Twenty-Five Years Using the Intermodal Preferential Looking Paradigm to Study Language Acquisition: What Have We Learned?

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Abstract

In the Intermodal Preferential Looking Paradigm (IPLP), infants' language comprehension is measured by their differential visual fixation to two images presented side-by-side. Only one of the images matches an accompanying linguistic stimulus. Since its creation in 1987, the IPLP has proved to be a powerful experimental tool. With carefully designed visual and linguistic stimuli, researchers examine burgeoning knowledge in the areas of phonology, semantics, syntax, and morphology in infants not yet speaking. The IPLP further allows for the exploration of the underlying mechanisms involved in language learning, illuminating how infants use the available data to find the regularities in the language they are acquiring. This selective review discusses how the use of the IPLP has transformed our knowledge of language acquisition in the past quarter of a century.

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In the early 1600's spectacle makers invented the microscope.
With the new instrument, scientists got a closer look at
some of the structures that they had hypothesized about but never seen.
Adapted from Boorstin's book, The Discoverers (1983)

"Pop goes weasel!"
Roger Brown's subject Adam upon being asked for a sentence judgment
R. Brown (1973)

Direct description of the child's actual verbal output
is no more likely to provide an account of the real underlying competence
than in the case of adult language…
Obviously one can find out about competence only by studying performance,
but this study must be carried out in devious and clever ways…
N. Chomsky (1964, p. 36)

Boorstin's description above is like many found in the history of science. The advent of new technological tools makes the invisible visible, permitting scientists to collect new data and sparking the development of new theories. Before the Intermodal Preferential Looking Paradigm (IPLP) appeared (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987), the field of language

acquisition had been forced to rely almost exclusively on descriptive studies of young children's language output. Undoubtedly, the focus on language production provided a rich source for language acquisition theories (e.g., Braine, 1963; Brown, 1973; Shatz, 1978). However, a reliance on language production missed important but hidden language sensitivities that fueled the child's language development. Language production reflected the *observable* half of the child's language ability; their comprehension was the other, inaccessible half of what they knew about language. Just as astronomers were not satisfied to study the light side of the moon, researchers in language acquisition recognized that the *dark* side -- language comprehension -- held secrets to the process that had to be unlocked.

Yet when researchers probed language comprehension they were often greeted with irrelevant and non-compliant responses by children in the proverbial "terrible two's." Other common procedures such as asking children to act out commands, point to pictures, and make sentence judgments, or eliciting production of specific structures, also met with resistance and non-compliance (e.g., Brown, 1958; Shatz, 1978). Consider the task of picture pointing. What appears to be a reasonable task, given that parents and children engage in book-reading together, actually has a number of problems. First, young children do not understand the conventions artists use to indicate action (Friedman & Stevenson, 1975). Those little lines around joints designed to indicate motion have little significance for children until age 5 (Cocking & McHale, 1981). Second, distinctions between who is doing what to whom in events may only be incompletely captured in static two-dimensional displays, making it difficult to study children's comprehension of relational terms like verbs. Finally, children may understand the linguistic structure in questions but be unwilling to respond to a request. Furthermore, for elicitation tasks

or corpus analysis, the absence of a particular structure does not necessarily mean that that structure is beyond children's ken.

Birth of the Intermodal Preferential Looking Paradigm (IPLP)

What was needed was a method that did not demand overt responses from non-compliant "preverbal" children and that allowed them to reveal what they knew of language before it fully emerged and their ability to learn novel words under experimental conditions. But how could researchers study language development before language is produced? The ancestor of the IPLP is Fantz (1958) who discovered that infants looked differentially on two stimuli of varied complexity, thereby revealing their ability to make visual discriminations. In 1974, Horowitz asked whether visual fixation might be used as a window onto language development (and see Colombo & Bundy, 1981). Then Spelke (1979), in a dynamic version of Fantz's paired comparisons method, showed 4-month-olds two events side-by-side (e.g., a person clapping hands *vs.* a donkey jumping onto a table) accompanied by an auditory stimulus matching only one of them (e.g., the sound of clapping hands). Infants looked at the event that matched the auditory stimulus longer than the event that did not. This inspirational study led to the introduction of linguistic stimuli and the birth of the IPLP (Golinkoff et al., 1987; Hirsh-Pasek & Golinkoff, 1996).

