International Journal of Psychophysiology 106 (2016) 106–114

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

An ERP study of recognition memory for concrete and abstract pictures in school-aged children☆

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ARTICLE INFO

Article history:
Received 22 January 2016
Received in revised form 6 June 2016
Accepted 17 June 2016
Available online 18 June 2016

Keywords:
Abstract
Children
Concrete
Event-related potentials
Familiarity
Recognition memory

ABSTRACT

Recognition memory for concrete, nameable pictures is typically faster and more accurate than for abstract pictures. A dual-coding account for these findings suggests that concrete pictures are processed into verbal and image codes, whereas abstract pictures are encoded in image codes only. Recognition memory relies on two successive and distinct processes, namely familiarity and recollection. Whether these two processes are similarly or differently affected by stimulus concreteness remains unknown. This study examined the effect of picture concreteness on visual recognition memory processes using event-related potentials (ERPs). In a sample of children involved in a longitudinal study, participants ($N = 96$; mean age $= 11.3$ years) were assessed on a continuous visual recognition memory task in which half the pictures were easily nameable, everyday concrete objects, and the other half were three-dimensional abstract, sculpture-like objects. Behavioral performance and ERP correlates of familiarity and recollection (respectively, the FN400 and P600 repetition effects) were measured. Behavioral results indicated faster and more accurate identification of concrete pictures as "new" or "old" (i.e., previously displayed) compared to abstract pictures. ERPs were characterized by a larger repetition effect, on the P600 amplitude, for concrete than for abstract images, suggesting a graded recollection process dependent on the type of material to be recollected. Topographic differences were observed within the FN400 latency interval, especially over anterior-inferior electrodes, with the repetition effect more pronounced and localized over the left hemisphere for concrete stimuli, potentially reflecting different neural processes underlying early processing of verbal/semantic and visual material in memory.

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1. Introduction

In visual recognition memory paradigms, concrete pictures of familiar and meaningful objects are typically recognized faster and more accurately when compared with abstract, unfamiliar and meaningless pictures (Bellhouse-King and Standing, 2007; Smith et al., 1990). An explanation for this phenomenon is provided by the dual-coding theory, according to which concrete pictures are processed into both verbal and image codes, whereas abstract pictures are primarily processed only in image codes (Paivio, 1975). Consequently, the connection between these two systems, visual and verbal, enhances the memory trace and allows a concrete object to be more easily recognized than an abstract one. Although several studies have examined the temporal dynamics of material-specific effects in recognition memory (e.g., Ecker et al., 2007; Galli and Otten, 2011; Küper et al., 2012; Küper and Zimmer, 2015), to our knowledge, none has focused on the picture concreteness effect.

The neuropsychological dissociation between verbal and visual memory is well established. These separate memory systems appear to be asymmetrically represented in the human brain, in such a way that, memory for verbal material is generally associated with the recruitment of brain regions that are located within the dominant hemisphere (in most cases, the left hemisphere), whereas memory for visual/non-verbal material is believed to rely on the non-dominant

☆ Sources of supports: NIH/NIEHS R01-ES007902; Northern Contaminants Program, Indian and Northern Affairs, Canada; NIH/NIAAA F32-AA14730 (M. Burden); Lycaki-Young, Sr., Fund from the State of Michigan; Post-doctoral grants from the Canadian Institutes of Health Research (O. Boucher).

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http://dx.doi.org/10.1016/j.ijpsycho.2016.06.009
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(right) hemisphere (Banks et al., 2012; Golby et al., 2001; Goldstein et al., 1988; Powell et al., 2005; Wagner et al., 1998; Weber et al., 2007). However, some studies have suggested that the lateralization effect is more pronounced in or is restricted to specific brain areas (e.g., Guerin and Miller, 2009; Kelley et al., 1998; Wagner, 1999), depending on the specific memory processes that are solicited (Banks et al., 2012; Kennepohl et al., 2007).

Current models of recognition memory posit that judgment of a prior occurrence of a stimulus relies on two distinct processes, namely familiarity and recollection (Jacoby, 1991; Mandler, 1980). Familiarity refers to simply knowing that something previously occurred or was experienced, whereas recollection involves the retrieval of specific details about something recognized (Mandler, 1980; Yonelinas, 2002). Consistent with this “dual process model” of recognition memory, studies using event-related potentials (ERPs) during visual recognition paradigms have revealed the existence of two successive, topographically distinct components that are modulated by stimulus repetition and are differently affected by experimental manipulations aimed at modulating familiarity and recollection, respectively (Curran, 2000; Rugg and Curran, 2007; Wilding, 2000). Specifically, the “mid-frontal” (also termed FN400) repetition effect is a reduction in amplitude of a negative component (less negative) that occurs 300–500 ms after the onset of a repeated stimulus and has been proposed to reflect familiarity, although alternative explanations, based on its temporal and topographical similarity with the N400 component, link it to conceptual priming (Voss et al., 2010a; Voss and Federmeier, 2011). The “parietal” (or P600) repetition effect, occurring from 400–500 ms to 700–800 ms after the stimulus, manifests as a larger positive component (more positive) for recognized than new items and is considered a neurophysiological marker of the active recollection of information in memory. The FN400 and P600 repetition effects have been observed in response to several types of stimuli, including concrete pictures and abstract designs (Curran and Cleary, 2003; Maillard et al., 2010). The existence of these two neurophysiological markers of recognition memory processes offers the opportunity to study, simultaneously, the impact of stimulus concreteness on both the familiarity and recollection processes that underlie judgements of recognition. Moreover, they make it possible to examine whether stimulus concreteness influences the lateralization of the ERP repetition effects observed during visual recognition paradigms, and whether this laterality effect differs according to the specific process measured (i.e., familiarity vs. recollection).

