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The influence of contour fragmentation on recognition memory: An event-related potential study

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ABSTRACT

The present study was carried out to examine how the event-related potentials to fragmentation predict recognition success. Stimuli were abstract meaningless figures that were either complete or fragmented to various extents but still recoverable. Stimuli were first encoded as part of a symmetry discrimination task. In a subsequent recognition phase, encoded stimuli were presented complete along with never presented stimuli and participants performed an old/new discrimination task. Fragmentation stimuli elicited more negative ERPs than complete figures over the frontal, central and parietal areas between 180 and 260 ms, and over the occipito-temporal areas between 220 and 340 ms. Only this latter effect was modulated as a function of whether stimuli were recognized or not during the recognition phase of the memory test. More specifically, the effect occurred for stimuli that were later forgotten and was absent for stimuli that were later recognized. This ERP to fragmentation, the occipito-temporal N_{frag}, possibly reflects the brain response to encoding difficulty, and is thus predictive of recognition performance.

1. Introduction

In everyday life, people can recognize objects viewed a second time despite first perceiving them in impoverished conditions. This happens because the perception taking place in impoverished conditions is generally extrapolated well beyond the available information captured by the retina. Sometimes, this perception may have precedence over the perception of available information and induce a bias with respect to what will later be remembered. This memory bias was reported by Foley and colleagues (1997). Their participants were first shown complete and fragmented pictures of objects and, later, with names of these objects. When asked to use these words for recollecting the picture version (i.e., complete or fragmented) from memory, participants tended to over-categorized fragmented objects as having been presented complete. In a different approach, Snodgrass and her colleagues used recognition (Snodgrass & Hirshman, 1994) and implicit fragment completion (Snodgrass & Feenan, 1990) memory tasks to verify whether fragmented objects could be recollected as well as complete ones. In the former study, subjects encoded line drawings that were complete or fragmented by a partial deletion of their contours. Depending on the magnitude of the deletion, imagining the stimulus as complete and identifying it was either possible (i.e., recoverable stimuli) or not (i.e., unrecoverable stimuli). In the recognition phase, participants were presented with the complete version of the encoded objects and with never seen (i.e., new) objects. Recoverable stimuli were better recognized than unrecoverable stimuli, suggesting that cognitive processes in response to fragmentation, which likely contributed to the integration of the fragments into a well defined global form, may improve recognition.

The contribution of fragmentation processing on recognition can be directly assessed by computing the event-related potentials (ERPs) evoked across different levels of fragmentation and by examining whether the resulting ERP effects predict recognition performance. Fragmentation processing has been associated with several ERP components that all had negative polarity and peaked between 200 and 450 ms. The Ncl (standing for negativity to closure) is one of these ERPs. The first Ncl to have been described started approximately at 230 ms and peaked around 290 ms over occipito-temporal scalp sites (Doniger et al., 2000). It was obtained by presenting the stimuli following the ascending method of limits (Snodgrass, Smith, Feenan, & Corwin, 1987). Stimuli first appear in a very fragmented version and, gradually, several contour fragments are added until participants succeed at object identification. Doniger et al. (2000) found that the voltage of the Ncl became incrementally more negative as levels of fragmentation approached the level of identification, with a particularly marked

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change of amplitude at identification. A second well-established ERP in response to fragmentation is the N350, a frontal negativity first described by Schendan and Kutas (2002). In one task, pictures were presented according to the ascending method of limits. Pictures presented two fragmentation levels prior to identification elicited a larger N350 than identified pictures, a result opposite to the Ncl modulation, which was rather larger at identification. In other tasks, an N350 modulation was also found between unidentified and identified objects that were fragmented at the same level and which were therefore controlled for physical dissimilarities. Schendan and Kutas (2002) assumed that their frontal N350 and the temporo-occipital Ncl reflect identical processes and argued that their difference of scalp distribution was due to the use of different electrodes of reference (on the nose in Doniger et al., 2000 and on the left mastoid, recomputed offline to the averaged mastoids in Schendan & Kutas, 2002). Negativities revealed with comparable paradigms do not systematically peak at the same latencies. For instance, the Ncl recorded by Sehatpour and colleagues (2006) peaked at 320 ms, 30 ms later than the first reported Ncl. Latencies might thus be highly sensitive to subtle variables across experiments and to differences between groups of participants. Differences between the Ncl and the N350, however, go beyond simple difference of latencies and it would be premature to conclude that they are the expression of the same brain processes (see also Sehatpour et al., 2006 for further arguments).

