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Real-time interpretation of novel events across childhood

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ABSTRACT

Despite extensive evidence that adults and children rapidly integrate world knowledge to generate expectancies for upcoming language, little work has explored how this knowledge is initially acquired and used. We explore this question in 3- to 10-year-old children and adults by measuring the degree to which sentences depicting recently learned connections between agents, actions and objects lead to anticipatory eye-movements to the objects. Combinatory information in sentences about agent and action elicited anticipatory eye-movements to the Target object in adults and older children. Our findings suggest that adults and school-aged children can quickly activate information about recently exposed novel event relationships in real-time language processing. However, there were important developmental differences in the use of this knowledge. Adults and school-aged children used the sentential agent and action to predict the sentence final theme, while preschool children's fixations reflected a simple association to the currently spoken item. We consider several reasons for this developmental difference and possible extensions of this paradigm.

Introduction

Fluent listeners understand spoken sentences in their native language by integrating informative cues that span multiple words in real-time and actively generating expectations about upcoming language. For example, adults and preschool children can predictively interpret relationships that extend across an agent and an action (e.g. *The pirate hides the…*) to determine the likelihood of future words in a sentence (e.g. treasure vs. cat; Borovsky, Elman, & Fernald, 2012; Kamide, Altmann, & Haywood, 2003). This example highlights two (of the many) cognitive mechanisms recruited for simple spoken language interpretation: (1) the ability to rapidly activate knowledge of world events underlying multi-word contingencies and to (2) generate predictions during language processing. The developmental timescales of these two processes may not be identical. While it is thought that the knowledge needed to interpret combinatorial relationships in language is gradually acquired across childhood via extensive world and linguistic experience, basic predictive mechanisms of language processing are evident from at least infancy, though this ability is gradually refined with age (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998; Fernald, Thorpe, & Marchman, 2010; Fernald, Zangl, Portillo, & Marchman, 2008). Yet listeners of all ages often encounter (and comprehend) spoken language that describes infrequent or novel situations. Until recently, combinatorial processing has only been examined in cases where the event knowledge underlying these sentential and lexical relationships is highly familiar, and only a single prior study has examined how this knowledge becomes instantiated in sentential processing (and only in adults;

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Amato & MacDonald, 2010). Here we ask: How do adults and children interpret language depicting novel events? We investigate developmental differences in children's and adults' online processing of novel event relationships and examine what these differences reflect. After familiarizing adults and children with novel (cartoon) relationships between agents, actions and objects (such as monkeys riding buses), we measured their subsequent online comprehension of these events conveyed in simple transitive sentences using a visual world eye-tracking task.

Linguistic processing in the visual world

Paradigms that measure eye-movements in response to spoken language have significantly advanced our understanding of how children and adults engage in real-time linguistic processing. In this method, variously termed the Visual World Paradigm (VWP) or Looking-while-Listening (LWL) method, visual attention towards objects is monitored as speech unfolds (Fernald et al., 2008; Huettig, Rommers, & Meyer, 2011; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). Because listeners often orient their gaze towards an object before its label is completely spoken (Allopenna, Magnuson, & Tanenhaus, 1998; Dahan, Magnuson, & Tanenhaus, 2001), or even before it is mentioned (Altmann & Kamide, 1999; Altmann & Mirkovic, 2009; Kamide et al., 2003), gaze is used as an index of real-time comprehension of language (Tanenhaus, Magnuson, Dahan, & Chambers, 2000).

These eye-tracking paradigms have revealed that adults and children can make use of a variety of linguistic and nonlinguistic cues to generate predictions about likely sentence continuations. For example, adults and children as young as two can actively predict a thematically related item (e.g. *cake* or *cookie*) when provided a highly selective verb (e.g. eat; Altmann & Kamide, 1999; Fernald et al., 2008; Mani & Huettig, 2012). More recently, predictive linguistic processing has been observed in cases that require sensitivity to higher order contingencies that extend across multiple linguistic items. For example, adults and children as young as three can make use of combinatorial information that exists across a sentential agent and an action to generate differential expectations of likely sentence themes (Borovsky et al., 2012; Kirkham, Cruess, & Diamond, 2003).

This process is demonstrated in a study where adults and children (aged 3–10) heard sentences like, *The pirate chases the ship*, while simultaneously viewing a scene consisting of items that were thematically related to the agent "pirate" (e.g., SHIP and TREASURE), related to the action "chase" (e.g., SHIP and CAT) or unrelated to either agent or action (e.g., BONE Borovsky et al., 2012). After hearing the verb, even the youngest participants directed most of their fixations towards the SHIP, indicating that they had successfully integrated across the agent and action to anticipate the likely sentential theme. These results further revealed that listeners as young as age three incrementally integrated these combinatorial contingencies as the sentence unfolded. As soon as listeners heard the sentential agent (*pirate*), the majority of fixations were directed towards the agent-related items (SHIP and TREASURE). After the verb denoting the action was spoken (*chases*), they generated a small percentage of fixations towards the locally coherent item, "CAT" even though it did not cohere with the global sentential message. Interestingly, even preschool aged listeners displayed fixation patterns similar to that of older children and adults on this task, suggesting that even young listeners are able to activate world knowledge to generate predictions about upcoming items while simultaneously considering less likely outcomes to a lesser degree. However, this prior research considered only highly familiar sentential relationships that were well known to even the youngest participants.

Learning about event relationships

How do adults and children interpret multi-word contingencies that they have only recently encountered, and which are not yet highly familiar? To succeed at this task, listeners need to initially encode and later (re)activate this event information when it is encountered in speech. There are a number of cases in the developmental learning literature that suggests even young children learn some aspects of lexical and event information from limited experience. For instance, children can acquire novel lexical mappings after a single exposure (Carey & Bartlett, 1978; Dollaghan, 1985; Heibeck & Markman, 1987), although these representations may not be as stable or fully developed as words that have been more extensively trained (McMurray, Horst, & Samuelson, 2012). There is also evidence that this ability may extend to information about novel events. For example, 3–7 year olds (Hudson & Nelson, 1983) and kindergartners (Fivush, 1984; Smith, Ratner, & Hobart, 1987) are able to provide well-organized and detailed accounts of events like a first day at school, or the steps in a recipe after only a single experience, although the amount of detail that children provide about these events improves with age. Similarly, infants and toddlers ranging from 11 to 30 months of age (Bauer & Fivush, 1992; Bauer & Mandler, 1989; Bauer & Shore, 1987; Mandler & McDonough, 1995) are able to re-enact novel event sequences by carrying out a previously observed series of actions with a group of toys after only a single observation. Therefore, it seems likely that even preschool-aged children may be able to quickly learn novel multi-word contingencies from events expressed a single time in stories.

The learning of combinatorial relationships in unfamiliar events has been recently explored in adults in an artificial language learning paradigm accompanied by a cartoon world (Amato & MacDonald, 2010). Adults were extensively exposed to novel events via a text-based artificial language (with an unfamiliar lexicon and grammar) accompanied by illustrations that depict various agents (cartoon monsters) performing various actions on objects. Self-paced reading times to sentences in this artificial language were used to subsequently assess knowledge of these event relationships. Although learners did not seem to show explicit awareness of the relationships trained in this paradigm, reading times indicated otherwise. Adult learners were faster to interpret sentences that contained