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# Semantic processing of actions at 9 months is linked to language proficiency at 9 and 18 months

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### ABSTRACT

The current study uses event-related potential methodologies to investigate how social–cognitive processes in preverbal infants relate to language performance. We assessed 9-month-olds' understanding of the semantic structure of actions via an N400 event-related potential (ERP) response to action sequences that contained expected and unexpected outcomes. At 9 and 18 months of age, infants' language abilities were measured using the Swedish Early Communicative Development Inventory (SECDI). Here we show that 9-month-olds' understanding of the semantic structure of actions, evidenced in an N400 ERP response to action sequences with unexpected outcomes, is related to language comprehension scores at 9 months and is related to language production scores at 18 months of age. Infants who showed a selective N400 response to unexpected action outcomes are those who are classed as above mean in their language proficiency. The results provide evidence that language performance is related to the ability to detect and interpret human actions at 9 months of age. This study suggests that some basic cognitive mechanisms are involved in the processing of sequential events that are shared between two conceptually different cognitive domains and that pre-linguistic social understanding skills and language proficiency are linked to one another.

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## Introduction

Young infants show sophisticated abilities across an array of cognitive domains during early development (Mandler, 2006). One example of this is the ability to determine outcomes of actions, which is linked to the capacity to process other people's goals and their intentions (Baldwin, Baird, Saylor, & Clark, 2001). It is possible to conceptually divide human action into two primary forms. On the one hand, actions can be communicative in nature and are designed to directly engender social understanding of information. Within this framework, infants' preverbal social-communicative capacities such as the ability to follow others' eye gaze (e.g., Brooks & Meltzoff, 2005, 2008, 2015) and to process pointing (e.g., Brooks & Meltzoff, 2008; Butterworth & Morissette, 1996; Tomasello, Carpenter, & Liszkowski, 2007) and gestures (e.g., Kraljević, Capanec, & Šimleša, 2014; Rowe & Goldwin-Meadow, 2009a, 2009b) are well studied and have been related to various aspects of later language abilities.

A second form of actions incorporates all of those actions that are non-communicative in nature but still convey goal directedness. Such goal-directed actions can be observed repeatedly in typical environments by infants during early development, ranging from parents cleaning the home to the preparation and consumption of food. In such scenarios, adults as well as young children readily construct action representations that are organized with respect to this ultimate goal (Baldwin et al., 2001; Zacks et al., 2001). For example, infants from 6 months of age can accurately predict that a cup (Hunnius & Bekkering, 2010) or a spoon (Kochukhova & Gredebäck, 2010; Reid et al., 2009) should go toward a person's mouth rather than toward a person's ear. These representations allow for the prediction of the consequences of actions, including the ability to interpret and describe actions and categorize action sequences (Sommerville & Woodward, 2005). Prior research has shown that the structure of actions parallels that of linguistic utterances and that both actions and language show comparable hierarchical structures (Baldwin et al., 2001; Zacks et al., 2001). It has been argued that human language emerged from the hierarchical structure of instrumental actions. The same neural circuits that control the hierarchy of these instrumental actions served as a basis on which the newly acquired function of language syntax has emerged (Gallese, 2007). The parallels that can be seen between the semantic organization of non-communicative actions and the semantics within linguistic structures raise the possibility that processing of this action type during early development may be related to language. The context that is present within the execution of sentences and actions conveys information that facilitates the prediction of future events. Situational knowledge thereby provides infants with a mechanism to use semantic rules during action observation (Ni Choisdealbha & Reid, 2014). Among other cognitive and social advantages, this enables infants to reenact the final goal of a modeled action (Gergely, Bekkering, & Kiraly, 2002) and to infer goals of an uncompleted action without seeing the achievement of the goal itself (Daum, Prinz, & Aschersleben, 2008). Given these parallels in the organization of non-communicative actions and the structure of language, it has been conjectured that the ability to process these hierarchically structured actions during early development may pave the way for language acquisition (Reid et al., 2009). From the evolutionary account, it has been suggested that language has its origin in the ability to interpret others' gestures and actions (e.g., Corballis, 2003; Rizzolatti & Arbib, 1998). Together, these findings indicate that in addition to previous findings, which demonstrated strong relations between infants' preverbal social-communicative capacities and language and have already been well studied, understanding of non-communicative action may also be linked to the development of language or share similar domain-general processes. To date, there is no empirical evidence to support the notion that links between the two domains exist during early development. Consequently, the current study investigated the relation between the semantic processing of non-communicative instrumental actions during infancy, that is, the ability to detect and interpret others' action end states as either expected or unexpected and relate this ability to language abilities during the first and second postnatal years.

In language research, the N400 component of the event-related potential (ERP) has been identified as a neural signature related to the formation of a semantic representation because the N400 is elicited when a word does not fit an expected context (e.g., Kutas & Hillyard, 1980). In the action domain, N400 effects are observable when action outcomes are violated in infants and adults (e.g., Parise & Csibra,

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