG laterizations were computed. Variability at the moment of orienting may have been greater in the precue condition. As a consequence, averaging leads to a less pronounced laterization which could explain the observed difference (Van der Lubbe et al., 2012). A second explanation, not mutually exclusive with the one mentioned above, involves an increase in the perception-action cycle for the postcue condition leading to a more pronounced laterization. Data obtained in the Van der Lubbe et al. (2012) study will be reexamined in order to shed light on the increased perception-action cycle hypothesis.

1.2 The perception-action cycle account.

The differences in laterizations found by Van der Lubbe et al. (2012) were localized in the posterior parietal cortex, around the PO7 and PO8 electrodes. This ERP component is called the N2pc or alternatively posterior contralateral negativity (PCN) to indicate it is not related to the N2 component. As this component appears to reflect mismatch detection and possibly executive cognitive control. The N2pc is a greater negativity found contralateral to the visual field of an attended stimulus relative to the voltage of the corresponding ipsilateral area and occurs around 180-300 ms after stimulus onset. The N2pc is usually associated either with suppression of distracters during visual processing (Luck, Chelazzi, Hillyard, & Desimone, 1997) or with target processing (Eimer, 1996). Although its specific role remains

unclear, it is agreed on that a N2pc depicts the operation of visual-spatial attention (e.g. Eimer, 1996; Jolicoeur, Sessa, Dell'Acqua, & Robitaille, 2006; Woodman & Luck, 2003).

Kiss, Van Velzen, and Eimer (2008) used informative and uninformative cues within a visual search task to find that N2pc's did not differ between conditions even though RTs were significantly faster for informative cues. This indicates that the N2pc is not elicited due to attentional shifts but instead, it was suggested that the negativity reflects spatially specific processing of the stimulus prior to target selection.

Within stimulus-response compatibility paradigms the N2pc has also been observed but is generally less pronounced than in visual search paradigms. Differences in posterior lateralized potentials were expressed by a more pronounced EEG for noncorresponding trials. This finding is appointed to the additional attentional processing required for noncorresponding trials (e.g. Wascher & Wolber, 2004).

The found discrepancy in amplitude between corresponding and noncorresponding trials is a point of concern. Is it safe to assume attention is completely directed at either side in the current task? One may argue that when prompted to respond with the right hand while attending the left side after cue onset, one also has to keep the right hand (with which to respond) in mind. Therefore not only will a distinction be made between posterior and central areas but also between corresponding and noncorresponding trials while analyzing EEG data.

Although not the primary focus of this paper, this separation of corresponding and noncorresponding trials might also give further insight in the increased variability at the moment of orienting account for the observed differences in laterizations. Because this effect should impact both corresponding and noncorresponding trials for precues, no significant differences in negativity between this condition should be observed.

While using horizontal stimuli, two other ERP laterizations are generally observed at central electrodes (e.g. C4/3), LRP and N2cc. Whereas the LRP is associated with movement

related ERP activity originating from the primary motor cortex (e.g. Eimer, 1998), the N2cc was recently associated with preventing responses based on stimulus position and is likely to stem from the premotor cortex. Research indicates a double dissociation exists between N2pc and N2cc, and it is suggested the latter is responsible for the Simon effect (Cespón, Galdo-Álvarez, & Díaz, 2012). The LRP and N2cc components have a significant overlap and are both expressed by a lateralized negativity over central electrodes. Distinguishing between activity originating in these two cortices is however beyond the purpose of this study.

Therefore central contralateral negativity is viewed as a general measure of action, in which preparation and execution are taken together. Importantly, because stimulus and response side differ for noncorresponding trials, the way lateralized ERPs are computed should result in positivity instead of negativity

In the current task for postcues, target and cue appear simultaneously. While considerable time remains between the onset of the cue and the target (1300 ms) in case of precues, thereby separating perception and action. This leads to a hypothesis that can be tested using EEG. If the increased perception-action cycle account were to be true, the more pronounced posterior negativity should be accompanied by a more pronounced central negativity and positivity for respectively corresponding and noncorresponding trials for postcues when compared to precues.

