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Research report

# Structural encoding processes contribute to individual differences in face and object cognition: Inferences from psychometric test performance and event-related brain potentials

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ABSTRACT

The enhanced N1 component in event-related potentials (ERP) to face stimuli, termed N170, is considered to indicate the structural encoding of faces. Previously, individual differences in the latency of the N170 have been related to face and object cognition abilities. By orthogonally manipulating content domain (faces *vs* objects) and task demands (easy/speed *vs* difficult/accuracy) in both psychometric and EEG tasks, we investigated the uniqueness of the processes underlying face cognition as compared with object cognition and the extent to which the N1/N170 component can explain individual differences in face and object cognition abilities. Data were recorded from $N = 198$ healthy young adults. Structural equation modeling (SEM) confirmed that the accuracies of face perception (FP) and memory are specific abilities above general object cognition; in contrast, the speed of face processing was not differentiable from the speed of object cognition. Although there was considerable domain-general variance in the N170 shared with the N1, there was significant face-specific variance in the N170. The brain–behavior relationship showed that faster face-specific processes for structural encoding of faces are associated with higher accuracy in both perceiving and memorizing faces. Moreover, in difficult task conditions, qualitatively different processes are additionally needed for recognizing face and object stimuli as compared with easy tasks. The difficulty-dependent variance components in the N170 amplitude were related with both face and object memory (OM) performance. We discuss implications for understanding individual differences in face cognition.



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## 1. Introduction

In everyday life, we perceive and recognize many different kinds of objects, such as vehicles, buildings, plants, animals, human bodies, and faces. Out of all these stimuli, the specificity of the cognitive and neural mechanisms underlying face cognition is being discussed controversially and addressed from several scientific perspectives. Many researchers favor the idea of domain specificity of face cognition, postulating specialized mechanisms for processing faces (see Kanwisher & Yovel, 2006, for review). Others favor the alternative, domain-general hypothesis, holding that under certain conditions the same mechanisms may operate in processing face and non-face visual stimuli (e.g., Diamond & Carey, 1986).

### 1.1. *Face processing from a clinical and experimental perspective*

Evidence for distinct mechanisms involved in face recognition is provided by persons with developmental prosopagnosia (DP) characterized by an isolated disability in recognizing faces but not other objects (e.g., Duchaine & Nakayama, 2006; Duchaine, Yovel, Butterworth, & Nakayama, 2004), and by brain damaged patients, with acquired prosopagnosia, who lost their ability to recognize faces while recognition of other objects remained largely intact (Wada & Yamamoto, 2001; see Young, 2011, for review). In many experimental studies, it has been shown that the facility of holistic processing supports face perception (FP) more than non-face object perception (OP). For example, the classic behavioral paradigms testing holistic processing by producing the inversion (Yin, 1969), part-whole (Tanaka & Farah, 1993), and composite effects (Young, Hellawell, & Hay, 1987), yield stronger effects for faces than for other types of complex object stimuli.

In contrast, there is also some evidence supporting domain-generality of face processing. A series of experiments on visual expertise done by Diamond and Carey (1986) showed that faces are not unique in terms of the inversion effect. For example, for dog experts (but not for non-experts), recognition of dogs was as disrupted by inversion as was face recognition. In addition, neuroimaging studies showed increased activation of the fusiform face area in recognizing non-face objects of expertise, for example cars and birds (Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Xu, 2005). Hence the putative face-specific mechanisms may not be specialized for FP per se, but engaged in processing of many kinds of visual stimuli for which we have expertise.

From a neuroscience perspective, face processing is also considered specific because it activates a dedicated cortical brain network. In functional imaging studies some visual regions in occipito-temporal cortex, such as fusiform face area (FFA; e.g., Kanwisher, McDermott, & Chun, 1997) and occipital face area (OFA; Pitcher, Walsh, & Duchaine, 2011) respond to face stimuli more strongly than to non-face visual stimuli (e.g., Haxby, Hoffman, & Gobbini, 2000; Kriegeskorte & Bandettini, 2007; Sergent, Ohta, & MacDonald, 1992).

Furthermore and particularly important in the present context, a large number of studies have shown face-specific electrophysiological responses around 170 msec after stimulus onset in the electroencephalogram (N170) or magnetoencephalogram (M170) (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer & McCarthy, 1999; Eimer, 2011; Jeffreys, 1996). The N170 is a negative-going event-related potential (ERP) component over the inferior occipito-temporal cortex, which is usually larger in amplitude for face than for non-face object stimuli, especially in the right hemisphere (Scott & Nelson, 2006). The N170 has been associated with perceptual structural encoding of faces (e.g., Eimer, 2000; Rossion & Jacques, 2008; Sagiv & Bentin, 2001).

It is important to point out that the N170 to faces may be considered to be an enhancement of the N1 component observed to any visual stimulus. However, it is unclear to which degree the neural processes underlying N1 and N170 components are overlapping. Thus, the N170 could be merely an enhancement of the N1 component or the increase of the N170 beyond the N1 could represent separable processes.

In general, pursuing an experimental approach, it is often difficult to determine whether the mean difference between the variables measured in experimental and control conditions arise from more or less activity of the same set of neural processes (quantitative change) or may be due to additional resources or neural processes needed for processing in one of the experimental conditions (qualitative change). However, in an individual differences approach, testing the effect of experimental manipulations on the variance across persons and covariances between control and experimental conditions can help to distinguish between these two alternatives. If only a quantitative change within the same set of processes is induced by an experimental manipulation, no change in the rank order of persons is expected, because for every individual the processes involved in the experimental condition are the same as the processes involved in a control condition. If qualitatively different sets of processes are recruited by a given experimental manipulation as compared with a control condition, a systematic change in the rank order of persons and not only a shift of means is expected (Oberauer, Wilhelm, & Schmiedek, 2005). Thus, the differential approach goes beyond experimental studies by addressing qualitative differences in specific cognitive processing domains.

Following the individual differences approach, we can investigate whether the N170 component is induced by face-specific neural processes or is reflecting domain-general neural processes, only in different intensity as compared with the N1 component. Thus, if the variance observed in the component in face cognition tasks is separable from the variance observed in object cognition tasks, we can conclude that the object-elicited N1 is qualitatively different from the enhancement of the N1 (i.e., N170) component. In contrast, if the variance is inseparable, N1 and N170 are reflecting indistinguishable neurocognitive processes, potentially of different intensity.

### 1.2. *Face processing from an individual differences perspective*

The vast majority of EEG and fMRI studies on face specificity have used experimentally induced task condition specific