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Short Communication

Semantic activation, letter search and N400: A reply to Mari-Beffa, Valdes, Cullen, Catena and Houghton (2005)

Jan-Henryk Dombrowski, Martin Heil*

Institute of Experimental Psychology, Heinrich-Heine-University, Universitaetsstr. 1, 40225 Düsseldorf, Germany

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ABSTRACT

From a behavioural point of view, the automaticity of semantic activation was denied because letter search eliminates semantic priming effects on RT. From a neuroscience point of view, two recent studies used the N400 to test this claim with antithetic results. Here, we replicate N400 priming effects in the letter search task. The negative results might be traced back to the use of an inappropriate reference electrode. Thus, the theory of semantic activation being an automatic process should not be abandoned prematurely.

The processing of meaning (semantic activation, SA) when reading a word is considered an automatic process, i.e., one that occurs without intention or awareness, requires no limited-capacity resources and is uncontrollable (Neely and Kahan, 2001). Priming procedures are used to demonstrate SA. Target word processing is facilitated if a semantically associated prime is presented before (semantic priming) or if the target is a repetition of the prime (repetition priming). This effect is due to a combination of different mechanisms only some of which are assumed to be automatic (Neely, 1991). We will concentrate on the more general question of whether SA indeed is automatic.

This question was recently massively challenged by Stolz and Besner (1999) in a number of studies using a letter search task. In this task, a single letter is duplicated above each letter of the prime word. Subjects have to indicate whether the letter appears in the prime or not. The prime is followed by a target word on which a lexical decision has to be performed. Prime letter search almost always eliminates semantic priming effects in lexical decision RT but at the same time does not eliminate repetition priming (Friedrich et al., 1991). According to Stolz and Besner (1999), this pattern of results suggests that the prime was processed at a lexical but not at a semantic level. As a consequence, SA, according to Stolz and Besner (1999), cannot be automatic.

This inference in fact would only be valid if SA is a sufficient condition for the lexical decision time effects to occur, i.e., whenever SA is present, then the RT effect should be observed. The RT measure may simply not be sensitive enough or may be influenced by processes other than SA so that its presence is overwritten. At the same time, however, an alternative measure of SA might reveal its presence. Converging evidence is strongly needed, and thus event-related potentials (ERPs) were recently used in 2 letter search studies with antithetic results (Heil et al., 2004; Mari-Beffa et al., 2005).

Priming effects are not only manifested in reduced RT to related target words, but they can also be observed by means of the N400 effect. The N400, originally observed by Kutas and Hillyard (1980), initially was thought to be a reflection of post-

* *Corresponding author.*
E-mail address: dombrows@uni-duesseldorf.de (J.-H. Dombrowski).

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lexical processes (see, e.g., Brown and Hagoort, 1993). Recently, a number of studies revealed that automatic processes alone seem to be sufficient to evoke an N400 amplitude modulation (Luck et al., 1996; Deacon et al., 2000; Kiefer and Spitzer, 2000). Moreover, our own work suggests that, compared to behavioural effects, the N400 might even be considered as the more sensitive method to measure semantic priming effects (Rolke et al., 2001; Heil and Rolke, 2004; Heil et al., 2004). Howsoever, the interpretation of the N400 is far from being solved, and we will return to this point later on.

While Mari-Beffa et al. (2005) obtained some ERP evidence for semantic processing of the prime word during letter search (the so called Recognition Potential, RP, which is not the topic of the present study), they found no N400 effect as a function of semantic priming. In contrast, Heil et al. (2004) found exactly this N400 priming effect in the letter search task. Both studies indeed differed in the one or other aspect from the "standard" version of the letter search semantic priming paradigm with the latter one (Heil et al., 2004) realised solely a single but possibly crucial difference to this standard. In this study, repetition priming was realised in addition to a semantic priming condition. This manipulation potentially might have increased the salience of the prime's meaning (Henik et al., 1994). Therefore, the goal of our study was to investigate the N400 semantic priming effect in the exact standard version in order to clarify whether this effect is present as suggested by Heil et al. (2004) or absent as suggested by Mari-Beffa et al. (2005).

Twenty subjects participated in the study. Two were excluded from data analysis due to massive eye movement artefacts. Since our study investigated the N400 semantic priming effect in the standard letter search paradigm in the absence of RT effects, data of six subjects were excluded because they showed semantic priming effects of 55.2 ms on average. Additional experiments will investigate this pattern that goes beyond the scope of this paper.