In addition to the variability at the moment of orienting and the increased perception-action hypotheses, the final hypothesis assumes that the added attention that is needed for the hand on top of the attention for the stimulus, results in more pronounced posterior laterization for postcue compared to precue trials. However, as mentioned before, this should only be the case for corresponding trials. Because for noncorresponding trials the processing of stimulus and hand location should not occur in the same hemisphere. Importantly, none of these hypotheses excludes another.

2. Methods

2.1. Participants

Sixteen participants were drafted from the local student population and received course credit for their participation. Two participants were excluded from analysis due to procedural errors and four more were removed for having artifacts in their EEG (see EEG data analysis), which left ten participants (nine right-handed, one left-handed, mean age 19.2 years, five women and five men). Informed consent was obtained from all participants, none of the participants reported any history of neuronal disease and all had normal or corrected to normal vision. The study was approved by the ethics committee of the faculty of Behavioral Sciences.

2.2 Stimuli and procedure

Participants were shown stimuli on a 16 inch monitor at a distance of 40 cm in a dimly lit room. A default screen consisted of a black background with a white fixation dot in the center accompanied by four unfilled white dots at 26.6° from each corner of the screen. A trial commenced with the default screen appearing for 700 ms followed by the word 'left' or 'right' in the center for 400 ms. This last screen indicated the required response key in case of Go trials. After 600 ms two possible order of events occurred based on two conditions.

In the precue condition a rhomb appeared in the center for 1000 ms consisting of a green and a red triangle pointing either to top left and bottom right or top right and bottom left corner. Participants had to attend one of the unfilled circles based on the defined relevant color. Then for 200 ms, two of the lateral circles were filled white, one in the left and one in the right field, resulting in four possible situations. If the attended circle was filled ("Go"), participants had to press the key indicated at the start of the trial. In case of an unfilled circle ("Nogo"), no response should be given. The default screen reappeared 300 ms after the circles

were filled.

In contrast, the postcue condition starts with filling two lateral circles, one at each side, also resulting in four possible situations. After 1000 ms the rhomb was added, indicating the possibility of participants to attend a circle based on the relevant color of the side of the rhomb also leaving participants with a decision to respond or not. Finally, the default screen appeared after 300 ms. In both conditions the following trial started after 900 ms. Presentation software was used on a PC presenting the stimuli and an experimenter was in the room the whole experiment to answer questions and check the procedure.

2.3 Task

Participants were asked to attend a circle based upon the color of the relevant part of the rhomb. Both conditions consisted of two blocks in which either green or red side of the rhomb was marked as relevant. The order of the color blocks remained the same for both conditions, but was counterbalanced between participants. Counterbalancing was also used in the order of the precue and postcue conditions. Participants were asked to attend the circle indicated by the relevant part of the rhomb while keeping their gaze on the center point. Responses were to be made with left and right index fingers on respectively left and right “shift” keys on a standard QWERTY keyboard. Chances for Go and Nogo trials were distributed evenly (50% each), whereby false key presses or key presses at a Nogo trial resulted in an “Incorrect” message.

Both cue conditions consisted of two color blocks of 256 trials each. Trials consisted of: relevant stimulus position (4) × hand (2) × Go/Nogo (2). Resulting in 1024 trials with each combination repeated 16 times. Participants were given 32 practice trials before each block and they could take a short break halfway each block. All four blocks were completed in approximately 80 minutes. Participants were asked to keep their gaze on the center point, to respond as fast and accurately as possible for Go trials and withhold action on Nogo trials.

2.4 Data acquisition

Brain Vision Recorder software continuously measured EOG, EEG, digital codes signaling the onset of events and behavioral responses at a sample rate of 500 Hz. Using the locations of 10-20 system with a QuickAmp 72 amplifier (BrainProducts) EEG was registered from 61 Ag/AgCl electrodes. Bipolar Ag/AgCl electrodes located on the outer canthi of the eyes and from above and below the left eye measured horizontal and vertical EOG. Electrode resistance was kept below 5 k Ω .