The very first study using the IPLP (Golinkoff et al., 1987) showed that 17-month-old children comprehended a range of nouns (e.g., boat, shoe) and verbs (e.g., dance, wave). The IPLP gives children a choice between two visual stimuli presented simultaneously. Only one of the visual stimuli "matches" an accompanying linguistic stimulus (Figure 1) (for details see Hirsh-Pasek & Golinkoff, 1996; Hollich, Hirsh-Pasek, & Golinkoff, 1998). If infants comprehend the linguistic stimuli, they are predicted to look longer at the matching than the non-

matching display. Thus, this is not a visual fixation paradigm such as habituation (e.g., Cohen, Amsel, Redford, & Casasola, 1998) that trades on the perception of novelty; rather, the IPLP and its offshoots (the Interactive IPLP, the Preferential Looking Paradigm [PLP], and the Looking-while-listening [LWL] procedure) are premised on infants' ability to use the language they hear to find a matching display.

---------- Insert Figure 1 about here ----------

A typical IPLP design contains three types of trials. Trials are usually preceded by an attention getter such as a baby face or a blinking light that draws infants' attention to the center in between two displays. Thus, children are prepared to make gaze shifts between the two visual stimuli that will follow (Table 1).

---------- Insert Table 1 about here ----------

An IPLP design usually starts with a *salience* trial to familiarize children with the two-image display and allows for inspection of the visual stimuli before language is overlaid. The salience trial permits researchers to test whether stimuli within a pair are equated for visual attractiveness – a premise of the paradigm as children's responses should be driven by the accompanying language and not by the appeal of one visual stimulus over another. Neutral language (e.g., "What do you see?") is often used during salience trials (e.g., Golinkoff et al., 1987; Naigles, 1990; Piotroski & Naigles, 2012). In a word-learning task, an IPLP design contains *training* trials, in which a single image is accompanied by a linguistic label, allowing children to make a word-referent association (e.g., Houston-Price, Plunkett, & Harris, 2005; Schafer & Plunkett, 1995). In a *test* trial, children are shown two visual stimuli side-by-side – the same as they have seen in the salience trial, while hearing linguistic stimuli that match only one scene. Infant-

directed speech is typically used, as infants prefer infant-directed over adult-directed speech (e.g., Cooper & Aslin, 1990; Werker, Pegg, & McLeod, 1994).

The IPLP capitalizes on children's tendency to look towards an image that is being named. A variety of dependent variables – all variants on visual behavior – have been used to compare children's looking to the matching versus the non-matching image. Children, however, are not expected to look *exclusively* at the target (e.g., Golinkoff et al., 1987), since the stimuli are designed to be of approximately equal interest. The side on which a particular stimulus appears is usually counterbalanced between children, as is the target in a pair.

The Validity of the IPLP

Does the differential visual fixation of two images reliably reflect children's language knowledge? One way to test what the IPLP is measuring is to see if the results from its use relate to other measures of children's burgeoning linguistic knowledge. IPLP findings have been corroborated with parental reports of children's word knowledge (e.g., Behrend, 1988; Houston-Price, Mather & Sakkalou, 2007; Robinson, Shore, Hull Smith & Martinelli, 2000). In these studies, parents were first asked to indicate whether children understood some words. The IPLP task that followed examined whether infants looked at the matching scene when hearing these words. The IPLP results confirmed parental reports by showing that infants comprehended the *known* words according to parents. However, in the IPLP procedure, infants also showed comprehension of words that parents did not think they understood, suggesting that the IPLP may be a more sensitive measure of children's language knowledge than parental reports.

In Robinson et al.'s study (2000), parents marked the to-be-tested words as either "understood", "heard before but not understood" ("frontier" words), or "never heard before." Then, in an IPLP task, 15-, 18-, and 22-month-old infants showed comprehension of the "understood" words, but

not of the "never heard before" words. Furthermore, the 22-month-olds also showed comprehension of the "frontier words", suggesting that the IPLP may be a more sensitive measure of children's language knowledge than parental reports. A similar study found that 15-, 18-, and 21-month-old infants preferred to look at target images of even the *unknown* words (based on the parental report) (Houston-Price et al., 2007).

The validity of the IPLP is not only shown in children's receptive word knowledge, but also reflected by children's novel word learning performance, word production, and syntactic understanding. In a novel word-learning task, Ma, Golinkoff, Houston, and Hirsh-Pasek (2011) reported that infants at 21 months with larger vocabularies relative to their peers were able to learn novel words presented in adult-directed speech while infants with smaller vocabularies were unable to do so. Thus, children's performance in an IPLP word-learning task is associated with the store of words they have already acquired. Similarly, using the LWL, Lew-Williams and Fernald (2007) found that children's word recognition ability was correlated with their concurrent productive vocabularies and grammatical competence. Furthermore, longitudinal studies showed that children who were faster and more accurate in online word recognition at 25 months of age showed faster and more accelerated growth in expressive vocabulary across the second year (Fernald, Perfors, & Marchman, 2006). There are also data that show that children's interpretation of sentence structure in the IPLP relates to their language level. Fisher, Klinger, and Song (2006), for example, found that the 2.5-year-olds with high vocabulary relative to their peers used syntactic information to interpret the meaning of a novel word as either a preposition (as in "This is acorp my box") or a noun (as in "This is a corp").

