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Event-related potentials to intact and disrupted actions in children and adults

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ABSTRACT

The current research used event-related potentials (ERPs) to investigate neurophysiological responses to intact and disrupted actions embedded within an event in children and adults. Responses were recorded as children (24-month-olds) and adults observed a relatively novel event composed of three actions. In one condition pauses were inserted at intact boundaries (i.e., at the endpoint of each action), whereas in the other condition they were inserted at breakpoints that disrupted the action (i.e., in the middle of each action). Evoked responses revealed differences across conditions in both groups; disrupted actions elicited a prolonged negative slow wave from 100 to 700 ms in children, whereas adults demonstrated two distinct negative peaks between 50–150 and 250–350 ms. These findings contribute the first electrophysiological evidence that children readily detect disruptions to ongoing events by the end of the second year, even with limited exposure to the event itself. Furthermore, they suggest that adults rely on two distinct mechanisms when processing novel events. Results are discussed in relation to the role of perceptual and conceptual levels of analysis in the development of action processing.

Introduction

From the very beginning, human action unfolds around infants and young children. The temporal and hierarchical organization of these actions is a crucial component of event meaning. Take, for

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example, the busy mother who is simultaneously preparing for work and getting her children ready for school. The mother's dressing and collecting of her documents is distinct from dressing her children and preparing breakfast. Each event is composed of action units that, in sum, distinguish it from simultaneously occurring events as well as from events that have occurred in the past or may occur in the future. The ability to detect relevant action units within the event stream may serve as a foundation for forming logical conclusions about observed behaviors, planning and executing appropriate responses within a dynamic environment, and developing an understanding of what people do and why they do it. To date, however, we have very little evidence as to how children process unfamiliar events, and we know even less about the development of neural mechanisms that subserve this ability. The current article contributes to the field by bringing neurophysiological evidence to bear on the question of whether observed human action is processed meaningfully from early in life.

Multiple sources of information operating in tandem facilitate adults' ability to process (Raisig, Welke, Hagendorf, & van der Meer, 2010; Zacks & Swallow, 2007) and evaluate the rationality of actions (Jastorff, Clavagnier, Gergely, & Orban, 2011) with bottom-up perceptual cues complementing top-down conceptual knowledge (Zacks & Tversky, 2001). Whereas a substantial body of literature suggests that children also exhibit at least some ability to evaluate the rationality of observed actions within the first and second years (Biró, Csibra, & Gergely, 2007; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Klossek & Dickinson, 2012), greater uncertainty surrounds the mechanisms that subserve this developing capacity. According to the "teleological" stance, 12-month-olds evaluate action as it pertains to the intended goal and situational constraints (Gergely & Csibra, 2003); adults rely on the same trichotomy (i.e., action, goal, and constraints) but extend their representations by attributing mental intentional states to the agent. Alternatively, it has been suggested that infants' ability to evaluate others' actions may reflect a statistical learning mechanism (Cicchino, Aslin, & Rakison, 2011; Kirkham, Slemmer, & Johnson, 2002; Olofson & Baldwin, 2011). In one recent study, adults rapidly modified their expectations, whereas 9-month-olds continued to predict an inefficient action based on frequency of exposure (Paulus et al., 2011). Whether and to what extent action processing in children is similarly governed by perceptual versus conceptual processes, and whether the two systems are both activated in response to relatively novel events, is currently unknown.

To address this issue, the current study used event-related potentials (ERPs, i.e., electrical activity time-locked to the presentation of a stimulus and recorded at the scalp) to measure neural responses as children and adults observed a relatively novel event[1] composed of three actions in which an agent manipulated objects. For the purpose of this article, we consider an "event" to be a set of interrelated agents, actions, and objects situated in a specific time and space. Importantly, in the current research, there are temporal contingencies between actions within the larger event such that the completion of each action leads logically and proximally to the beginning of the next action. This is consonant with usage in developmental literature focusing on event perception (Baillargeon & Wang, 2002; Johnson, Amso, Frank, & Shuwairi, 2008), event segmentation (Baldwin, Baird, Saylor, & Clark, 2001; Friend & Pace, 2011), and event memory (Bauer et al., 2006; Carver, Bauer, & Nelson, 2000). The event was relatively novel in the sense that participants had not previously observed this particular sequence of actions involving this unique combination of objects. Thus, we could be sure that participants had not established any a priori expectations about the event. We emphasize novelty to contrast with previous research that has focused on familiar everyday events such as eating and washing the dishes (Baldwin et al., 2001; Meints, Plunkett, & Harris, 2008; Reid et al., 2009). The increased processing of unexpected variations in familiar events suggests early sensitivity to violations of rationality. In the current study, we asked whether children evince similar sensitivity in unfamiliar events.

Several questions regarding the development of early rationality emerge from the literature on action perception and comprehension in young children. Foremost is how observers construct accurate representations of events, especially when they are initially encountered. Developing the ability to perceive the hierarchical organization of an event may lay the groundwork for more sophisticated action interpretation (Reid, Hoehl, Landt, & Striano, 2008). Converging behavioral and neural evidence

[1] Note that, in this context, "event" refers to a general category of observed human action. We are not referring to the events to which EEG is time-locked during ERP collection.