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Infant Behavior & Development 25 (2002) 466–494

Infant Behavior & Development

Theoretical and methodological implications of variability in infant brain response during a recognition memory paradigm

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Received 31 August 2001; received in revised form 31 January 2002; accepted 15 February 2002

Abstract

Previously published reports have sought to elucidate the development of visual recognition memory in the human infant by investigating the modulation of infant ERPs by a familiar and novel face (e.g., de Haan & Nelson, 1997, 1999). Variability in infants' brain responses elicited under the same mnemonic condition, however, has not been previously examined. The present report undertook two separate analyses in order to examine two kinds of variability: variability in the brain's response to a stimulus over time as a function of stimulus repetition, and variability in the brain's response between subjects as a function of the total number of trials completed in an ERP session. There were three major findings: (a) the mid-latency negative component (Nc) and long-latency slow wave (SW) were found to dissociate cognitive processes associated with familiarity from processes associated with stimulus repetition, (b) individual differences in the number of trials an infant completes in an ERP session were observed to be associated with differences in the amplitude and latency of the Nc, and (c) individual differences in the number of trials an infant completes appear to reflect differences in the extent to which the familiar and novel faces are encoded. The implications of these results are discussed with respect to models of habituation and preferential looking, infant ERP methodology, and developmental processes.

Keywords: Infant memory; Recognition; Event-related potentials; Faces

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0163-6383/02/$ – see front matter © 2002 Published by Elsevier Science Inc.
PII: S0163-6383(02)00146-7

1. Introduction

Event-related potentials (ERPs) reflect the synchronous firing of neuronal populations in the cortex, and represent transient changes in the brain in response to a discrete event. These potentials propagate through extracellular space and are measured by electrodes placed on the scalp. ERPs have excellent temporal resolution, and thus can provide milliseconds by milliseconds information about ongoing cognitive processes. Due to the physical and physiological properties of the skull, scalp, and the brain, however, the signal-to-noise ratio during this type of recording can be quite low. In order to increase the signal relative to the noise, stimuli are presented such that the responses to a particular condition or category can be averaged across multiple trials. In order to create a stable average, psychophysiologists who study adults often collect hundreds of trials from an individual participant. As would be expected, the requirements for developmental populations are reduced and the total number of trials for many infant-based experiments is between 40 and 100.

ERPs have been used to provide an important source of information about the development of visual recognition memory. The spatial and temporal information provided by ERPs permits the differentiation of cognitive processes that may not be directly reflected in behavior, as the recording method does not require a behavioral response by the subject. For example, de Haan and Nelson (1997) showed that the ERP to an a priori familiar stimulus depended on the context in which the stimulus was viewed (i.e., the perceptual properties of a novel stimulus with which it was paired). In this study, both the morphology and topography of infants' brain activity that differentiated the familiar and novel stimulus depended on the degree of perceptual similarity between the stimuli. Such differences suggest that different neural circuits, and hence, different cognitive processes may be invoked, depending on the context in which a stimulus is viewed.

Despite an increase in the use of ERPs with developmental populations, infant ERP studies have typically used one of two paradigms. The first is a standard oddball paradigm, in which two or more stimuli are presented repeatedly, with different frequencies of presentation, while ERPs are recorded. The second is a modified habituation paradigm in which the infant is first familiarized to a stimulus, and then presented with the familiar and a novel stimulus repeatedly while ERPs are recorded (Nelson, 1994; Nelson & Monk, 2001 for review). In addition, the majority of these studies have used faces as stimuli. To date, there are several major components that have been observed in the infant ERP. The two that are most relevant to this report include the middle-latency negative component (Nc) and the long-latency slow wave component (SW).

The Nc is a negative deflection in the ERP that peaks between 400 and 800 ms following stimulus onset. It is commonly observed to be maximal over fronto-central scalp regions, and is thought to reflect an obligatory attentional response. In general, the Nc is more negative to unexpected, unrecognizable events or to an infrequent stimulus (Courchesne, Ganz, & Norcia, 1981; Karrer & Ackles, 1987), is sensitive to experience or familiarity (Courchesne et al., 1981; de Haan & Nelson, 1997, 1999; Webb & Nelson, 2001a), and can index habituation effects (Nikkel & Karrer, 1994; Snyder & Nelson, in preparation). Nelson (1994) has suggested that the Nc may be an obligatory attentional response, since the component is present in the overall waveform to some degree regardless of the experimental manipulation.

The SW generally begins around 1,000 ms following stimulus onset and is commonly observed to be maximal over temporal scalp regions. Courchesne and colleagues (1981) have