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Proactive and reactive sequential effects on selective attention

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ABSTRACT

Sequences of events can affect selective attention either through proactive mechanisms, through reactive mechanisms, or through a combination of the two. The current study examined electrophysiological responses to both prime and target stimuli in a primed dichotic listening task. Each trial presented a distractor prime syllable followed by two simultaneous syllables, and participants were asked to report one of the simultaneous syllables. Trials where the participant reported the non-primed syllable showed more negative event-related potentials at prime presentation, which may indicate inhibition of the prime representation. Trials where the participant reported the primed syllable showed more negative event-related potentials at target presentation, which may indicate cognitive conflict and effortful response selection. In context of current theories, the data suggest that the interplay of a proactive inhibition bias and a reactive potential for conflict is involved in causing sequential effects on selective attention mechanisms.

1. Introduction

Research on trial-to-trial modulation of responses has shown that subtle changes in a task context or task behavior can influence subsequent response times, response choices and activated brain regions (Sætrevik & Specht, 2009, 2012; Weissman, Roberts, Visscher, & Woldorff, 2006). There are converging findings from different experimental settings, including task switching (Kiesel et al., 2010; Monsell, 2003; Yeung, Nystrom, Aronson, & Cohen, 2006), negative priming (de Fockert, Mizon, & D'Ubaldo, 2010; Egner & Hirsch, 2005) and conflict adaptation (Danielmeier & Ullsperger, 2011; King, Korb, von Cramon, & Ullsperger, 2010; Ullsperger, Bylsma, & Botvinick, 2005), although the exact mechanisms might vary across paradigms.

The leading account of such sequential effects has been based on biased competition models of attention (Botvinick, Braver, et al., 2004; Desimone & Duncan, 1995; Gazzaley & Nobre, 2012; Miller & Cohen, 2001), which emphasize the interplay of cognitive mechanisms controlling information processing flow and mechanisms detecting conflicts in information processing. Such models suggest that goal oriented behavior is controlled by a neural network that includes a set of *pathways* that associate stimuli with responses, and a *cognitive control set* that biases the activation level of these pathways in order to achieve the aims according to the task set. The pathway attaining the highest level of activation comes to represent the selected response. Co-activation of more than one pathway, e.g. due to input from two equally salient stimuli (Petersen & Petersen, 1988; Spreen & Benton, 1969) or in situations where the participant is asked to act in opposition to a dominant response (e.g. having to name the color of a word rather than reading it in the Stroop task, Stroop, 1935), implies a risk for crosstalk interference, which is registered by a *conflict set*. Activation of the conflict set has a propagating effect of increasing the engagement of the cognitive control set, thus self-regulating the amount of control according to needs. Cognitive control can amplify the processing of one part of the network and/or inhibit processing in another part of the network. The conflict registration set and the control set have been argued to be separable mechanisms in the human attention system, located in medial and dorsolateral frontal cortex, respectively (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004). Such models have been argued to explain behavioral, neuroimaging and modeling results in a number of experimental tasks (Botvinick, Braver, et al., 2004; Botvinick, Cohen, et al., 2004; Jones, Cho, Nystrom, Cohen, & Braver, 2002).

To account for sequential effects, it may be assumed that cognitive control's network modulation endures after the initial processing is complete, so that network weights are retained at the onset of new stimuli, and thus influence the baseline for further processing (Sætrevik, 2012). In more detail, the sequential effect may instantiate through proactive mechanisms, reactive mechanisms or a combination of the two. A proactive mechanism would focus on the effect the processing at time t has in setting up a network state with a differentiated baseline for response processing at a later time t^{+1} (e.g. by increasing or decreasing activation levels of

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different processing pathways). A reactive mechanism would focus on how the processing at time t^{+1} may conflict with network state retained from time t, and how the conflict may lead to recruiting additional cognitive control resources. Thus both mechanisms involve information from two time points, but while a proactive account suggests that the processing during prime presentation determines sequential effects, a reactive account suggests that processing during target presentation is critical.

The *primed dichotic listening task* (Sætrevik & Hugdahl, 2007a, 2007b; Sætrevik & Specht, 2009) has shown effects indicating sequential modulation of attention in an ambiguous response selection situation. The task instructs participants not to pay attention to a distractor prime syllable presented binaurally (equally to both ears) and to report the most clearly perceived syllable from a subsequent dichotic pair of target syllables (different syllables presented simultaneously, one to each ear). Behavioral responses show that participants are less likely to attend targets that repeat a syllable that was recently presented as an ignored prime (Sætrevik & Hugdahl, 2007b). This effect has also been found when using a cross-modal prime (Sætrevik & Hugdahl, 2007b), and when the participant is instructed to attend a given side, the priming effect interacted with selective attention (Sætrevik & Hugdahl, 2007a).