In summary, the IPLP, and its offshoots (the Interactive IPLP, the PLP, and the LWL procedure), appear to be valid, sensitive measures of children's language knowledge and

language learning ability. Once the first IPLP study (Golinkoff et al., 1987) supported what parents had long claimed -- that children understood more words than they produced (Goldin-Meadow, Gelman, & Seligman, 1976; Houston-Price et al., 2007; Benedict, 1979) -- researchers began to use the IPLP as a tool. We next discuss the findings that the procedure has yielded and the procedural variants that have illuminated our understanding of the course of language acquisition.

The Emergent Coalition Model (ECM)

To assist in organizing these findings we introduce the Emergent Coalition Model of language acquisition (hereafter ECM) (Golinkoff, Hirsh-Pasek, & Hollich, 1999; Hirsh-Pasek & Golinkoff, 1996; Hollich, Hirsh-Pasek, & Golinkoff, 2000), a hybrid model that combines contributions from three competing and leading theoretical approaches: the perceptual (e.g., Plunkett, 1997; Smith, 2000; Yu & Smith, 2007), pragmatic (e.g., Nelson, 1996; Tomasello, 2000a), and constraints theories (e.g., Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1989; Merriman & Bowman, 1989; Waxman & Kosowski, 1990). The ECM is not an *either/or* theory but rather a *when* and *how* account of language growth, positing that children use different strategies for language learning at different points in time.

The ECM model makes three, testable assumptions. First, children are surrounded by multiple inputs to language acquisition in the form of perceptual, social, and linguistic information. Second, these inputs are differentially weighted over development such that children first rely on perceptual information, later attending to social cues in the service of language learning, and finally, to linguistic information. Third, these principles emerge as children weigh the different types of information over time although none disappear. Given that the model predicts that children differentially weight perceptual, social, and linguistic cues, we present the data that has

resulted from the IPLP and its offshoots in a developmental sequence. We first present findings from the *nonlinguistic* version of the IPLP, the *Preferential Looking Paradigm,* which taps into the perceptual and conceptual underpinnings of language knowledge by probing how infants analyze and encode the events that language will describe. Second, we review findings from the *Interactive IPLP* that delivers linguistic stimuli through a human experimenter rather than on a television (Figure 2). This alteration in the procedure allows researchers to examine the effect that social cues (such as eye gaze or object holding) have on language learning. Finally, we review selected findings from both the original IPLP and the LWL procedure. These studies assess knowledge of linguistic information, whether of the building blocks of language (morphological cues, e.g., Kedar, Casasola, & Lust, 2006, and lexical items, e.g., Ma et al., 2011), or the information available in full sentences (Fisher & Song, 2006). All the methods to be described use visual fixation time to a target versus a non-target. The LWL procedure even captures how quickly a child orients to a target from a distracter image in real time. This important extension of the IPLP allows for the examination of individual differences in the efficiency of language processing (e.g., Fernald, Swingley, & Pinto, 2001; Hurtado, Fernald, & Marchman, 2007).

---------- Insert Figure 2 about here ----------

The Preferential Looking Paradigm (PLP) without Language: Perceptual and Conceptual Underpinnings of Language Knowledge

Perceiving and conceptualizing the world is the first step in language learning. This entails not only finding the individuable objects named by nouns, but also carving the flow of events into the actions named by verbs, and zeroing in on the properties adjectives label. The PLP has permitted researchers to study how infants segment and analyze the nonlinguistic events that will

ultimately be encoded by language. Thus, the PLP is used to study the intersection of language and event processing, bringing together theorizing in linguistics and the burgeoning field of event perception in psychology.

