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Mismatch negativity: A tool for studying morphosyntactic processing?

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ABSTRACT

Objective: Mismatch negativity (MMN) was originally shown in a passive auditory oddball paradigm to be generated by any acoustical change. More recently, it has been applied to the study of higher order linguistic levels including the morphosyntactic level in spoken language comprehension. In this study, we present two MMN experiments to determine whether morphosyntactic features are involved in the representations underlying the morphosyntactic processing.
Methods: We reported two MMN experiments in passive auditory oddball paradigm with pairs of French words, a pronoun and a verb, differing in agreement grammaticality. These two experiments differed in the number of morphosyntactic features producing agreement violations, i.e. either of person and number features or of person feature.
Results: We observed no effect of grammaticality on the MMN response for these two experiments.
Conclusions: Our studies highlight the difficulties encountered in studying morphosyntactic level with the passive auditory oddball paradigm.
Significance: The reasons for our inability to replicate previous studies are presented, and methodological changes in the passive auditory oddball paradigm are proposed to better tap into the morphosyntactic level.
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1. Introduction

In the auditory domain, mismatch negativity (MMN) is an event-related potential (ERP) generated by automatic cerebral responses to any change in auditory stimulation. The MMN response is generally obtained in the oddball paradigm for an infrequent auditory stimulus, the so-called deviant stimulus, which interrupts a succession of repeated stimuli, the standard stimulus. The MMN is a negative wave observed at frontocentral electrodes peaking at 110–250 ms from the onset of physical change in the absence or presence of focused attention to the stimuli (for reviews, Näätänen and Winkler, 1999; Näätänen, 2001). The MMN reflects the detection of an acoustic change from the repeated auditory stimuli to the deviant stimuli. It has been assumed to depend upon either the short-term memory traces of the standard stimuli or the extraction of regularities in the auditory stimulation (Winkler, 2007).

In addition to being sensitive to the acoustical properties of the input, the MMN has been discovered more recently to also reflect long-term memory traces of language experience at various higher linguistic levels including phonological, lexical, semantic and syntactic levels. When investigating the amplitude of the MMN response to vowel changes in native Finnish speakers, Näätänen and collaborators (1997) found a larger effect for the deviant Finnish vowel /ö/ than for a deviant Estonian vowel that did not exist in Finnish. Crucially, they observed this result despite the fact the acoustic distance between the Estonian vowel and the standard Finnish vowel /e/ was larger than that from the deviant Finnish vowel /ö/. These results suggest that the MMN is a promising tool for studying higher level processes in speech perception in which the participant does not focus attention on the stimuli. Indeed, it was subsequently shown that, for example, at the lexical level, the MMN effect after a syllable was larger when this syllable is presented in a deviant word than in a deviant pseudoword (Pulvermüller et al., 2001). Moreover, magnetoencephalographic results showed that the peak latencies of the MMN sources in the left superior temporal areas were correlated with word recognition points (Pulvermüller et al., 2006). MMN has also been shown to be sensitive to semantics. Words referring to face movements activated inferior frontocentral areas more strongly, whereas words related to leg movements elicited a larger activation in the superior central areas (Pulvermüller et al., 2005). Several MMN studies have investigated morphosyntax by comparing the MMN amplitude after correct sentences to that after sentences with morphosyntactic violations. Four studies reported enhanced MMN amplitudes

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associated with a violation in pronoun–verb agreement in several languages (Finnish, English, French and German) at 100–200 ms after the violation point (Shtyrov et al., 2003; Pulvermüller and Shtyrov, 2003; Brunellière et al., 2007; Hasting et al., 2007; Pulvermüller et al., 2008). When investigating case violations between a determiner and its noun in German, Menning and colleagues (2005) also found a MMN effect modulated by the case violation at about 150–200 ms after the onset of the deviant word. Together, these findings suggest the MMN is sensitive to morphosyntactic processing and hence allows us to tap into the nature of the morphosyntactic representations.

