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Research Report

Word comprehension facilitates object individuation in 10- and 11-month-old infants

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ABSTRACT

The present study investigated the role that comprehending words for objects plays in 10- and 11-month-old infants' ability to individuate those objects in a spatiotemporally ambiguous event. To do this, we employed an object individuation task in which infants were familiarized to two objects coming in and out from behind a screen in alternation, and then the screen was removed to reveal either both or only one of the objects. Results show that only when 10- and 11-month-olds comprehend words for *both* objects seen do they exhibit looking behavior that is consistent with object individuation (i.e., looking longer when one of the objects is surreptitiously removed). Neither level of object permanence reasoning nor overall receptive vocabulary had an effect on performance in the object individuation task, indicating that the effect was specific to the immediate parameters of the situation, and not a function of overall precocity on the part of the succeeding infants. These results suggest that comprehending the words for occluded/disoccluded objects provides a kind of "glue" which allows infants to bind the mental index of an object with its perceptual features (thus precipitating the formation of two mental indexes, rather than one). They further suggest that a shift from object indexing driven by the *where* (dorsal) system to one which is driven by integration of the ventral and dorsal neural systems, usually not observed until 12 months of age, can be facilitated by word comprehension in 10- and 11-month-old infants.

1. Introduction

This special issue examines the comprehension of the meanings of words in real-life contexts. The present study approaches this question from the standpoint of very early language development. Specifically, it asks: how does the comprehension of the meanings of words act to change an infant's perception and cognition about the world? To explore this, we use a well-known paradigm in infant research which evaluates infants' abilities to individuate objects. Object individuation involves determining the discrete number of objects involved in an event. This is a task that infants are continuously faced with in their lives. Consider the following scene: A baby sees her mother retrieve a baby bottle from the diaper bag. The mother re-considers, places the bottle back into the diaper bag, and her hand comes back out, instead,

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with a sippy cup. Does the infant understand that this is not the same object she briefly saw a few seconds ago? Does she expect that a second object remains in the diaper bag? Does she further expect that the object in the diaper bag is a *bottle*, rather than a sippy cup (and would she be surprised, if she looked inside, to find another sippy cup there?) Thanks to years of clever experimentation on the part of developmental psychologists, we have strong predictions about what infants' behaviors will be in these types of situations depending on their age, the properties of the objects they see disappear, whether or not the objects disappear into the same or into two spatially distinct locations, and so on. We first review what is already known about this ability, what insights we have from neuroscience research about the underpinnings of this ability, and about how labeling objects plays a role in this knowledge. We then present two experiments that probe, in a given infant, the relationship between knowing the words for objects and his or her ability to represent those objects numerically when they go out of sight.

1.1. *What properties do infants rely on in individuating objects, and at what ages?*

It is well established that spatiotemporal information (information about spatial location and motion) is a robust cue to object individuation in infants. A number of studies have converged on the finding that unambiguous spatiotemporal information enables infants to succeed in individuation at an age much younger than they are able without such information. One example comes from complex, single-screen *event-mapping* tasks. In these tasks, infants are first familiarized to two objects emerging and returning behind a single screen, and then the screen is removed to reveal either the *expected* outcome of two objects or the 'unexpected' outcome of only one object. If the infant forms two distinct object representations (and thus succeeds in individuating the objects), then he/she should show surprise when only one of the objects is revealed behind the screen, as evidenced by longer looking at the *unexpected* outcome vs. the *expected* outcome. While it is not until 12 months of age that infants have been found to succeed in individuating objects based on kind-differences alone (i.e., objects that belong to different categories, such as a duck and a ball), 10-month-old infants are able to succeed in doing so when provided spatiotemporal information (i.e., when objects were shown simultaneously during familiarization) (Krojgaard, 2003; Xu and Carey, 1996). Similarly, while 12-month-olds are unable to establish a representation of two distinct objects that differ only in color, size, texture, or shape, they are able to do so when the objects are shown simultaneously during familiarization (Xu et al., 2004).

There is also evidence that spatiotemporal discontinuity leads to a representation of two distinct objects, and spatiotemporal continuity leads to a representation of a single, persisting object in infants as young as 4.5 months of age (Spelke et al., 1995). Similarly, 10-month-olds who were shown two identical objects (e.g., two rubber ducks) coming in and out from behind two spatially distinct screens expected to see two objects when the screens were removed (as long as they never saw a duck move through the space between the two screens) (Xu and Carey, 1996).

Finally, *event-monitoring* tasks, which present infants with one continuous event and ask the infant to judge whether the successive portions of the event are consistent, offer additional evidence of the primacy of spatiotemporal information in infants' object representation system. In these tasks, infants watch two objects emerge and return behind either a wide screen (one that is sufficient in width to fit both objects) or a narrow screen (one that is too narrow to fit both objects). Findings have revealed that infants in the narrow screen conditions look significantly longer at the event than infants in the wide screen conditions. Infants are said to succeed at individuating objects which differ in size alone and in shape alone at 4.5 months of age; which differ in object/kind (i.e., green spotted ball and red felt box) and in pattern, at 7.5 months of age; and which differ in color at 11.5 months of age (Wilcox and Baillargeon, 1998). Various explanations have been offered as to why infants look longer at the narrow versus wide screen events and whether or not infants are successfully individuating the objects in these events (Krojgaard, 2004; Wilcox, 2003; Xu, 2003). Nonetheless, the physical nature of this kind of display does appear to offer enough unambiguous spatiotemporal information so as to enable infants to detect the spatiotemporal violation within the narrow screen event, and thereby expect only one object to be involved.

In summary, when infants are provided with unambiguous spatiotemporal information that two objects (two-screen task) or one object (narrow-screen task) is involved in the event, they are able to detect the spatiotemporal and number violation that occurs within the event at significantly younger ages than when this spatiotemporal information is withheld (as in the one-screen, event-mapping tasks).

A prominent account of the aforementioned data has been offered by *Indexing Theory*, a model whereby infants set up an object representation for individuation (Kaldy and Leslie, 2003; Leslie and Kaldy, 2001; Leslie et al., 1998; Tremoulet et al., 2000; Xu, 1999). According to this model, object *identification* is accomplished only when the infant is able to use certain kinds of information stored in this representation to decide whether an object being encountered now is the same as that which was seen previously. Central to *Indexing Theory* is the concept of an initial *object index*—an abstract mental token that functions as a pointer to an object. According to *Indexing Theory*, an object index does not inherently contain any of the features (e.g., color, shape) possessed by the object it is pointing to. Typically, the assignment of indexes "sticks" to an object, even as it is moved through space and time, and so if the number of indexes in a scene is small enough, this system can be used to individuate objects (as in the two-screen object individuation events, or perhaps the narrow-screen event-monitoring events, reviewed above). In the special case of when the location information is absent, subtle, or ambiguous (as in the one-screen event-mapping procedure described earlier), the only way the index assignment can be accomplished is by assigning property information to the index. According to proponents of an *Indexing Theory*, this strategy may not be available to young infants, and thus the model predicts that infants will accomplish *individuation-by-location* before *individuation-by-feature*.

This notion of the dissociability of location and object feature information fits with the distinction made in the visual