A paired comparisons method with static stimuli was first developed by Fantz (1958) and subsequently developed to investigate infants' categorization of objects, animal species, and spatial relations (e.g., Eimas & Quinn, 1994; McDonough, Choi, & Mandler, 2003; Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). Inspired by Quinn's studies on how infants processed static spatial relations such as "between" and "over," and motivated by the question of how infants process events in order to learn verbs, Pruden and collaborators began to employ dynamic motion events in the PLP (e.g., Pruden, Göksun, Roseberry, Hirsh-Pasek, & Golinkoff, in press a; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, in press b). Learning to label motion events is different than labeling static objects. Verbs, as Slobin pointed out (2003), are not "verbal film clips of events." That is, they express not entire actions, but only parts of an event, such as *manner* (how an action is carried out, e.g., run, jump), *path* (an action's trajectory, e.g., exit, approach), or *results* (e.g., break, open) (Slobin, 2003; Talmy, 1985). To learn verbs children must first perceive the components of actions that verbs name. If infants cannot tell when manners and paths, for example, change in events, they could not be expected to learn the verbs that label those actions. Pulverman, Buresh, Golinkoff, and Hirsh-Pasek (2008) used an animated starfish and ball in a habituation design to uncover whether 14-month-old infants (and later 7-month-old infants) could discriminate between changes in *path* and *manner* in dynamic events. Furthermore, learning a verb entails that it should be extended to other instances of the same action. Could infants tell that running was 'running' regardless of the path the agent followed?

Using the PLP, Pruden et al. (in presses) asked whether infants could form *nonlinguistic categories* of manner and path. Pruden et al. (in press a) found that 13-month-old infants could extract an invariant manner across four different changes in path. Learning a preposition also requires forming a spatial category with various instances (e.g., "over" is over whether "over a log" or "over a chair"). Pruden et al. (in press b) showed that 10-month-old infants abstracted an invariant path from motion events involving different manners. These were the first studies to show that the problems children faces in learning verbs or prepositions were not likely attributable to difficulty in identifying components of motion events or forming categories of those components (Parish-Morris, Pruden, Ma, Hirsh-Pasek, & Golinkoff, 2010). However, these events used animated objects in tightly controlled scenes and could therefore be subject to the criticism that they were too simplistic and not enough like real-world events. Using similar designs, researchers expanded these investigations to show that infants could form categories of manner with naturalistic actions performed by multiple human agents across diverse paths (Song, Golinkoff, Stahl, & Hirsh-Pasek, 2010). Studies on infants' processing of other event components such as figure and ground (Goksun, Hirsh-Pasek, & Gokinkoff, 2010), also conducted using the PLP, are yielding important new information about how infants perceive the events in the world that language encodes.

How is event perception influenced by the ambient language (see Goksun et al., 2010 for a review)? Manner languages such as English, German, and Chinese often encode the *manner* of motion in the main verb and use a "satellite" such as a preposition to portray the *path.* In contrast, path languages such as Spanish, Turkish, and Greek, frequently conflate motion and path in the main verb while adding an optional gerund to express the manner (Talmy, 1985). For example, unlike in English, in Spanish, one would likely describe an event of a woman running

out of the house as "a woman exits the house (running)," with path conflated in the main verb and the mention of *how* she exited (running) optional. Given that languages of the world are biased to encode certain aspects of events over others, infants must be able to detect the lexicalization bias of their ambient language. Maguire et al. (2010) tested when children would show this language-specific influence and construe a novel verb as adult native speakers of a language did. English-, Japanese-, and Spanish-speaking adults, toddlers, and preschoolers were shown videos of an animated star performing a novel manner along a novel path paired with a language appropriate nonsense verb. They were then asked to extend that verb to either the same manner or the same path as in training. Across languages, toddlers (2- and 2.5-year-olds) revealed a significant preference for interpreting the verb as a *path* verb. In preschool (3-and 5-year-olds) and adulthood, the participants displayed language-specific patterns of verb construal. These findings illuminate how verb construal comes to reflect the properties of the input language. The PLP has been useful to researchers who study the conceptual underpinnings of language by permitting the portrayal of dynamic events.

The Interactive Intermodal Preferential Looking Paradigm (Interactive IPLP): The Role of Social Cues in Word Learning

The ECM predicts that children first rely primarily on *perceptual cues* – such as the visual salience of an object and the exaggerated phonological properties of infant-directed speech – to tune into language, followed by social cues, and finally linguistic cues to learn novel words (Brandone, Golinkoff, & Hirsh-Pasek, 2007; Golinkoff & Hirsh-Pasek, 2006; Hollich et al., 1998; 2000). To examine the effect of social cues on language learning in the Interactive IPLP, the stimuli are delivered by a human experimenter. An infant sits on a blindfolded parent's lap on one side of a flip-board placed on a table in an interactive IPLP design. The experimenter

attaches two objects when the board is turned to her side of the board and then rotates the board to reveal the objects to the infant. Depending upon the nature of the trial, the experimenter either prompts the infant to look at the objects or labels *one* of the objects (Figure 2). Critically, when labeling the object, the experimenter can provide social cues (e.g., enthusiastically looking back and forth between the object and the child's eyes).