2.5 Behavioral data analysis

In the precue condition keypresses were considered correct when they were made within 100 to 1000 ms after the filling of the circles or after onset of the rhomb in the postcue condition. For correctly responded trials without detectable eye-movements (see EEG data analysis) the reaction times (RTs) were registered. Trials were marked corresponding when the side of the stimulus and the side with which to respond (hand) corresponded and noncorresponding when these sides did not. Finally, mean RT and percentage of correct trials (PCs) were computed for all conditions. For the reaction times, a repeated measures ANOVA was carried out with the factors timing of the cue (precue/postcue) and correspondence (corresponding/noncorresponding). The same analysis was done for correct responses (PCs).

2.6 EEG data analysis

EEG and EOG were cut into epochs of 3000 ms and started 500 ms before onset of the word that indicated with what hand to react and a baseline was set from 500 ms before word onset. Segments in which horizontal EOG movements exceeded ± 60 μV , were removed from 0 to 1300 ms after onset of the precues until offset from the target, or after filling the circles in the postcue condition until offset from the postcue. Participants who lost more than 33% of their trials due to horizontal EOG movements. Segments containing artifacts were excluded

from further analysis. Behavioral data analysis was only applied for segments without horizontal eye movements and within the time intervals mentioned above. Next, both pre- and postcue were divided into lateralized EEG potentials as a function of the to-be-attended side. This allowed dividing trials into corresponding and noncorresponding conditions for all homolog electrode pairs. For instance for the C4/3 electrode pair the following procedure was used for corresponding trials: [left hand, attend left (C4-C3) + right hand, attend right (C3-C4) / 2] and for noncorresponding trials: [right hand, attend left (C4-C3) + left hand attend right (C4-C3) / 2]. A new baseline was applied from -100 to 0 ms before cue onset.

3. Results

3.1 Behavior

Mean RTs and PCs for all conditions are displayed in Table 1. Responses were faster for precues (397 ms) compared to postcues (414 ms), $F(1,9) = 15.7$, $p < 0.005$, and faster for corresponding (386 ms) than for noncorresponding trials (425 ms), $F(1,9)=8.0$, $p < 0.05$. An interaction effect was found between timing of the cue and correspondence, $F(1,9)=19.8$, $p < 0.005$. A small, not significant Simon effect (19 ms), was found for precues, $F(1,9)=2.2$ and a large Simon effect (58 ms) was found for postcues $F(1,9)=14.1$, $p < 0.005$. No significant effects were found in the timing of the cue, correspondence or their interaction for PC's.

Additionally no significant Simon effect was observed for PC's.

Table 1

Mean RTs (ms) and PCs (in % for Go trials) with their standard errors (enclosed in brackets) as a function of the timing of the cue (pre- or postcue) for both corresponding (Corr) and noncorresponding (Ncor) trials.

Timing of the cue	Reaction times		Percentage correct	
	Corr	Ncor	Cor	Ncor
Precue	387 (152)	407 (124)	99.6 (0.64)	99.5 (1.07)
Postcue	385 (147)	443 (141)	98.7 (2.04)	99.0 (1.03)

3.2 EEG

For the C4/3 electrode pair a repeated measures ANOVA from 180 to 280 ms after target onset with the within-factor timing of the cue was done. No effects were found.

Including the factor correspondence lead to an interaction effect between timing of the cue and correspondence, $F(1,9)=24.5$, $p < 0.002$, for the C4/3 electrode pair. This effect is shown in Fig. 2. Additionally performing a one-sided t-test against zero, reflects a negativity for corresponding trials in the postcue condition $t(9)=-3.3$, $p < 0.005$ and a positivity in the precue condition, $t(9)=2$, $p < 0.05$ (see table 2). The onset of negativity in the inspection of EEG data

suggests using a timeframe closer to cue onset for the C4/3 electrode pair but further statistical analysis in the 105 to 280 ms timeframe did not result in differences, compared to the first used timeframe.

