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Representation and processing of multi-word expressions in the brain

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ABSTRACT

Language comprehension is sensitive to the predictability of the upcoming information. Prediction allows for smooth, expedient and successful communication. While general discourse-based constraints have been investigated in detail, more specific phrase-level prediction has received little attention. We address this gap by exploring the ERPs elicited during the comprehension of English binomials – familiar and predictable multi-word expressions. In Experiment 1a, participants read binomial expressions (*knife and fork*), infrequent strongly associated phrases (*spoon and fork)*, and semantic violations (*theme and fork*). In Experiment 1b, participants read the same stimuli without "and". Experiment 1a revealed that binomials elicited larger P300s and smaller N400s compared to the other conditions, reflecting the activation of a 'template' that matches the upcoming information (P300) and pointing to easier semantic integration (N400). In contrast, no differences were observed between binomials and associates in Experiment 1b. We conclude that distinct mechanisms underlie the processing of predicable and novel sequences.

1. Introduction

Although human language can be original and highly creative, we rarely fully exploit its creative potential. Evidence suggests that much of the language we encounter on a daily basis is 'formulaic'. That is, words tend to co-occur in specific linguistic configurations, known as multi-word expressions (MWEs),[1] and language users tend to draw on a vast, yet limited, repertoire of MWEs. MWEs are familiar sequences of words, such as, collocations (*strong tea*), binomials (*time and money*), multi-word verbs (*rely on*), idioms (*ring a bell*), speech routines (*How's it going?*), discourse markers (*on the other hand*), lexical bundles (*in the middle of*), and grammatical constructions (*the –er the –er*). A fundamental feature of MWEs is that they are extremely ubiquitous: a native speaker of English is believed to produce about four MWEs in every minute of discourse (Glucksberg, 1989; Pollio, Barlow, Fine, & Pollio, 1977). Studies looking at monologues and conversations found that around one quarter of the speech analysed was formulaic in nature (Van Lancker & Rallon, 2004; Van Lancker Sidtis & Postman, 2006). Other estimates suggest that the number of MWEs in American English is comparable to the number of single words (Jackendoff, 1995). Such prevalence clearly makes MWEs an essential component of mature linguistic competence.

Because MWEs are highly familiar, conventional ways of expressing thoughts and ideas, they render our discourse natural and easily comprehensible. It has long been argued that it is easier and more economic to remember and use language in chunks – which are highly predictable in nature – than having to create novel combinations of words anew (Wray, 2002). In his *Idiom Principle*, Sinclair (1991) proposed that language users have available to them thousands of semi-pre-constructed phrases that constitute "single choices", even though they might be analyzable into individual components (p. 110). Indeed, it has long been acknowledged that chunking is an important strategy in linguistic processing, and that in order to be able to process linguistic input in a smooth and expedient fashion, one has to operate with larger linguistic units, such as chunks (Miller, 1956). It appears then, that the focus of neurolinguistic enquiry should be as much on MWEs, as it has been on single words.

In what follows below, we first consider what is arguably one of the

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[1] In the present paper, we opted for the term *multi-word expressions*, because the focus is on strings of language longer than a single word. Another commonly used term to refer to familiar phrases is *formulaic language*. It is noteworthy, however, that formulaic language encompasses multi-word sequences, as well as single-word items, such as expletives and exclamations *(darn, wow)* and conversational speech formulas (*okay, right, yeah, hello*).

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defining characteristics of MWEs – predictability; a feature that has far reaching consequences for how MWEs are processed in the brain. We then turn to a more theoretical debate about the nature of the mental lexicon and the role of multi-word information.

1.1. Contextual predictability in language comprehension

Predictive mechanisms play an important role in language comprehension. A multitude of studies employing a range of paradigms and tasks have attributed their findings to the degree of contextual predictability. For example, eye movement studies have shown that predictability of a word, given the preceding sentential or phrasal context, is one of the key factors known to affect fixation durations, number of fixations, as well as the likelihood of the word being skipped (Balota, Pollatsek, & Rayner, 1985; Rayner & Well, 1996). From a neurophysiological perspective, a negative deflection in the 250–500 ms time window peaking around 400 ms after stimulus onset – known as the N400 – has been linked to a word's predictability given the preceding context (Kutas & Hillyard, 1980, 1984; Van Petten & Kutas, 1990). The N400 has also been associated with the reader's or listener's expectations based on their real-world knowledge (Hagoort, Hald, Bastiaansen, & Petersson, 2004). In Hagoort et al. (2004), sentences that violated participants' world knowledge (*The Dutch trains are white and very crowded*) resulted in a larger N400 effect than sentences in which this knowledge was not violated (*The Dutch trains are yellow and very crowded*).

Central to the description of the N400 is the concept of cloze probability (Kutas & Hillyard, 1984), which establishes the proportion of respondents that provide the correct completion of a phrase or a sentence. Cloze probability is known to be inversely correlated with N400 amplitudes (Kutas, Van Petten, & Kluender, 2006). The higher the cloze probability of a word, the smaller the N400 amplitudes. In Kutas and Hillyard (1980, 1984), unexpected sentence completions with low cloze probability (the word *hour* in *The bill was due at the end of the hour*) elicited larger N400s than expected ones with high cloze probability (the word *month* in *The bill was due at the end of the month*).