To test whether infants use perceptual cues to learn novel words, or whether they can also make use of social cues such as eye gaze, Pruden, Hirsh-Pasek, Golinkoff, and Hennon (2006) showed 10-month-olds an interesting object (e.g., a colorful noisemaker) and a boring object (e.g., a beige soda cap opener) side-by-side on the flip-board. After the experimenter gained the child's attention, she looked back and forth between the child and the object while offering a novel name, e.g., "Look at the modi!" Infants learned the name of only the *interesting* object, suggesting that they attached the name to the object they preferred. In fact, when eye gaze was put into *conflict* with perceptual salience as the speaker looked at and named the *boring* object, 10-month-olds reliably *mismapped* the word to the perceptually interesting object, suggesting that the social cues were either not noticed or ignored. Twelve-month-olds advance to the point that they no longer mismap the name for the boring object onto the interesting object, although they still fail to learn the name of the boring object (Hollich et al., 2000). By 19 months (and robustly by 24 months), children used the speaker's eye gaze reliably to learn the name of the boring object, overriding the lure of perceptual salience.

The Interactive IPLP permitted us to put social and perceptual cues into conflict and discover that infants rely on different cues to learn words over the first 2 years of life.

The Intermodal Preferential Looking Paradigm (IPLP): Examining Children's Emerging Language Knowledge

To learn a language, children must map words onto entities and events and then extend those words to other instances of the same category, disregarding perceptual variations irrelevant to category membership. The IPLP allowed researchers to examine the effect of perceptual variation on different types of language input.

Properties of the acoustic signal. As a listener, speech signals enter the ear as sound waves, and are transmitted to the auditory cortex, from which the brain extracts speech sounds and sequences and further activates the meaning of the word (Pulvermüller & Fadiga, 2010; Hu, Zhang, Zhao, Ma, Lai, & Yao, 2011; Ma, Lai, Yuan, Wu, & Yao, in press). An immediate question arises: Do children attend to the acoustic details of the language input or do they engage in a broad brush analysis of what they hear? To address this question, IPLP studies examined children's detection of mispronunciations when only one phoneme was changed in a familiar word. This is based on the logic that if children *do* attend to acoustic detail, they should notice mispronunciations (e.g., Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Mani & Plunkett, 2007; Swingley, 2003; Swingley & Aslin, 2000, 2002). Swingley and Aslin (2000) found that 18- to 23-month-old infants recognized correct pronunciations faster than mispronunciations (e.g., baby vs. vaby). In the LWL, they turned more quickly to the word's referent (e.g., a baby) as opposed to a non-target (e.g., a cat) when they heard a correct pronunciation (Figure 3). This finding has been replicated with 14- and 15-month-olds (Swingley & Aslin, 2002), and with word-initial consonants in newly learned words (Bailey & Plunkett, 2002; Ballem & Plunkett, 2005), with word-medial vowels with 14-month-old English-speaking infants (Mani & Plunkett, 2007; 2008), and with word-medial consonants with 19-month-old Dutch-speaking children (Swingley, 2003). Using the IPLP, research showed that children appear to store more specific information about new words than they need to. For example, Hollich (2006) taught 23-month-

old infants two novel words. At test, infants showed word learning performance when the original speaker produced the word, but they failed to do so when a *new* speaker produced the word (see Newman, 2008 for a review).

---------- Insert Figure 3 about here ----------

Another IPLP study showed that infants distinguish between the acoustic properties of the speech signal when learning new words. Using the IPLP, Ma et al. (2011) found that 21-month-olds were able to learn novel words presented in infant-directed speech but not in adult-directed speech; by 27 months, however, the use of the infant-directed register did not offer infants an advantage; children learned the novel words in both types of speech.

Mapping words to entities: The origins of word meaning. To learn new words, children must map auditory information (i.e., words) onto visual stimuli (e.g., objects or actions). In a stunning demonstration using the IPLP, Tincoff and Jusczyk (1999) showed that 6-month-old infants were linking phonological forms to meanings. When shown videos of their own parents and strangers, infants were able to associate the word "mommy" and "daddy" to their own mothers and fathers respectively. The IPLP thus provided the earliest demonstration of word mapping.

