International Journal of Psychophysiology 75 (2010) 339–348

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Flanker negative priming from spatially unpredictable primes: An ERP study

Henning Gibbons [a,*], Christian Frings [b]

[a] Georg-August University of Göttingen, Germany
[b] Saarland University, Saarbrücken, Germany

ARTICLE INFO

Article history:
Received 20 August 2009
Received in revised form 22 December 2009
Accepted 5 January 2010
Available online 14 January 2010

Keywords:
Human subjects
Event-related potentials
Negative priming
Distractor inhibition
Flanker task

ABSTRACT

In a typical flanker task, a to-be-selected central target is flanked by two to-be ignored, identical distractors. The flanker negative priming (NP) effect denotes increased reaction time and error percent when the distractor of a first display serves as the target in the next. Most theories of NP are consistent with the idea that during processing of the first display, the identity of the distractors is inhibited. If the target of the subsequent display has the same identity, NP occurs because of persisting or retrieved inhibition. However, in the standard flanker task stimuli appear at the same screen locations for all trials, allowing for anticipatory spatial selection. No strong additional inhibition of stimulus *identities* may then be required. Therefore, besides the standard flanker task we employed a modified task in which the location of the stimulus triplet slightly differed across trials, thus disabling spatial pre-selection. Event-related potentials (ERPs) were recorded to identify brain correlates of NP in the two tasks. Behavioral NP was present in the modified task but absent in the standard task. An ERP correlate specific to NP in the modified task concerned larger amplitude of a left-posterior processing negativity. Results support the idea that stronger inhibition of distractor identities contributes to NP in the flanker task when spatial pre-selection is disabled.

1. Introduction

It is well accepted that, if a to-be-ignored stimulus (distractor) from a first prime display becomes the to-be-selected stimulus (target) in a subsequent probe display, then a person's response to this target will be impaired in terms of latency and/or accuracy (Dalrymple-Alford and Budayr, 1966). This phenomenon has been labeled negative priming (NP; Tipper, 1985).[1] NP is a robust empirical finding which has been observed in a wide variety of different tasks, stimuli, and populations (see Fox, 1995; Tipper, 2001, for reviews). For example, in a typical NP task based on the flanker task (Eriksen and Eriksen, 1974), participants respond to the identity of a central target stimulus (e.g., a digit) which is flanked by two identical distractor digits different from the target. In the *ignored-repetition* (IR) condition, the prime distractor serves as the target in the subsequent probe, whereas in the *control* condition no prime digits are repeated in the probe. The NP effect is computed as the difference in RT and/or error percent between IR and control conditions.

A coarse-grained taxonomy of NP theories differentiates between persisting-inhibition (e.g., Frings and Wühr, 2007; Houghton and Tipper, 1994; Tipper, 1985) and episodic-retrieval accounts (e.g., Mayr and Buchner, 2006; Neill et al., 1992; Rothermund et al., 2005). Inhibition theory assumes that, in identity-based NP tasks, the distractor stimulus identity is actively suppressed by mechanisms of selective attention during the processing of the prime display and that this inhibition persists until the next display. Thus, when in the IR condition the prime distractor serves as the target of the subsequent probe, a still-inhibited representation has to be activated in order for the participant to respond, and this causes the NP effect.

By contrast, retrieval theories argue that NP is due to the fact that perceiving a target activates memory traces associated with that particular stimulus. In the IR condition, the last memory trace of the current target stimulus may contain information like "distractor" or "do-not-respond" (Neill et al., 1992), or it will retrieve the (incompatible) prime response (Rothermund et al., 2005). This information then interferes with a person's ability to respond quickly and accurately to the target. Both accounts are well supported by the literature, and several authors concluded that both persisting inhibition and episodic retrieval may contribute to NP (see Kane et al., 1997). Note however that both frameworks are compatible with the idea of *distractor inhibition* as a major source of NP (Tipper, 2001).

---

* Corresponding author. University of Göttingen, Institute for Psychology, Department of Biological Psychology of Personality, Gosslerstr. 14, D-37073 Göttingen, Germany. Tel.: +49 551 398198.
E-mail address: hgibbon@uni-goettingen.de (H. Gibbons).

