available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

ELSEVIER

BRAIN RESEARCH

Research Report

# Cognitive load reduces visual identity negative priming by disabling the retrieval of task-inappropriate prime information: An ERP study

*Henning Gibbons*[a,*], *Jutta Stahl*[b]

[a]*Department of Medical Psychology and Medical Sociology, University Medical Center Göttingen, Waldweg 37, D-37073 Göttingen, Germany*
[b]*Department of Psychology, University of Köln, Köln, Germany*

ARTICLE INFO

*Article history:*
Accepted 6 March 2010
Available online 15 March 2010

*Keywords:*
Visual stimuli
Identity negative priming
Event-related potential
Cognitive load
Episodic retrieval

ABSTRACT

The present event-related potentials (ERP) study investigated the mechanisms by which cognitive load reduces the negative priming (NP) effect in a letter flanker task. On each trial, participants ($N=20$) first encoded a set of one to five digits, then responded to two successive flanker displays (prime, probe), and finally recalled a certain digit from the set. The flanker NP effect (i.e., increased probe RT when the prime distractor repeated as the probe target) was significant under low (1–2 items) but not high cognitive load (4–5 items). NP in the low-load condition was accompanied by left-anterior P2/N2 amplitude modulation which was also observed for prime–probe target repetitions and hence may reflect the processing of prime–probe similarity. Under high load, the P2/N2 effect was absent. It is suggested that cognitive load interferes with a retrieval-based mechanism in NP. Findings support episodic-retrieval explanations of visual identity-based NP.



## 1. Introduction

Efficient goal-directed behavior requires preferential processing of relevant stimuli. In principle, this can be achieved by two different mechanisms, facilitation of relevant and inhibition of irrelevant information. Evidence for an inhibitory component of selective information processing seems to come from the negative priming (NP) phenomenon (Tipper, 1985). In a typical NP task, pairs of subsequent presentations (prime, probe) are considered which both contain a to-be-selected target and a to-be-ignored distractor. NP refers to an increase in response time (RT) and/or error percent in an ignored-repetition (IR) condition in which the prime distractor repeats as the probe target, compared to a control condition in which all probe stimuli are novel with respect to the prime[1]. Inhibition theory of NP (Houghton and Tipper, 1994; Neill, 1977; Tipper, 1985) holds that the prime distractor is actively inhibited during prime selection. Inhibition is assumed to persist until the probe, which in case of IR trials impairs the selection of the still-inhibited probe target.

An alternative explanation of NP comes from episodic-retrieval theory (Neill et al., 1992). Accordingly, probe stimuli that repeat from the prime trigger the retrieval of the prime episode. In case of IR trials, this episode contains information that describes the probe target as irrelevant (a so-called *do not*

[1] Note that this description only applies to NP in identification tasks. Spatial NP which is not addressed by the present study involves the presentation of probe target stimuli in locations that had been ignored during the prime. Furthermore, conclusions from the present study of visual NP may not generalize to the auditory domain.

* *Corresponding author*. Fax: +49 551 3913558.
E-mail address: hgibbon@gwdg.de (H. Gibbons).

0006-8993/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2010.03.022

*respond tag*). The retrieved information interferes with quick responding to the probe target, which explains the NP effect. Note that episodic-retrieval view is not necessarily incompatible with the concept of distractor inhibition, as has been pointed out by Tipper (2001). He argued that NP may result from the episodic retrieval of prior inhibitory states of stimulus representations.

Given compatibility of the concept of distractor inhibition with most theories of NP, it is important to learn more about the mental processes involved. One crucial characteristic of inhibitory processes may be their resource dependence. Support for this assumption was provided by Lavie and colleagues (De Fockert et al., 2001; Lavie, 2000; Lavie et al., 2004) who observed greater distractor interference effects in Stroop-like tasks under high versus low cognitive load. Furthermore, it was shown that an irrelevant but salient singleton distractor more strongly captured attention when working memory was loaded (De Fockert et al., 2004; Lavie and de Fockert, 2005, 2006). This allows for the conclusion that distractor inhibition became less efficient as load increased. Consequently, if NP is considered as an indirect measure of distractor inhibition, one would expect the effect to be reduced under cognitive load.