Interestingly, early word meanings may be more narrowly construed than they will be after children gain more experience with the categories that words name. This is analogous to what infants do in the domain of phonology: They store more details of the acoustic stimulus than they need to (e.g., Newman, 2008), failing to appropriately generalize a word they hear used in a new context. Additionally, using the IPLP, researchers found that infants' initial understanding of familiar words tends to be limited to *prototypical* exemplars. This tendency occurs with nouns (Meints, Plunkett, & Harris, 1999), prepositions (Meints, Plunkett, Harris, & Dimmock, 2002), and verbs (Meints, Plunkett, & Harris, 2008). For example, Meints, Plunkett, and Harris (2008)

found that children were reluctant to accept atypical exemplars for a word. Thus, 2-year-old English-reared children looked significantly longer at typical events (e.g., a woman eating *an apple*) than at atypical events (e.g., eating *a houseplant*) in a paired display when hearing the verb (e.g., *eating)*. Only the 3-year-olds accepted atypical instances. When children failed to extend words to less typical exemplars, it suggested that their construals included more visual details compared to those of the adults'. It is also possible the typicality effect is simply driven by the different naming frequencies between typical and atypical exemplars in children's language input. A positive way to look at these data, however, is that children are aware of the visual features that contribute to word meaning.

Children's attention to detail in language learning is also demonstrated by their initial *underextension* of familiar verbs (e.g., Forbes, & Poulin-Dubois, 1997). Using the IPLP, Forbes and Poulin-Dubois familiarized 20- and 26-month-old English-reared children with video clips of two actions (*kick* and *pick up*) labeled with novel names. At test, children saw the two actions side-by-side, with either the agent, the outcome, or the manner changed from the original event. Among the 20-month-olds, only those with large expressive vocabularies found the target of the verb when the action was performed by a new agent. They did not find the target when the actions had new outcomes or manner variations. The 26-month-olds looked at the target action even when it had a new agent or a new manner, but not when the outcome changed. These findings suggest that children initially construe noun and verb meaning narrowly.

If children intially have difficulty abstacting the action commonality shared by a range of exemplars, a prediction follows: Words whose referents are more variable should be harder for children to learn than words whose referents are more similar. In general, the referents of nouns are more readily individuated from their backgrounds and more imageable than verbs (Ma,

Golinkoff, Hirsh-Pasek, McDonough, & Tardif, 2009; McDonough, Song, Hirsh-Pasek, Golinkoff, & Lannon, 2011). Verbs are inherently relational and are performed by different agents and in different ways (Hirsh-Pasek & Golinkoff, 2006). Research supports this prediction and finds that verbs are generally harder for children to learn than nouns (e.g., Bornstein et al., 2004; Childers & Tomasello, 2002; Fenson et al., 1994; Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996; Kersten & Smith, 2002). Yet the verb is the architectural centerpiece of the sentence and understanding how verbs are used is tantamount to understanding the grammar of one's language. Importantly, observation of the world is insufficient for learning verbs, as Gleitman and her colleagues showed using the Human Simulation Paradigm (Gillette, Gleitman, Gleitman, & Lederer 1999; Snedeker & Gleitman, 2004). Even adults cannot guess the names of actions in silent scenes of mother-child interaction – although they can guess the relevant nouns.

Despite the fact that researchers expected the IPLP to show early evidence of verb learning, children's difficulty in learning verbs became a significant finding in its own right. For example, Maguire, Hirsh-Pasek, and Golinkoff (2006) showed that 18-, 24-, and 30-month-olds could not learn a novel name for a new action (*jumping jacks*) presented in the IPLP, although even 10-month-olds could form an action category of the same action (*jumping jacks*) *without language*. A recent IPLP study underscores the difficulty of verb learning in comparison to noun learning and the necessary conditions required for verb learning in the laboratory. Waxman, Lidz, Braun, and Lavin (2009) presented 24-month-olds with the opportunity to learn a new noun or a new verb. Noun learning was, as usual, a task readily surmounted. However, children were able to show verb learning only when they saw the target action performed on multiple objects (by a single agent) and received a "contrast" trial (e.g., "No, that's not glorping"). Even among children learning so-called "verb-friendly" languages such as Chinese and Japanese, where verbs

can appear in isolation or in a salient position at the end of sentences, verb learning and extension are challenging. Using children's pointing rather than looking behavior, Imai et al. (2008) presented an IPLP task to English-, Japanese-, and Chinese-learning children in which they asked whether children could point, rather than look at, the targets upon hearing novel nouns or verbs. All three groups successfully learned the nouns but failed to learn the verbs at age 3, and succeeded only under favorable conditions at age 5.