[1] It should be emphasized that, although the present study investigated the effect of a spatial manipulation on NP, it is still concerned with identity-based NP and not with spatial NP (or, NP from localization tasks). In visuo-spatial NP, pre-defined targets have to be localized, that is, a button has to be pressed that spatially corresponds to the location of the target on the screen ("select what, respond where", cf., Tipper et al., 1990). By contrast, in the present flanker task – even in the modified varied-locations variant – the correct response critically depends on the identity of the central stimulus ("select where, respond what"; cf. Tipper et al., 1990). In general, the distinction between identity-based and location-based (spatial) NP is an important one because different mechanisms seem to be involved (Fox, 1995; May et al., 1995).

0167-8760/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpsycho.2010.01.004

According to Tipper (2001), the original episodic-retrieval (e.g., Neill et al., 1992) and persisting-inhibition views (e.g. Tipper, 1985) may only differ with respect to the assumption of whether inhibition allocated to the prime distractor is actively reinstated by a retrieval mechanism during probe processing, or passively persists from the prime to the probe.

Recently, there have been attempts to use event-related potentials (ERPs) to enhance our understanding of the processes involved in NP. In the following, we briefly summarize this literature (see Mayr and Buchner, 2007, for a review). Mainly three different ERP components have been found sensitive to visual NP. First, NP-related enhancement of (frontal) N200 components was observed in target identification (Frings and Groh-Bordin, 2007; Hinojosa et al., 2009) and target localization (Gibbons, 2006) tasks. Also Daurignac et al. (2006) found NP in a number conservation task similar to those of Piaget to be accompanied by larger N200. Generally, the N200 NP effect was assumed to reflect persisting inhibition. For example, Frings and Groh-Bordin (2007) suggested that in IR trials the still-inhibited probe target has to be selected against non-inhibited probe distractors. Since this persisting inhibition may already affect *early* probe processing, it implies the risk that IR probe distractors can quickly activate their associated response. This may require immediate response inhibition and hence can explain the frontal N200 (cf., Eimer, 1993; Heil et al., 2000).

Second, in several studies a modulation of the P300 complex was observed. For example, Kathmann et al. (2006) reported larger P300 amplitude to accompany identity-based NP. This finding was interpreted as reflecting increased attentional resources to be required for the processing of IR probe displays. Although the authors originally did not draw this conclusion, larger P300 seems well in line with persisting-inhibition view of NP (cf., Stahl and Gibbons, 2007). However, three studies (Gibbons, 2006; Gibbons, 2009; Stahl and Gibbons, 2007) found NP-related P300 amplitude *reduction* in flanker-like identification tasks, which was interpreted as a correlate of retrieval processes. More specifically, it was argued that smaller P300 reflects perceived prime–probe similarity which may correspond to a central concept of episodic-retrieval theories, i.e., the “retrieval cue”. Interestingly, also with auditory NP tasks smaller late posterior positivity in the IR condition was found (Mayr et al., 2003, 2006), and interpreted as support for episodic-retrieval view.

A third ERP correlate of NP was recently reported by Gibbons (2009) who employed a flanker task and distinguished reduced amplitude of left-posterior early P300 (300–400 ms; this finding was not specific to the IR condition, see below) from an *IR-specific* P300 amplitude reduction in a later time range (400–500 ms). This latter effect was interpreted as an N400-like processing negativity which overlapped the late P300 time range specifically in the IR condition and may reflect more effortful processing.

The present study aimed at testing a prediction that can be derived from the notion of distractor inhibition being a major source of NP (cf., Tipper, 2001). To be specific, a strong anticipatory spatial selection component can be assumed to be at work in the standard flanker task. With all triplets appearing at the center of the screen, selection can benefit from inhibition of *any* information at the fixed lateral flanker locations. Moreover, the more effective this spatial (stimulus-unspecific) inhibition, the less additional (stimulus-specific) distractor inhibition should be required for successful target selection. Note that only the latter, stimulus-specific inhibitory component of selection would contribute to a flanker NP effect that is caused by distractor inhibition. Interestingly, with fixed and therefore predictable locations of the flanker triplets, NP diminished to a non-significant level when the distance between target and flankers was too large (Fox, 1994; Ruthruff and Miller, 1995). In sum, it can be concluded that the standard flanker task with fixed locations may not provide optimal conditions for the investigation of a possible distractor-inhibition component of NP.