Evidence suggests that contextual cues shape word processing from its earliest stages and pre-activate the features of a likely upcoming word (Kutas & Federmeier, 2011). The predictive mechanisms are so strong that the processing of an unexpected word may, in fact, be facilitated if it shares some features, semantic or orthographic, with the expected stimulus (Laszlo & Federmeier, 2009; for a review, see Kutas & Federmeier, 2011).

Contextual predictability has long been linked to the N400 component. However, recently, Lau, Namyst, Fogel, and Delgado (2016) pointed out that researchers have often tended to confound congruity and predictability. That is, congruous endings were also predictable given the preceding context (Kutas & Hillyard, 1980). In a series of experiments, Lau et al. (2016) observed reduced N400s for (equally congruous) predictable versus unpredictable adjective-noun pairs where the noun was kept constant (*mashed potato* vs. *shredded potato*), and for (equally unpredictable) congruous versus incongruous adjective-noun pairs where the noun was kept constant (*yellow bag* vs. *innocent bag*). While predictability had a large effect on N400 amplitudes, congruency was found to have only a small effect on the size of the N400. These results suggest that although higher predictability and greater congruency given the preceding word/s may result in the modulations of the same ERP component, N400 effects of predictability and (in)congruency are, in fact, due to different underlying mechanisms (Lau et al., 2016).

1.2. Predictive mechanisms and MWEs

While general sentence level constrains exert a powerful influence on how we process language, there are linguistic contexts whose canonical structure and meaning are believed to be stored in memory, and which lend themselves particularly well to the study of predictive mechanisms. If a native speaker of English is asked to complete the phrase "fish and …", "you can't judge a book by its …", or "as a matter of …", the answers will invariably be the most expected completions *chips, cover,* and *fact* (see Van Lancker Sidtis, Cameron, Bridges, & Sidtis, 2015). These and thousands of other MWEs are familiar, conventional ways of using language. As a result, they are highly, and often uniquely, predictable strings of language. This makes them ideal candidates for the investigation of predictive mechanisms in language comprehension.

In line with probabilistic models of language, information about the co-occurrence of words is represented in a speaker's mind (Gregory, Raymond, Bell, Fosler-Lussier, & Jurafsky, 1999; Jurafsky, 1996; McDonald & Shillcock, 2003a, 2003b; Seidenberg & MacDonald, 1999). As McDonald and Shillcock (2003a, 2003b) argue, the vast amounts of language that a speaker encounters are a rich source of statistical knowledge about the way in which the language is used. The brain is capable of storing and subsequently using large amounts of statistical information during language comprehension to estimate the probability of *word n* following *word n − 1*. In addition, integrating a word into one's mental lexicon also involves encoding its surrounding (phrasal) context into the mental lexicon (McDonald & Shillcock, 2003b; also see Goldberg, 1995, 2006; Langacker, 1987).

It has been argued that the expectations driven by a highly conventional string of language (the word *cover* following *you can't judge a book by its …*) should be different from the more general discourse-based constraints, such as those observed in Kutas and Hillyard (1984). Specifically, the activation of the final word within a MWE should be stronger and more categorical than that of a plausible, but not uniquely predictable, word in a sentence that does not contain a MWE (Molinaro & Carreiras, 2010; Vespignani, Canal, Molinaro, Fonda, & Cacciari, 2010). Although electrophysiological research into MWEs is still in its infancy, current evidence tentatively points to two processes associated with the comprehension of such sequences compared to novel language: (1) easier semantic integration of familiar information, and (2) the activation of template matching mechanisms for uniquely predictable linguistic information.

Of the many types of MWEs, idioms have received by far the most attention in ERP research. In one of the earliest such studies, Strandburg et al. (1993) recorded ERPs on the final word of idiomatic, literal (novel), and nonsensical phrases. Participants had to decide whether or not the phrase was meaningful. Smaller N400s were observed for idiomatic phrases compared to literal and nonsensical ones, with an ordered increase in the N400 amplitudes from idiomatic to literal to nonsensical phrases, suggesting progressive increases in their depth of processing. In another study by Laurent, Denhières, Passerieux, Iakimovac, and Hardy-Baylé (2006) participants performed a semantic relatedness task on French idioms and metaphors that varied in their degree of salience (strongly and weakly salient). The authors defined salient meanings as those foremost on our mind due to their frequency, conventionality, familiarity, or prototypicality. The authors observed smaller N400 amplitudes on the last word of the strongly salient idioms compared to the last word of the weakly salient novel metaphors. More recently, Vespignani et al. (2010) investigated the processing of Italian idioms before and after the recognition point (the point at which the idiom becomes uniquely recognizable). Three conditions were looked at: one idiomatic and two literal control conditions (substitution and violation) embedded in a sentence context. Similar to the earlier studies, Vespignani et al. (2010) found that idiomatic phrases elicited smaller N400s than literal phrases for the word that represented the recognition point of the idiom.

The finding of reduced N400s for conventional idioms in these studies was interpreted as an indicator of easier processing and semantic integration for salient figurative expressions than for their novel counterparts. The N400, however, is not the only ERP component involved in the processing of highly predictable information. The P300 has also been implicated in phrasal processing, albeit in fewer studies