Evidence supporting this prediction was reported by Engle et al. (1995) and Conway et al. (1999). In their NP task, a red target letter had to be selected against an overlapping green distractor letter. After each prime–probe pair, a to-be-remembered item was presented, and after each five pairs, a test item had to be evaluated for whether or not it matched one of the four previously presented items. Thus, memory load started at zero items for the first NP trial and increased to four items for the last. The general finding was that NP was significant at low loads (load 0 in Conway et al., 1999; loads 0 to 2 in Engle et al., 1995) and absent or even reversed at higher loads.

However, as has already been pointed out by Lavie and Fox (2000, p. 1040), the finding of reduced NP with increasing memory load can also be explained without assuming a diminishing effect on distractor inhibition[2]. In the studies by Engle et al. (1995) and Conway et al. (1999), both prime and probe displays were processed under the same level of memory load. Thus, from an episodic-retrieval point of view it could be argued that NP was reduced because memory load during *probe* processing impaired the retrieval of prime information, thereby reducing behavioral NP without necessarily affecting prime distractor inhibition. To better understand which component of NP is affected, an independent manipulation of memory load during prime as opposed to probe processing would be required. This however implies a substantial change to the NP procedure by which prime and probe displays are separated by either the presentation of to-be-encoded items (if memory load shall be selectively imposed on probe processing), or a test item (if memory load shall be selectively imposed on prime processing). Because differences in NP could be due to the mere presence of these additional stimuli, such a modification of the NP design seems not useful.

In this situation, event-related potentials (ERPs) could be a promising tool for the investigation of load effects on NP, because ERPs can provide online measures of the mental processes at work without requiring changes to the core experimental design. Although recent ERP studies of NP have yielded rather heterogeneous results (see below), this does not necessarily preclude the usefulness of ERPs for NP research. Rather, depending on the experimental task, NP may emerge on different levels of information processing (Neill, 2007) and may reflect contributions from both persisting-inhibition and episodic-retrieval mechanisms (Kane et al., 1997). The heterogeneity of the ERP correlates of NP thus seems to correspond to the multitude of mental processes involved.

Two ERP studies of NP (Frings and Groh-Bordin, 2007; Kathmann et al., 2006) seemed to support an inhibition view. While Frings and Groh-Bordin (2007) reported IR-related enhancement of frontal N2, Kathmann et al. (2006) observed larger P300 amplitude in the IR condition. The former finding is in line with the idea that, on IR trials, the novel probe distractor has an early processing advantage over the still-inhibited probe target. Probe distractors may then quickly access their associated (wrong) response, which calls for response inhibition and is reflected in larger frontal N2 (Eimer, 1993; Heil et al., 2000; Yeung et al., 2004). Regarding the latter finding, a larger P300 amplitude may indicate increased effort with stimulus evaluation (cf. Donchin and Coles, 1988) for IR targets whose internal representations are still in a state of below-baseline activation, due to persisting inhibition.

Other studies on visual identity-based NP suggested episodic-retrieval mechanisms to be effective (Gibbons, 2006, 2009; Gibbons and Stahl, 2008; Stahl and Gibbons, 2007). This conclusion was partly based on a certain pattern of ERP priming effects which, besides the IR condition, also involves the analysis of yet another priming condition called attended repetition (AR). In the AR condition, the prime target repeats as the probe target, which is usually accompanied by positive priming (PP; i.e. shorter RTs and fewer errors compared to control). If the central assumption of episodic-retrieval view is true, that is, if prime stimuli that repeat in the probe do indeed trigger the retrieval of prime information, then one should find *common* ERP effects of AR and IR conditions. This is because in both, AR and IR conditions the probe target is a repeated prime stimulus; consequently, processes related to the detection of prime–probe similarity and/or the subsequent retrieval of prime information should take place in both conditions.

In two studies using a standard visual NP task, the Eriksen flanker task, we observed such an ERP effect in the early P300 time range (300–400 ms); for both AR and IR conditions which did not differ from each other, P300 amplitude was reduced compared to control (Gibbons, 2009; Stahl and Gibbons, 2007). It is worth noting that persisting-inhibition view cannot easily account for identical AR and IR effects on the ERP. Because there should be persisting activation in the former condition, as opposed to persisting inhibition in the latter, information

[2] Lavie and Fox (2000) distinguished between perceptual and cognitive load effects on NP. While these authors predicted a reduction of NP under increased cognitive load, they predicted *larger* NP with increasing *perceptual* load. The argument was that under extreme perceptual load, distractors are not at all processed, don't have to be inhibited, and no NP can occur. Please note however that the present study is exclusively about cognitive load effects.