In the ERP studies described above, the landmark signaling when the brain has successfully managed fragmentation is the accurate identification of the stimulus or its recognition from a set of stimuli previously encoded. One may assume that prior to the identification, knowledge associated with the stimuli is well controlled and causes no confounding effect on fragmentation processing. In fact, the inability to identify a stimulus does not signify that there is no associated knowledge. It is indeed possible that, prior to identification, some pieces of the contour are locally integrated into a meaningful but partial structure which alone is insufficient to allow full identification of the object (Doniger et al., 2000). For instance, perceiving the legs of a fragmented horse is enough to determine that the stimulus is an animal but not sufficient to identify the horse. It is also possible that the perception of only several fragments is sufficient to correctly identify the whole object. Therefore, identification does not necessarily mean that fragments have all been fully processed or closed.

The potential effect of associated knowledge on the identification of the stimuli can be attenuated by using abstract figures instead of recognizable objects. Fragments of gabors (cosine patches within a gaussian window) (see Hess & Field, 1999 for a review) delineating very simple shapes elicit negative components of the ERPs but they generally peak earlier than the negativities obtained with recognizable objects (Mathes, Trenner, & Fahle, 2006). A second way to control for potential effects of associated knowledge consists in modulating fragmentation within the limits of recoverability. In such conditions, all stimuli benefit from the contribution of associated knowledge equally and only fragmentation varies across conditions. ERP modulations across recoverable stimuli have not been extensively examined. Stuss and colleagues (1992) compared the ERPs to stimuli that were incomplete to different extents but were all correctly identified. Their results indicate that between 250 and 450 ms, at Cz, the amplitude was more negative to stimuli that were the most incomplete. Taking a different approach, Viggiano and Kutas (1998), Viggiano and Kutas (2000) compared the ERPs evoked at the identification level with those at one higher level with more fragments added to the stimulus. Consistent with the results of Stuss and colleagues (Stuss et al., 1992), the amplitude was more negative for the identification level, thus for the most fragmented level. The authors mentioned that this effect was restricted to posterior sites, but the electrodes, as well as the latencies, were not specified more precisely. A visual inspection of the ERPs depicted in their Fig. 8 (p. 114) (Viggiano & Kutas, 2000), however, suggests that the effect peaked somewhere between 200 and 300 ms.

The present study tested whether the ERP effect to fragmentation are predictive of the subsequent recognition in a memory recognition task. Figures were abstract and meaningless and the encoding task targeted a physical aspect of the stimuli, namely their symmetry (Boucart & Humphreys, 1994). To further control for semantic effect, fragmentation was manipulated within the limits of recoverability. Figures could thus all be imagined complete but the effort to achieve this changed as a function of fragmentation levels. Fragmentation elicited a brain correlate referred to as the N_{frag} (standing for negativity to fragmentation). The magnitude of the N_{frag} can only be assessed if contrasted to the ERPs evoked by a control figure involving no fragmentation processing. This latter was a complete figure, and the comparison of its ERPs with the N_{frag} was referred to as the N_{frag} effect.

Based on the results of Stuss and colleagues (1992) and Schendan and Kutas (2002), we expected an N_{frag} effect to be elicited mainly over central and posterior scalp areas. The effect of fragmentation on encoding was tested by comparing the N_{frag} effect of stimuli subsequently recognized with the N_{frag} effect of stimuli subsequently forgotten. Predictions about these effects depend on the nature of the processes underlying the N_{frag} and how efficient they are. On the one hand, the N_{frag} may reflect a successful perceptual closure of the figure that necessarily improves recognition. Accordingly, the N_{frag} effect should be greater between the complete and fragmented stimuli that were subsequently recognized. On the other hand, the N_{frag} could reflect a brain response to a perceptual problem and the compensatory processes engaged to overcome this problem. Since this problem would likely hinder subsequent recognition, the N_{frag} effect should be greater for figures that were subsequently forgotten.

2. Methods

2.1. Subjects

Twenty-five participants (9 females) aged between 21 and 30 were recruited, though one had to be excluded from the analyses because of his performance (see the behavioral analyses section). All met the inclusion criteria typically used for ERP studies, in that they were right-handed and had normal or corrected-to-normal vision. All participants reported that they and their first-degree relatives had no history of neurological or psychiatric disorders. Participants provided written consent on a form approved by the Douglas Institute Research Ethics Board.

2.2. Stimuli

Stimuli were 400 abstract figures not associated with *a priori* knowledge. Figures were built from an 8×8 grid measuring 6 cm $\times$ 6 cm on the computer screen (8.5° of visual angle) (see Brodeur, Pelletier, & Lepage, 2008b for further details). Example stimuli are depicted in Fig. 1. Half of the figures were symmetric across the vertical axis and half were asymmetric. The contours of 150 figures were fragmented by means of creating gaps with lengths totaling 70% of the remaining fragment lengths. None of these fragments were removed in 50 figures, the Frag-0% figures (e.g., the first figure of the encoding session in Fig. 1). In 50 other figures, 15% of the fragments were removed (e.g., the third figure of the encoding session in Fig. 1) and in 50 different figures 25% were removed (e.g., the fourth figure of the encoding session in Fig. 1). These figures constitute what we have labeled the