These studies not only demonstrate that verbs are hard to learn but also begin to probe the factors that influence verb learning. Based on the literature on relational category formation (Casasola & Cohen, 2002; Kersten & Smith, 2002; Quinn, Polly, Furer, Dobson, & Narter, 2002), Maguire, Hirsh-Pasek, Golinkoff, and Brandone (2008) argued that before infants attend to a relation *between* objects, they first focus on the *objects* composing that relation. With repeated exposure, infants' attention shifts to the relation between the objects. Based on this reasoning, limiting the visual variability of exemplars used to instantiate a *relation* should benefit children's category formation and word learning. Consistent with this hypothesis, using an IPLP pointing task, Maguire et al. (2008) showed that for initial verb learning, limited variability of the agent of action exemplars facilitated 2.5 and 3-year-old children's learning and extension of novel verbs. Using the same method, Ma (2010) found that for 3-year-olds, limited variability of the manner of action exemplars facilitated initial verb mapping but hindered verb extension to new manner variations. Thus, there may be a trade-off between initial mapping and extension depending on the variability of the exemplars.

Syntactic information. The IPLP has also made a contribution in the study of children's grammatical knowledge. Grammar allows us to specify the relations between objects in events. Combining words into sentences gives us the generative power to talk about past, future,

hypothetical events (Klima & Bellugi, 1966) and to pass on our cultural heritage without having to "re-invent the wheel" in each generation (Tomasello, 2000b).

But when do children know something about the syntax of their particular language? When the IPLP came on the scene, debate raged about whether children began their language journey with exclusively semantic knowledge or syntactic knowledge as well. Indeed, these debates still continue albeit in a slightly different form, focused on the nature of the syntactic generalizations children form (see Fisher, 2002 for Tomasello-Fisher discussion). Early on, the argument revolved around whether children had "semantic categories" like action, agent, and recipient of the action that reflected the roles played in the sentence (Brown, 1973; Golinkoff, 1981). For example, when a child said "Mommy sock," a possible gloss was, "Mommy (the agent) is putting on my sock (the object of the action)". On the other hand, some research supported children's possession of formal grammatical categories such as verb, subject, and object. For example, Bloom (1971) credited children with syntactic knowledge when she found that they produced contiguous sentences like, "Lamb go here. Put lamb here." These sentences indicated that "lamb" was not always treated as an agent (as in the first sentence) but also as a recipient of the action – as in the second sentence. Furthermore, as Gleitman (1981) noted, if children began with only semantic categories, there was a "tadpole to frog" problem: how did the tadpole of semantic categories transform into the frog of syntactic categories?

A preliminary question answered using the IPLP was whether children interpreted sentences as "packages of words" that bore some relationship to each other, or whether they just attended to individual words. Hirsh-Pasek and Golinkoff (1996) showed that by 13 months of age children recognized that words conjoin to specify unique events in the world. Children were shown a video of a woman kissing a set of keys and holding a ball in the foreground versus the same

woman kissing the ball and dangling the keys in the foreground. The accompanying linguistic stimulus referred to only one of the events (e.g., "She's kissing the keys!"). Infants looked significantly more at the matching event, suggesting that they recognized that words in sentences formed units and were not just isolated elements.

Perhaps if children recognized that words in a sentence functioned together to specify events in the world, they might also attend to word order, a grammatical device used heavily in English but less so in languages with strong inflectional systems (such as Hungarian, MacWhinney, 1976). For instance, "Brutus killed Caesar" preserves history while "Caesar killed Brutus" does not. Golinkoff et al. (1987) showed that 28-month-olds who were *already* using word order productively could use word order to comprehend contrasting events. Shown two dynamic events of, for example, *Cookie Monster tickling Big Bird* on one screen and *Big Bird tickling Cookie Monster* on a second screen, accompanied by the linguistic stimulus, "Where is Cookie Monster tickling Big Bird?," they watched the target event significantly more than the non-target event. This was the first demonstration that the IPLP was sensitive to grammatical knowledge older children appeared to possess. No reliable prior test of word order comprehension existed at that time.