Each trial consisted of a prime word in upper case letters presented together with a lower case letter duplicated above each letter of the prime with a vertical separation of 0.5° followed by the target in lower case letters. On half of the trials, the letter appeared in the prime word, drawn equally often from the beginning, middle or end of the word. Each subject was presented with 256 stimulus pairs, 128 word pairs and 128 word–nonword pairs. Nonwords were created by changing one letter of a real word. Fifty percent of the word pairs were semantically related. The 50% unrelated pairs were formed by randomly recombining the related ones.

Subjects decided whether the specified letter was present in the prime and then decided whether the target was a real word. The prime word was presented for 250 ms. The interval between the response to the letter search task and target presentation was 1200 ms, the target was presented for 1000 ms irrespective of RT. Before presentation of the 256 experimental trials, 48 unrecorded practice trials consisting of words not used in the experiment itself were given. Subjects were seated in a dimly lit, electrically shielded, sound-attenuated room.

The EEG was recorded monopolarly, with AgAgCl electrodes from F3, Fz, F4, T3, C3, Cz, C4, T4, P3, Pz, P4, O1, O2 and from the left and the right earlobe with the left mastoid as reference. Average earlobe activity was calculated digitally, and EEG data were re-referenced to this average (Nunez, 1991) online. Eye movements and blink artifacts were monitored by two channels. Electrode impedance was kept below 5 kΩ. Band pass was set from DC to 40 Hz. The digitisation rate was 250 Hz. All trials were inspected off-line, and those contaminated with artifacts were rejected. Blink artifacts were not corrected; instead, trials with blinks in the 750 ms period following target presentation were rejected. From the edited set of raw data, we extracted ERPs by averaging single trials with correct responses separately for subjects, electrodes and experimental conditions. The amplitude of the N400 was quantified as the mean voltage of the interval 350–450 ms after target presentation referred to a 128 ms prestimulus baseline. This interval was used in contrast to the 300–650 ms interval in the Heil et al. (2004) study because the effect showed a more phasic progression in the present study.

RT in the semantically related condition did not differ from the unrelated condition (665.7 ms vs. 671.6 ms, $F(1,11) = 3.15$, $P > 0.10$). Error rates were low (9.2% vs. 11%) and did not differ between conditions ($F(1,11) = 1.15$; $P > 0.31$). The N400 amplitude in the semantically related condition, however, differed reliably from the unrelated condition ($F(1,11) = 5.94$). Moreover, we obtained an interaction of the factors relatedness and electrode location ($F(12,132) = 3.42$, both $P < 0.05$). Replicating the results of Heil et al. (2004) and the general topography of the N400, the relatedness effect turned out to be reliable at electrode locations C3, Cz, C4, P3, Pz, P4, O1 and O2 ($F(1,11) = 2.26$, 2.44, 2.21, 2.75, 2.92, 2.93, 2.89 and 3.03, respectively, all $P < 0.05$; see Fig. 1, upper part).

Recently, Stolz and Besner (1999) called automatic SA a myth based on the absence of a semantic priming RT effect in the letter search task. Convergent evidence was sought by using an alternative measure of SA, i.e., the N400 effect. Mari-Beffa et al. (2005) found no N400 semantic priming effect, while Heil et al. (2004) did. The present paper disproves the assumption that these conflicting results are due to the fact that Heil et al. (2004) artificially increased the salience of the prime's meaning by additionally introducing a repetition priming condition (Henik et al., 1994). Instead, the discrepancy of the results might be due to the choice of the reference. In the present study, the digitally averaged earlobe activity was used as reference. Whereas Heil et al. (2004) used shunted earlobes (with problems in itself, see, e.g., Miller et al., 1991), Mari-Beffa et al. (2005) used Cz as reference. Due to its topography (Kutas and Hillyard, 1980), the N400 effect is reliably found at Cz, and, since the N400 effect is relatively small in the letter search task, the effect is dramatically reduced as a consequence of using an active electrode as reference placed where the effect almost has its maximum (Cz). In the bottom part of Fig. 1, we present the data of the present experiment re-referenced to Cz. Obviously, because Cz is close to the location of the N400 peak amplitude, no N400 effect is present anymore.

To sum up, by replicating the results of Heil et al. (2004), our data clearly demonstrate that, when the letter search task is imposed on the prime word, the meaning of the