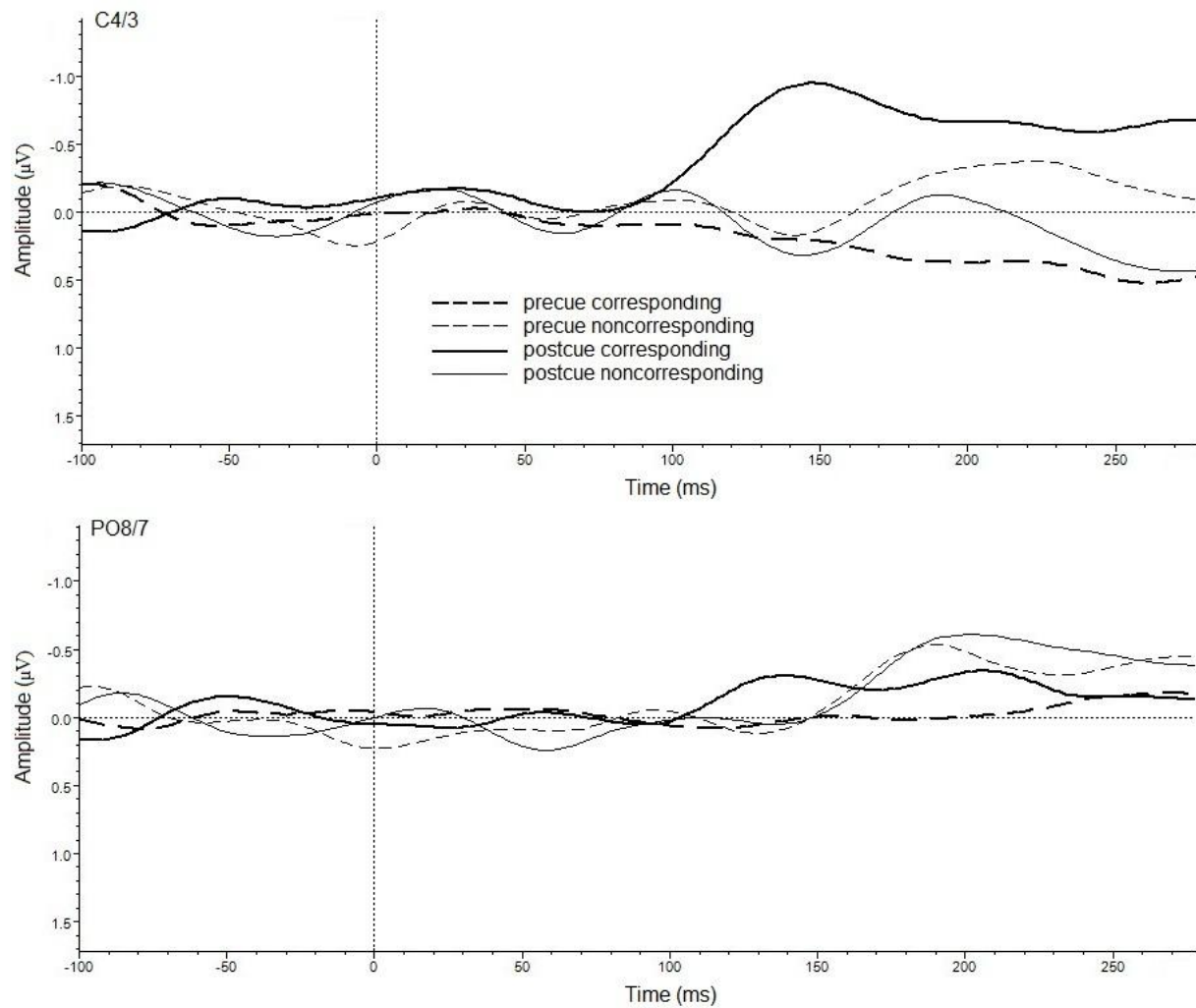
Applying a repeated measures ANOVA on the PO8/7 pair from 180 to 280 ms after target onset resulted in no significant effects, implying neither timing of the cue nor correspondence differed significantly in this sample (see Fig. 2). Performing a one-sided t-test against zero replicated an N2pc for precue noncorresponding trials, $t(9)=-2.7$, $p < 0.02$ and for postcue noncorresponding trials, $t(9)=-2.1$, $p < 0.05$ (see table 2). Inspection of the EEG suggests the onset of corresponding postcue negativity was likely before 180ms, however expanding the timeframe to 105-280 and reanalyzing the data with a one-sided t-test against zero did not result in a significant negativity.