The response pattern in the *primed dichotic listening task* may be due to proactive inhibition of the mental representation of the task-irrelevant binaural prime syllable in order to facilitate processing of the task-relevant dichotic syllables. The inhibition involved in ignoring the prime may have a residual effect that influences the processing of the dichotic target stimuli, thus constituting a proactive mechanism. A recent fMRI study using the *primed dichotic listening task* (Sætrevik & Specht, 2009), supported this model by showing that medial frontal cortex activation increased on trials where one of the dichotic syllables repeats the distractor prime, indicating increased cognitive conflict when attending a recently ignored stimulus. At the time of target onset, the representation of the repeated stimulus is less activated than the representation of the non-repeated target stimulus, which manifests as a response bias for selecting the non-repeated stimulus. Responses that follow this inhibitory bias (*prime ignored* trials) represent more fluent reactive target processing than responses not following the bias. Trials where the participant responds by selecting the target repeating the distractor prime syllable (*prime reported* trials) may reflect more effortful processing since they require changing stimulus–response bindings from inhibiting the prime to attending the same representation, which would cause increased cognitive conflict (Spapé, Band, & Hommel, 2011). In this account, adjusting network weights in order to minimize response-processing conflict constitutes a reactive mechanism. Such a mechanism was indicated in the aforementioned fMRI study (Sætrevik & Specht, 2009), where right ventrolateral gyrus activation increased on *prime ignored* trials, which may be associated with successful inhibition of the prime, while dorsal medial frontal and left frontal cortex activation increased on *prime reported* trials, which may be associated with cognitive conflict and more effortful response selection. The above account thus includes both proactive and reactive mechanisms, in contrast with competing accounts that attempt to explain sequential attention effects as being due to proactive mechanisms alone (e.g. the distractor inhibition account of negative priming, Houghton & Tipper, 1994; Tipper, 1985), or reactive mechanisms alone (e.g. the episodic retrieval account, Mayr & Buchner, 2007; Neill, Valdes, Terry, & Gorfein, 1992).

However, fMRI's poor temporal resolution makes it difficult to say whether the observed activations are associated with the processing of the binaural prime, processing of the dichotic target stimulus, or if they reflect processes related to both prime and target processing. In order to temporally disentangle the effects, the current experiment collected electrophysiological data from participants performing the *primed dichotic listening task*. Brain responses to both prime and target stimuli were analyzed according to three conditions: the prime syllable matched one of the dichotic targets and was reported (*prime reported*), the prime matched one of the syllables of the dichotic target and was not reported (*prime ignored*), or the prime did not match any of the two syllables of the dichotic target (*control* condition, regardless of response). We expected the most dominant ERP effects to occur centrally between 200 and 400 ms post-stimulus onset for both prime and target. In this time frame, negative deflections (referred to as N200s) are linked to various processes of cognitive control (see Folstein and Van Petten (2008) for a review). Thus, the analysis will focus on ERPs occurring along the midline at 200–400 ms after prime and target presentation, although other components will also be screened for. The sequential response effects reported in previous studies using the primed dichotic listening task, may be due to either proactive, due to reactive mechanisms, or due to both working in concert. If proactive mechanisms (e.g. prime inhibition) determine sequence effects mainly by setting up a baseline for target processing, we expect to see increased Cz N200-like activity in the prime window for trials where the response indicates sequential attention modulation (i.e. the *prime ignored* trials). Alternatively, if the sequence effect in this task is mainly due to stimuli constellations activating cognitive conflict in target processing, we expect Cz N200-like activity to increase in the target window for responses that are incompatible with the stimulus–response binding indicated by the instructions (i.e. the *prime reported* trials).

2. Methods

2.1. Participants

Fifteen undergraduate students (ten female, five male) aged 20–30 participated in the study. All were right handed (as measured by the Edinburgh Handedness Inventory, Oldfield, 1971), had Norwegian as first language, had normal hearing (tested with audiometer screening), and reported no history of neurological or psychiatric illness. One male participant was excluded from analysis because response patterns and information volunteered during debrief indicated that the task instructions had not been followed, and one female participant was excluded due to overall error rates exceeding 15%.

2.2. Stimuli

The experiment used consonant–vowel syllables consisting of the six stop-consonants and the vowel "a", constituting the syllables /ba/, /da/, /ga/, /pa/, /ta/ and /ka/. Six wave format sound files from the "Bergen dichotic listening task" (Hugdahl, 1995) were used. Each syllable is pronounced by a Norwegian male voice, has a duration of 450–500 ms of which the consonant constitutes approximately 70 ms, and is aligned in order to have initial energy release at the same latency after file onset. For prime stimuli, one syllable was presented equally to both headphone channels (binaural presentation). For target stimuli, two different syllables were presented simultaneously, one in each headphone channel (dichotic presentation). All six prime syllables were combined with all 30 pairs of different dichotic syllables.

2.3. Apparatus

Participants were seated in an armchair in a sound and radiation attenuated chamber. Auditory stimuli were presented through a pair of closed system headphones (Sennheiser HD250 linear II), and visual stimuli were presented on a 17″ CRT monitor running