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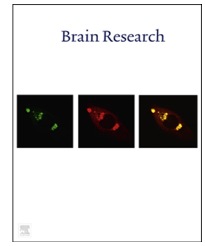

Research Report

Inefficient stimulus processing at encoding affects formation of high-order general representation: A study on cross-modal word-stem completion task

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ABSTRACT

Priming is an implicit memory effect in which previous exposure to one stimulus influences the response to another stimulus. The main characteristic of priming is that it occurs without awareness. Priming takes place also when the physical attributes of previously studied and test stimuli do not match; in fact, it greatly refers to a general stimulus representation activated at encoding independently of the sensory modality engaged. Our aim was to evaluate whether, in a cross-modal word-stem completion task, negative priming scores could depend on inefficient word processing at study and therefore on an altered stimulus representation. Words were presented in the auditory modality, and word-stems to be completed in the visual modality. At study, we recorded auditory ERPs, and compared the P300 (attention/memory) and N400 (meaning processing) of individuals with positive and negative priming. Besides classical averaging-based ERPs analysis, we used an ICA-based method (ErpICASSO) to separate the potentials related to different processes contributing to ERPs. Classical analysis yielded significant difference between the two waves across the whole scalp. ErpICASSO allowed separating the novelty-related P3a and the top-down control-related P3b sub-components of P300. Specifically, in the component C3, the positive deflection identifiable as P3b, was significantly greater in the positive than in the negative priming group, while the late negative deflection corresponding to the parietal N400, was reduced in the positive priming group. In conclusion, inadequacy of specific processes at encoding, such as attention and/or meaning retrieval, could generate weak semantic representations, making words less accessible in subsequent implicit retrieval.

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1. Introduction

The defining characteristic of implicit memory is that it is used without awareness; thus, the content of implicit memory cannot be reported (Schacter, 1987; Schacter and Buckner, 1998). In contrast with explicit tests, in which participants consciously attempt to recollect information encountered in an earlier phase of the experiment (the study or encoding phase), in implicit tests participants perform tasks that are apparently unrelated to the previously presented information —i.e. identification of degraded words or word stems completion with the first word that comes to mind. In these tasks, subjects perform better at test when presented with information beforehand, even though they typically make no conscious attempt at remembering. This facilitation is termed priming. Priming has also been found when the physical attributes of the study stimuli do not match those of the test stimuli (Rajaram and Roediger,1993; Jackson and Morton, 1984; Pilotti et al., 2000). The fact that mismatch does not eliminate priming supports the idea that stimulus processing forms representations spanning multiple modalities, even when information is conveyed by means of a specific one.

Linguistic processing is based on the integration of different modalities (Frost and Katz, 1989; Grainger and Ferrand, 1996; Plaut et al., 1996; Seidenberg and McClelland, 1989; Ziegler et al., 2003). One of the most accredited model of word recognition, based on the strong interactivity across modality-specific representations, is the bimodal interactive-activation mode (Grainger and Ferrand, 1994, 1996). According to the model, presentation of a word in the visual modality generates activation in orthographic codes, which rapidly activate the corresponding phonological codes thus improving the recognition process. The same applies for auditory word recognition, where phonological codes rapidly activate the corresponding orthographic representations (Kiyonaga et al., 2007). This interactive mechanism would be fundamental for a whole-word higher-level semantic representation.

Based on this assumption, implicit memory of linguistic information could refer to a general semantic representation of the word independent of the specific sensory modality engaged at encoding. According to this hypothesis, some studies have reported that the physical attributes of words play a role in priming even if these attributes are imagined rather than directly perceived (Pilotti et al., 2000; Stuart and Jones, 1996). In fact, imaging the sound of printed words at study (auditory imagery) (Pilotti et al., 2000) or forming images of spoken words as they would appear if printed (visual imagery) (Roediger and Blaxton, 1987) produces priming in the implicit tests of identification of words degraded by noise and in word fragment completion task, respectively.

Even though priming has been found when the physical attributes of studied words did not match those of the test words, smaller effects were generally found—i.e. spoken words produce less priming than printed words in the visual implicit tests of word stem and word fragment completion (Rajaram and Roediger, 1993), and printed words produce less priming than spoken words in the auditory version of these tests (Jackson and Morton, 1984; Pilotti et al., 2000).

In a pilot study of ours (Castellani, 2007, PhD Thesis) we found that about half of the individuals participating to a word stem completion task (WSCT) exhibited no implicit memory at all when the physical attributes of the study stimuli (spoken words) did not match those of the test stimuli (printed word stem). More specifically, their priming score that consists of the rate of correct completions on a studied list relative to the casual completions on a control list, was negative i.e. less correct completions on the studied than on control list. If cross-modal priming depends on the individuals' ability to form a general semantic representation, this effect could be related to factors at encoding such as attention and word processing that could have affected the formation and/or consolidation of the general high-order modality-independent representation of words.

In the present study we planned a cross-modal WSCT in which words were presented in the auditory modality at study, and word stems appeared in the visual modality in the test phase. Our aim was to evaluate whether negative priming scores at test could indicate a weak semantic representation likely owing to inefficient word processing at study. Specifically, we recorded auditory ERPs in the study phase and focused on the centro-parietal subcomponent of P300 (P3b) and the parietal N400 waves. P3b has been considered to reflect the activation of attentional networks and the integration of incoming information into memory representations of the stimulus (Polich, 2007; Azizian and Polich, 2007), and to be a possible electrophysiological marker of Locus Coeruleus (LC) noradrenergic function (Nieuwenhuis et al., 2005, 2011; Polich and Criado, 2006). On the other side, N400 is considered a good marker of the efficiency of word meaning processing (Kutas and Federmeier, 2011). Given that differences during word learning give rise to memory traces differing in strength and that word recognition is better with stronger traces than with weaker ones (Balass et al., 2010), we expected that, at study, individuals with negative implicit memory performance could be worse in terms of words processing than individuals with positive scores.

Besides a raw scalp-channels-based classical ERP analysis, we used a method based on independent component analysis (ICA) (Brown et al. 2001) in order to disentangle potentials related to the different processes contributing to the ERP dynamics (Pourtois et al. 2008). Our ICA approach named ErpICASSO, (Artoni et al., 2012b, 2014; Menicucci et al., 2013;) enabled us to derive templates of the independent ERP components that we chose to identify processing differences between subjects with different priming scores.

In particular, we used ErpICASSO with the aim to separate the two sub-components of P300 (P3a and P3b) that are easily discriminated with an oddball paradigm – P3a is evoked by unexpected novel stimuli and reflects stimulus-driven (bottom-up) attention capture, while P3b reflects top-down controlled detection of relevant/salient events – but appear greatly superimposed when task-relevant novel stimuli, as in our experimental protocol, are used (Debener et al., 2005; Heitland et al., 2013).

ErpICASSO could also help to discriminate between parietal N400 and FN400, a wave similar to N400 as for peak latency but with a more frontal localization than N400, which has been considered an index of familiarity rather than a general meaning retrieval one (Paller et al., 2007).