Table 2

t-values (df=9) followed by one-tailed significance levels (n.s. is not significant) on mean lateralized electrode activity tested against zero in the 180-280 timeframe as a function of the electrodepair and correspondence.

Timing of the cue	C4/3				PO8/7			
	Corr		Ncor		Cor		Ncor	
Precue	2	$p < 0.05$	-1,7	n.s	-0,6	n.s.	-2,7	$p < 0.02$
Postcue	-3,3	$p < 0.005$	0,7	n.s	-1,7	n.s.	-2.1	$p < 0.05$

Laterizations for the C4/3 and PO8/7 electrode pairs

**Fig. 2**

EEG laterizations for the C4/3 and PO8/7 electrode pair after presenting the pre- and postcues. The baseline was set -100 ms to 0 ms before presenting the cues. A distinction is made between timing of the cue (solid/dashed line) and correspondence (gray/black line).

4. Discussion

The goal of the current study was to investigate the cause of differences observed in posterior contralateral negativity found in the timing of the cue by reexamining data obtained in Van der Lubbe et al. (2012). Three hypothesis were put to the test. First if differences in the moment of orienting were to have an effect on precues, this would impact both corresponding and noncorresponding trials for posterior electrodes. Second the perception-action cycle account expected central differences in amplitude to accompany the posterior negativity for postcues. And finally more pronounced corresponding trials for precues would support the added hand attention hypothesis.

Although weak negativities can be observed in the EEG, posterior contralateral negativity only reached significance for noncorresponding trials. No effect of timing of the cue or correspondence was observed, thereby not replicating the results of Van der Lubbe et al. (2012). This may have been the result of a significant loss of trials due to the exclusion of participants. Additionally, distinguishing between correspondence cut the amount of trials per condition in half, leading to a decreased signal-to-noise ratio.

The greater significant negativity in noncorresponding precues compared to noncorresponding postcues and more importantly the absence of significant negativity for corresponding postcues for the PO8/7 pair suggests however that an increased perception-action cycle account for the previous observed differences is unfavorable. Because postcue negativity was expected to exceed precue negativity. In addition, a significant central negativity was only observed for corresponding postcues which was not replicated at posterior sites.

Another implication of the significant posterior negativity for noncorresponding precues is that increased variability at the moment of orienting for precues is not a likely cause for the previously found differences in negativity. Variability at the moment of

orienting would impact both corresponding and noncorresponding precue trials, but the newly obtained data provide clear evidence against this hypothesis. Also, the current data shows the added hand attention hypothesis seems unlikely, as noncorresponding postcues showed a greater negativity than their corresponding counterparts.

Interestingly, the current data shows a small Simon effect (19 ms) for precues whereas no such effect (0 ms) was found by Van der Lubbe et al. (2012). Because the same data was used, this means that this difference might be attributed to a bias in the exclusion of participants. First of all, the current study rejected participants when they did not pass a artifact-free threshold based on eye-movements. In contrast, the original study only rejected segments. Second, due to the added interest in central electrodes in the current study, a participant who showed exclusive artifacts over central areas was excluded in the current but not in the original study. The steeply increased standard error in the current (~140) compared to the original study (~34) and the small amount of participants renders speculation about the cause of the increased Simon-effect unnecessary.

In sum, the lack of trials due to exclusion of participants on the basis of both procedural errors as well as EEG artifacts was reflected in clouded effects. Nonetheless evidence against all accounts proposed in the current study for differences in the lateralized posterior negativity found by Van der Lubbe et al. (2012), was obtained. The data suggests future temporal separation of perception and action as was done in the present study should give additional insight on the N2pc, although using more participants is strongly advised.

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