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Research report

Predictability's aftermath: Downstream consequences of word predictability as revealed by repetition effects

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ABSTRACT

Stimulus processing in language and beyond is shaped by context, with predictability having a particularly well-attested influence on the rapid processes that unfold during the presentation of a word. But does predictability also have downstream consequences for the quality of the constructed representations? On the one hand, the ease of processing predictable words might free up time or cognitive resources, allowing for relatively thorough processing of the input. On the other hand, predictability might allow the system to run in a top-down "verification mode", at the expense of thorough stimulus processing. This electroencephalogram (EEG) study manipulated word predictability, which reduced N400 amplitude and inter-trial phase clustering (ITPC), and then probed the fate of the (un)predictable words in memory by presenting them again. More thorough processing of predictable words should increase repetition effects, whereas less thorough processing should decrease them. Repetition was reflected in N400 decreases, late positive complex (LPC) enhancements, and late alpha/beta band power decreases. Critically, prior predictability tended to reduce the repetition effect on the N400, suggesting less priming, and eliminated the repetition effect on the LPC, suggesting a lack of episodic recollection. These findings converge on a top-down verification account, on which the brain processes more predictable input less thoroughly. More generally, the results demonstrate that predictability has multifaceted downstream consequences beyond processing in the moment.

1. Introduction

Language input is to some extent predictable. Highly predictable words are easier to process than less predictable words, which is reflected in shorter fixation durations during natural reading and reduced lexical decision and pronunciation latencies (Ehrlich & Rayner, 1981; Fischler & Bloom, 1979; Kleiman, 1980; Stanovich & West, 1979). Studies on how and

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when effects of context manifest have led to a consensus that the available context can very rapidly influence incremental language processing (e.g., Altmann & Steedman, 1988; Hagoort & Van Berkum, 2007; Kutas & Federmeier, 2000; Tanenhaus & Trueswell, 1995). In event-related brain potentials (ERPs), predictability attenuates the N400, a centroparietally distributed negativity that peaks around 400 msec after the onset of a potentially meaningful stimulus and is a sensitive index of semantic processing (Kutas & Hillyard, 1980; for review, see; Kutas & Federmeier, 2011). N400 amplitude is strongly negatively correlated with the cloze probability of a word in a sentence (Kutas & Hillyard, 1984), which is the proportion of an independent group of participants who complete the sentence fragment with that word in an off-line task. Later studies have also shown post-N400 effects related to different aspects of predictability, suggesting that frontally distributed effects are elicited when predictions are disconfirmed (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007; Van Petten & Luka, 2012) or when situations arise in which the context needs to be reconsidered (Wlotko & Federmeier, 2012). However, it is unclear whether predictability only influences the rapid processes that unfold during the presentation of a word or also the resulting representations that comprehenders are left with. The present study sought to probe these representations in order to characterize the downstream consequences of word predictability.

In particular, this study examined the representations that are formed when processing predictable and unpredictable words, to gain insights into how thoroughly such words are processed. On the one hand, the fact that predictable words are easier to process might mean that time or cognitive resources are freed up, allowing for additional processing of the input. Further enhancement of the representations of predictable words in memory might come from the fact that, on top of stimulus-driven processing, aspects of predictable words can also become activated through sentence context in a top-down fashion (for reviews, see Altmann & Mirković, 2009; Federmeier, 2007; Kamide, 2008; Kutas, DeLong, & Smith, 2011). However, on the other hand, a sentence context that is strongly predictive of a particular word leads to a low likelihood of gaining new information, which might instead encourage the system to run in a top-down "verification mode" (e.g., Van Berkum, 2010). This would come at the expense of thoroughly processing the bottom-up input, such that predictability would decrease the quality of word representations in memory.

Previous studies, which differed in many ways and were not always explicitly designed to investigate these issues, have reported recall or recognition memory performance for some of the conditions of interest. Some of these data show better memory for predictable words (those with greater conditional probability or cloze probability) than for less predictable words (Miller & Selfridge, 1950; Riggs, Wingfield, & Tun, 1993), but other studies suggest that memory is poorer for predictable than unpredictable words (Cairns, Cowart, & Jablon, 1981; Corley, MacGregor, & Donaldson, 2007; Federmeier et al., 2007; O'Brien & Myers, 1985; Perry & Wingfield, 1994). Importantly, end state measures such as recall or recognition summate across the temporally extended perceptual and memory access processes that predictability may influence. To better examine the unfolding processing of predictable and unpredictable words upon first encounter and then downstream, this study recorded continuous electroencephalogram (EEG) signals while manipulating the predictability of words in sentences and then probing their fate in memory by presenting the words again a few sentences later. Analyses focused on the repetition effect, a multifaceted but well-documented phenomenon (with possible explanations including facilitation, fatigue, and sharpening; Grill-Spector, Henson, & Martin, 2006).

Compared with words presented for the first time in an experiment, repeated words are processed faster and more accurately in lexical decision and naming tasks (Feustel, Shiffrin, & Salasoo, 1983; Scarborough, Cortese, & Scarborough, 1977). In the ERP signal, repeated words elicit a reduced N400 in word lists (e.g., Rugg, 1985) as well as in sentences (Van Petten, Kutas, Kluender, Mitchiner, & Mcisaac, 1991). This is followed by a late positive complex (LPC), which is typically more positive at second presentation than initial presentation (Besson & Kutas, 1993; Besson, Kutas, & Van Petten, 1992; Rugg, 1985; Rugg et al., 1998; but see; Van Petten et al., 1991). Across intervening trials, the N400 repetition effect seems to be shorter-lasting than the LPC effect, dissipating at or before a lag of 15–20 min in word lists (Rugg, 1990), although when words are repeated in identical sentence contexts the N400 repetition effect can survive a lag of 45 min (Besson et al., 1992). When memory judgments are made in response to repeated ("old") and unrepeated ("new") items, similar N400 and LPC effects obtain. The two components show distinct relationships to memory performance, suggestive of a time course in which later conscious recollection follows earlier more implicit memory processes (or familiarity; Rugg & Curran, 2007). For example, the LPC is more positive in response to old words that are explicitly recognized as old (hits) than old words that are not recognized (misses) or new words (Van Petten & Senkfor, 1996), whereas N400 decreases relative to new words can occur regardless of recognition accuracy (Rugg et al., 1998). Furthermore, 'deep' encoding tasks that lead to high rates of recognition are associated with enhanced LPCs at retrieval, whereas N400 decreases can occur regardless of the depth of processing at encoding (Paller & Kutas, 1992; Paller, Kutas, & McIsaac, 1995; Rugg et al., 1998). LPC enhancements have also been associated with accurate memory for episodic details about encoding modality or source (Wilding & Rugg, 1996; Wilding, Doyle, & Rugg, 1995), and with subjective judgments of "remembering" a previous occurrence of a stimulus beyond just "knowing" that it had previously been studied (Smith, 1993; but see; Voss & Paller, 2009). Finally, in patients with amnesia, who have impaired explicit (declarative) memory abilities but relatively spared implicit (procedural) memory, the N400 repetition effect is preserved but the LPC repetition effect is not (Olichney et al., 2000). In sum, repetition effects in ERPs may speak to the nature of the stimulus representations that are formed and retrieved.

The present study evaluated repetition effects in response to words as a function of their prior predictability. Participants read words like "car" presented as either the most expected ending of a strongly constraining sentence frame ("Alfonso