We therefore developed a modified, *varied-locations* variant of the flanker task, with locations of the stimulus triplets slightly differing between subsequent trials (here, “trial” refers to a pair of consecutive prime and probe displays). Whereas the probe always appears in exactly the same screen location as the preceding prime, locations may slightly change between a probe and the next prime. Thus, anticipatory inhibition of the upcoming prime distractor locations is disabled. With this modified task, then, the prime distractors should no longer suffer from *a-priori* processing disadvantage caused by their appearance in already spatially inhibited screen locations. This should result in deeper processing of the prime distractor stimuli (i.e., their identity-specific conceptual representations are more strongly activated) before they are eventually inhibited when the prime target is selected. According to Houghton and Tipper (1994), stronger initial distractor activation should call for stronger subsequent distractor inhibition. If distractor inhibition is indeed a major source of NP, this should result in a stronger NP effect in the modified, varied-locations task, compared to the standard, fixed-location task.

Against this background, the present study aimed at a comparison of behavioral NP effects and ERP correlates of NP in the two tasks, to further investigate the role of inhibition of distractor identities in NP. The first prediction relates to larger behavioral NP for the varied-locations compared to the fixed-location task. Moreover, the larger NP effect in the modified task should have a distinct ERP correlate which is not observed in the fixed-location task. Given the above considerations about an inhibitory mechanism operating at a relatively *advanced level of distractor processing*, one would expect late-range ERP correlates. By contrast, NP in the varied-locations task may not be accompanied by early ERP effects in the N200 time range (e.g., Frings and Groh-Bordin, 2007). As noted earlier, N200 effects may indicate inhibition of the response associated with the distractors in IR probe displays, and hence be specific to NP operating at relatively early levels of processing, causing advantage for the probe distractors over the still-inhibited IR probe target early during probe processing.

Examples of late-range ERP correlates of visual NP concern P300 amplitude modulations (e.g., Kathmann et al., 2006; Stahl and Gibbons, 2007) or amplitude increase of an N400-like processing negativity (Behrendt et al., in press; Gibbons, 2009); similar findings can be expected for the present modified flanker task with variable prime locations. According to Donchin and Coles (1988), P300 reflects the effort with stimulus identification. For example, unexpected stimuli evoke a larger P300 because their internal representations are not pre-activated in a given context. Critically, distractor-inhibition accounts of NP predict that the representation of an IR probe target can be less easily activated, either because inhibition of this representation has persisted from the prime, or is reactivated during probe processing. Thus, like in Kathmann et al.'s (2006) study, larger P300 may accompany the present NP effect, particularly in the varied-locations task designed to strengthen the distractor-inhibition component of NP.

However, more effortful processing can also manifest itself in *reduced* P300 amplitude caused by a processing negativity (PN) overlapping the P300 time range (Kok, 2001). This interpretation was suggested by Gibbons (2009) for his late-range (400–500 ms), left-posterior ERP correlate of flanker NP. Importantly, the PN could be distinguished from an early (300–400 ms) P300 amplitude reduction in the IR condition, which had similar topography but was also found in yet another priming condition, the attended-repetition (AR) condition. In the AR condition the prime target is repeated as the probe target, which usually results in a strong facilitation of responding known as positive priming (PP). Therefore, the joint AR/IR effect on early P300 reported by Gibbons (2009) cannot be an index of more effortful processing in the IR condition. Interestingly, unlike the early P300 effect, the late P300/PN effect was functionally related to behavioral NP, insofar as it was more pronounced in participants showing an above-median individual behavioral NP effect. For the varied-locations task, therefore, NP effects on late P300/PN can be expected, but should be carefully distinguished from AR effects in this time range.