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Remember dax? Relations between children's cross-situational word learning, memory, and language abilities

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ABSTRACT

Learning new words is a difficult task. Children are able to resolve the ambiguity of the task and map words to referents by tracking co-occurrence probabilities across multiple moments in time, a behavior termed cross-situational word learning (CSWL). Although we observe developments in CSWL abilities across childhood, the cognitive processes that drive individual and developmental change have yet to be identified. This research tested a developmental systems account by examining whether multiple cognitive systems co-contribute to children's CSWL. The results of two experiments revealed that multiple cognitive domains, such as memory and language abilities, are likely to drive the development of CSWL above and beyond children's age. The results also revealed that memory abilities are likely to be particularly important above and beyond other cognitive abilities. These findings have implications for theories and computational models of CSWL, which typically do not account for individual children's cognitive capacities or changes in cognitive capacities across time.

Introduction

The world presents children with a seemingly infinite amount of information in just one moment in time. This large amount of information imposes a challenging task when learning language. For each new word that children learn, there are a theoretically infinite number of potential referents for this word. Despite the challenge of the task, children are remarkable word learners; after the first few years of life, children quickly map a word to the correct referent with only a few learning trials (e.g., Carey & Bartlett, 1978).

Research on word learning has historically focused on how children can resolve ambiguity in a single moment in time. However, in real-world language learning environments, children must resolve ambiguity across several moments in time to learn words. Thus, recent research has shifted toward examining whether children resolve ambiguity across multiple learning events. This work has revealed that infants and children can track the co-occurrence of words and objects across learning events and later use this information to infer word-object mappings. This behavior is commonly termed *cross-situational word learning (CSWL)*. Over the last 10 years, there has been significant growth in research on children's CSWL (Scott & Fisher, 2012; Smith & Yu, 2008, 2013; Suanda, Mugwanya, & Namy, 2014; Vlach & Johnson, 2013; Vouloumanos & Werker, 2009; Yu & Smith, 2011) and adult and computational models of children's CSWL (Fazly, Alishahi, & Stevenson, 2010; Fitneva & Christiansen, 2011; Kachergis, Yu, & Shiffrin, 2013; Medina, Snedeker, Trueswell, & Gleitman, 2011; Smith, Smith, & Blythe, 2011; Trueswell, Medina, Hafri, & Gleitman, 2013; Vlach & Sandhofer, 2014; Yu & Smith,

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2007, 2012; Yurovsky & Frank, 2015; Yurovsky, Yu, & Smith, 2013).

In a typical CSWL paradigm (e.g., Smith & Yu, 2008; Vlach & Johnson, 2013), children are presented with a series of ambiguous learning trials, each trial consisting of two novel words and two novel objects presented in random order. After learning, children are presented with test trials that consist of two objects presented during learning. Children are then asked to map a word to one of the two objects. The results of these studies have revealed that young infants can successfully infer word-object mappings using CSWL (Smith & Yu, 2008). Moreover, the ability to learn word-object mappings continues to develop across the second year of life (Vlach & Johnson, 2013; Vouloumanos & Werker, 2009) and early childhood years (Scott & Fisher, 2012; Suanda et al., 2014; Woodard, Gleitman, & Trueswell, 2016). A key finding of this research is that there are striking individual differences in the degree to which infants and children can learn words during CSWL (e.g., Scott & Fisher, 2012; Yu & Smith, 2011). Thus, a central pursuit in studying children's CSWL has been to identify the cognitive processes that drive changes and improvements in performance.

One proposal is that changes and improvements in language development are a result of general maturation and maturational constraints (e.g., Newport, 1990). According to this account, language learning abilities improve in efficiency and capacity via maturation of the brain over time. That is, the age of the learner, a proxy measure of maturation, is the largest contributor to language learning outcomes. Thus, the maturation account would predict a strong relation between children's age and CSWL performance. Additionally, the maturation account would predict that other factors (e.g., memory abilities) play a more minor role in driving changes in early word learning.

In contrast, other theoretical accounts propose that a certain cognitive system plays a particularly important role in development, above and beyond age. Cognitive systems are broadly defined as mental systems that share representations and mechanisms (e.g., Smith & Thelen, 2003; Van Geert, 1991), such as visual attention, language, and memory. For instance, one of these proposals is that children's general vocabulary development and word learning abilities drive CSWL. The central tenet of this account is that, as children have gained practice learning words, they learn new words faster and in more challenging learning environments (Scott & Fisher, 2012; Smith & Yu, 2013). Evidence for this proposal comes from studies examining children's vocabulary size in relation to their CSWL performance (Scott & Fisher, 2012); children with larger vocabularies have higher performance on more difficult CSWL tasks than children with smaller vocabularies. In brief, the language account proposes that children's developing language abilities drive changes in children's CSWL.

A final proposal is that changes in children's memory abilities contribute to CSWL (Vlach & Johnson, 2013; Vlach & Sandhofer, 2014). The central tenet of this account is that children must encode, retain, and retrieve a large amount of information during CSWL. That is, tracking and later retrieving co-occurrence information imposes a significant memory demand on young learners. Evidence for this proposal comes from studies demonstrating that placing small memory demands on learners during CSWL can make infants (Vlach & Johnson, 2013) and adults (Vlach & Sandhofer, 2014) fail to successfully retrieve and infer learned words. Thus, according to the memory account, improvements in memory abilities are likely to be the primary cognitive mechanism that drive changes in children's CSWL.

Although various theoretical accounts have emerged, many accounts have yet to be directly tested. For instance, researchers have argued that memory abilities are the primary driver of improvements in children's CSWL (e.g., Vlach & Johnson, 2013), but have yet to demonstrate that children's memory abilities predict their CSWL performance. The hypothesis that memory abilities are important is inferred from changes in learners' performance when memory demands are placed on learners (Vlach & Johnson, 2013; Vlach & Sandhofer, 2014) rather than testing relations between learners' abilities and CSWL performance. Moreover, many studies do not control for age in their examination of individual differences and CSWL performance. As a result, it could be that relations observed between a particular cognitive ability and CSWL (e.g., vocabulary size and CSWL) are a result of children's age, rather than a particular cognitive system. The current work addresses these limitations of previous research on CSWL.

Critically, this work is the first to empirically test a developmental systems theory of CSWL. According to this theoretical framework (for examples of systems theories, see Smith & Thelen, 2003; Van Geert, 1991), changes in CSWL performance are a result of several cognitive systems working together to support learning and development. That is, although one cognitive system may support and/or constrain learning more than other cognitive systems, several cognitive systems must co-contribute to learning for developmental change to occur. Thus, the goal of this work was to determine whether multiple cognitive systems, and many cognitive abilities within one system, contribute to individual and developmental differences in CSWL above and beyond age.

The current research examined relations between children's age, memory abilities, language abilities, and CSWL performance. We examined these relations in a broad age range of children (2–5-year-olds) to capture a wide array of individual differences in age, cognitive abilities, and CSWL performance. In Experiment 1, children were presented with a CSWL task, a general assessment of memory abilities (i.e., paired-associates task), and a general assessment of language abilities (i.e., Peabody Picture Vocabulary Test, 4th edition). In line with the research outlined above, we predicted that both memory and language abilities would predict children's CSWL performance. Moreover, we hypothesized that these cognitive capacities would predict children's CSWL performance above and beyond age. We also examined the relative contributions of age, memory abilities, and language abilities to children's CSWL.

To foreshadow the results of Experiment 1, children's memory abilities were a strong predictor of children's CSWL performance. To further test the developmental systems theory, we examined whether multiple cognitive