ERPs obtained from children may show qualitative and quantitative differences compared to those obtained from adults. For instance, the well-known late ‘P3b’ component elicited by attended target stimuli tends to appear at longer latencies and has been described as more posteriorly distributed in children as compared to adults (Flores et al., 2010; Johnstone et al., 1996; Picton, 1992). There is ample evidence from developmental ERP studies on recognition memory that the parietal repetition effect – the putative ERP correlate of recollection – can be reliably recorded at an early school age (Cycowicz et al., 2003; Van Strien et al., 2009), albeit at a longer latency relative to young adults (Czernochowski et al., 2004). However, with respect to the midfrontal FN400 repetition effect – the putative correlate of familiarity – the picture is less clear (Czernochowski et al., 2009; Friedman et al., 2010; Hepworth et al., 2001; Mecklinger et al., 2011). For instance, comparing the ERPs obtained during continuous recognition memory paradigms aimed to assess item and source memory in 10- to 12-year-old children and in adults, Czernochowski et al. (2009) found that only adults showed the typical reduction (less negative) of the early frontal negative component for repeated compared to new stimuli; in children, the repetition effect was reversed in polarity (more negative for old than for new items). By contrast, Mecklinger et al. (2011) reported that the typical early frontal repetition effect (reduced negativity) could be elicited in 8- to 10-year-old children and adults under speeded response conditions (Mecklinger et al., 2011). The scarcity of developmental ERP studies on recognition memory, the relatively small sample sizes used in these studies leading to low statistical power, and the heterogeneity in study methodology may have contributed to the lack of consensus on the presence of the FN400 repetition effect in children.

In order to improve our understanding of children's recognition memory, this study examined the effect of stimulus concreteness on visual recognition memory using ERPs recorded during a continuous recognition protocol employing pictures of common objects and abstract sculpture-like three-dimensional images. We studied a sample of school-aged Inuit children residing in Arctic Québec, Canada, who were participating in a longitudinal study on child development that was designed primarily to study effects of environmental contaminants and seafood nutrients on cognitive function (Jacobson et al., 2015; Muckle et al., 2001). We have previously reported beneficial effects of polyunsaturated fatty acids (PUFAs) on the ERP components recorded during this task (Boucher et al., 2011). The present study is a re-analysis of a subset of those previously published data, with a focus on the ERP correlates of the concreteness effect on visual recognition memory. Our main objectives here were 1) to compare the repetition effects obtained from concrete vs. abstract images on the FN400 familiarity and the P600 recollection ERP effects in a large sample of children; and 2) to explore hemispheric differences in these two ERP components obtained from concrete and abstract stimuli.

2. Methods

2.1. Subjects

An ERP continuous recognition memory task was administered to 192 school-aged Inuit children, who participated in the Nunavik Child Development Study (Jacobson et al., 2015; Muckle et al., 2001). Nunavik is a region of Québec located north of the 55th parallel, about 1500 km from Montréal. About 12,000 residents, mostly Inuit, live in 14 villages scattered along a 2000-km seashore line along Hudson Bay, Hudson Strait, and Ungava Bay. This population is exposed to relatively high levels of environmental contaminants, including methylmercury, lead (Pb), and polychlorinated biphenyls (PCBs), due to their traditional diet based on fishing and hunting products, but also have high body concentrations of beneficial PUFAs due to their diet. The study was conducted in the three largest communities (Kuujjuaq, Puvirnituq, and Inukjuak). Children residing in other villages were transported by plane with their parent on the day prior to testing.

Written informed consent was obtained from a parent of each participant; oral assent, from each child. The research was approved by the Laval University and Wayne State University ethics committees and was performed in accordance with ethical standards of the Helsinki Declaration (World Medical Association, 2008). A total of 165 children were eligible for the current study based on the following inclusion criteria (numbers of children excluded because they did not meet these criteria in parentheses): age between 10.0 and 13.0 years ($n = 2$), right-handed ($n = 21$), birth weight ≥ 2.5 kg, gestation duration ≥ 35 weeks, no known neurological or clinically significant developmental disorder [multiple sclerosis ($n = 1$), history of traumatic brain injury requiring >1 day of hospitalisation ($n = 1$), history of epilepsy ($n = 1$), history of meningitis ($n = 1$). Left-handers were excluded because of the possible effect of handedness on hemispheric dominance (Basic et al., 2004).

2.2. ERP protocol

Visual recognition memory was assessed in a continuous recognition memory task. Each child was tested individually in a quiet room, seated 57 cm from a 43-cm LCD monitor, on which pictures were displayed centrally within a 7 × 7 cm space. The child was asked to press one of

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