Despite this convergence, there is still considerable debate in the literature on the nature of the morphosyntactic representations. According to one theoretical approach taken in generative syntax, abstract morphosyntactic features such as gender, number and person are represented separately and are computed by an agreement mechanism (Chomsky, 1959; Harley and Ritter, 2002; Carminati, 2005). At present, experimental evidence concerning the representation of abstract morphosyntactic features is sparse and somewhat inconclusive. The event-related potentials studies exploring neuronal responses after agreement violations reported two main correlates of agreement violations, left anterior negativities (LAN) and a late positivity wave (P600) (Münte et al., 1998; Gunter et al., 2000; Wassenaar et al., 2004; Barber and Carreiras, 2005; Morris and Holcomb, 2005; Nevins et al., 2007; Silva-Pereyra and Carreiras, 2007; Leinonen et al., 2008). Instead of the LAN effect, some studies observed other negativities centered on the parietal sites, labeled N400, after gender violations (Barber and Carreiras, 2003, 2005, at the noun phrase level, Wicha et al., 2004, at the sentence level). However, N400 modulations for gender agreement cannot be associated with a neuronal response which distinguishes the gender feature from other features since these N400 modulations are reported only for a combined semantic and agreement violation or for gender violations in adjective–noun word pairs. Few studies have manipulated directly the number and/or the type of morphosyntactic features producing agreement violations in order to investigate the nature of morphosyntactic representations. Theories in favor of the representation of abstract morphosyntactic features in the brain make two types of predictions about the neuronal responses elicited after agreement violations. More precisely, they predict that each feature violation leads to a distinct neuronal response and that a double violation involving two morphosyntactic features elicits larger responses than a violation of a single feature. For example, some event-related potentials studies investigating morphosyntactic processing showed later latencies and greater amplitudes of a late positivity wave after gender violations than number violations (Barber and Carreiras, 2003, 2005). These results were interpreted as supporting the existence of the representation of abstract morphosyntactic features. Other studies did not confirm these effects with behavioural or event-related potential recordings (Lukatela et al., 1987; Colé and Segui, 1994; Nevins et al., 2007). In particular, Nevins and collaborators (2007) did not find a larger P600 or/and a P600 with later latencies either for gender violation than for number violation or for the double violation number/gender in comparison to the violations of single feature. However, these authors observed a larger P600 for the double violation person/gender in comparison to the other violations, suggesting that the person feature is stored in memory separately from the gender feature, contrary to the number and gender features which seem to be close together in their memory traces. Additionally, a recent ERP study investigating number and person agreement showed no difference between person and number violations but a greater response on the first phase of the P600 for a double person/number violation (Silva-Pereyra and Carreiras, 2007), thus reinforcing the conclusions of Nevins and collaborators (2007).

These studies which manipulate morphosyntactic features have produced ambiguous results concerning the existence of a separate representation for each morphosyntactic feature. Importantly, the studies which investigated this issue always used an attentional task and reported differences in the processing of morphosyntactic features only in late ERP components, i.e. on ERP components that are known to be confounded with attentional or strategic factors (Hahne and Friederici, 1999; Gunter and Friederici, 1999). Interestingly, in the MMN paradigm, the participant is not paying attention to the stimuli, so that the MMN paradigm is considered to be independent of attentional demands. In addition, as for the other paradigms, the use of the MMN paradigm makes it possible to manipulate morphosyntactic features, but more specifically to control the physical differences between the grammatically correct sentences and sentences with morphosyntactic violations. At present, no MMN study has yet been conducted to test whether morphosyntactic features are represented in morphosyntax. Indeed, all the research, including our earlier research (Brunellière et al., 2007), only investigated the effect of morphosyntactic violations on the MMN wave and did not manipulate the number of morphosyntactic features that were violated.

Given the theoretical importance of the nature of representations in the domain of the morphosyntax, it is crucial that an MMN experiment be conducted to determine whether morphosyntactic features are involved in the representations underlying the morphosyntactic processing. To test the hypothesis of morphosyntactic feature representations, we conducted a MMN experiment identical to that described in the study of Brunellière and collaborators (2007), with the exception that this new experiment contained violations of subject–verb agreement involving two morphosyntactic features (person and number) rather than only violations of subject–verb agreement related to one morphosyntactic feature (i.e. person). We predicted that if morphosyntactic features are represented, two morphosyntactic feature violations in the current experiment should elicit greater MMN effects than the violation of only one morphosyntactic feature as observed in our earlier study. Indeed, only a comparison between these two experiments makes it possible to interpret MMN effects in terms of representation of morphosyntactic features. Consequently, in the following part we describe in detail the methodology used in the present experiment and in the study of Brunellière and collaborators (2007).

2. Methods

2.1. Participants

Sixteen native French-speaking female students of the University of Geneva, aged 19–26 years, took part in this experiment. All students participated for course credits and gave their written informed consent. All were right-handed (handedness assessed according to the Edinburgh inventory, Oldfield, 1971) and had no neurological or hearing impairments. The participants of the present experiment had not taken part in the study of Brunellière and collaborators (2007). Fifteen other students had participated in the study of Brunellière and collaborators (2007). The studies were approved by the Psychology Research Ethics Committee of the University of Geneva.

2.2. Stimuli

2.2.1. Characteristics of experimental stimuli

Four French two-word pronoun–verb sentences were presented to the participants. Two sentences were grammatically correct (i.e. *nous vivrons* 'we will live' and *tu vivras* 'you will live') and the two

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