But could 17-month-olds, producing as few as two words in their productive vocabularies show comprehension of word order? Using the same stimuli, the answer was yes (Hirsh-Pasek & Golinkoff, 1996) and once again the linguistic capabilities of the young child were startlingly in advance of their production. Perhaps, however, children solved this word order task by relying on specific knowledge of specific verbs rather than a more general understanding of the grammatical function of word order (Tomasello, 2000b). On this argument, if infants were familiar with the verb "tickling," for example, they might look for the agent (the tickler) to come

before the verb and the recipient of the tickling to come after. Gertner, Fisher, and Eisengart (2006) circumvented this possibility by demonstrating that infants could perform the word order task in the IPLP with *unfamiliar* verbs. Twenty-one-month-old infants preferred to look at a duck doing an action to a bunny rather than a bunny doing a new action to a duck upon hearing, "Look! The bunny is *gorping* the duck."

Another surprising demonstration of grammatical capacity was offered by Seidl, Hollich, and Jusczyk (2003). A test session in the IPLP began with a single event (e.g., a book moving on its own, hitting some keys, and glancing off). Children were then shown the book and the keys side-by-side, while hearing either a subject question (e.g., "What hit the keys?") or an object question (e.g., "What did the book hit?"). By 15 months of age, children showed tremendous linguistic sophistication in their response to the subject question by looking more to the target – the book – a noun they had not heard mentioned. The only way they could have done that was to recognize which item was missing in the question, relying on grammar. By 20 months, children succeeded with subject and object questions. Given that research suggests that answering wh-questions is difficult even for 3-year-olds (Ervin-Tripp, 1970; Tyack & Ingram, 1977), the Seidl et al. study suggests that requiring children to produce a verbal response may have "masked their understanding" (p. 431) while the IPLP task allowed children to reveal their syntactic competence (Seidl et al., 2003).

Inherent in grammatical knowledge is an appreciation of the hierarchical structure of the sentence. For example, hearing "I'll play with this yellow ball and you can play with that one," adults treat the phrase "this yellow bottle" as a "determiner phrase," and assume that the word *one* maps back to the whole phrase. This is a "proform" analogous to a pronoun where one element can stand for another. It is also analogous to the way that –wh words in the Seidl et al.

study (2003) stand for the missing element in the question. To ask whether infants understand the hierarchical structure of noun phrases, Lidz, Waxman, and Freedman (2003) showed 18-month-old infants a yellow bottle on the screen while they heard, "Look! A yellow bottle." At test, children were shown two images side-by-side (a yellow bottle *vs*. a blue bottle), and heard "Do you see another one?" If infants merely had a novelty preference they should have looked at the bottle they had not seen – the *blue* bottle -- interpreting "another one" as meaning 'another bottle of the same type.' However, they did not do that. Instead, they interpreted *one* hierarchically as a proform, preferring to look at the "yellow bottle."

Using syntax as a cue to word meaning. If children have more grammatical knowledge than they had been given credit for, then it is possible that they can use the syntax *itself* as a cue to word meaning. The *syntactic bootstrapping hypothesis* (Landau & Gleitman, 1985; Gleitman, 1990) was born after Landau and Gleitman studied a blind child (Kelly) who was able to distinguish between the meaning of the verbs "look" and "see" without access to the visual world. It seemed that Kelly would have had only the syntax in which these words were encountered to uncover their meanings. Syntactic bootstrapping is the theory that children attend to the syntactic structures in which a novel word is embedded to glean something of its meaning. For example, listeners tend to take *blork* as a causative verb when hearing, "John blorked Mary", or an intransitive verb when hearing "John and Mary blorked," or a noun when hearing, "The blork hit John." Thus, the language learner uses the sentence structure in which a new word appears to look for correspondences between that word and a referent (Fisher, 2002; Gertner et al., 2006; Naigles, 1996; Lidz et al., 2003; Yuan, Fisher, Gertner, & Snedeker, 2007; Naigles, Bavin, & Smith, 2005; Waxman, 2004; but see Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008).

The first study to show that children could use syntactic bootstrapping to reason about word meaning was conducted by Naigles (1990) using the IPLP. Children at 25 months were shown videos of a duck and a rabbit. Either they were doing an action together or one actor was causing the other actor to do an action. When the videos were accompanied by a transitive sentence, as in, "The rabbit is kradding the duck," children looked to the causal event. When they heard an intransitive sentence (i.e., "The rabbit and the duck are kradding"), however, they looked to the event where the characters were performing the action together. Hirsh-Pasek, Golinkoff, and Naigles (1996) also provided data that 24-month-olds were using syntactic structure to narrow down possible verb meanings. A subsequent study by Yuan et al. (2007) showed that children could solve this task with an event that added an uninvolved *bystander*. Thus, on one side of the screen, a transitive action occurred between two participants; on the other side, an intransitive action was performed by a single participant with a bystander looking away in the background. If children primarily rely on the number of characters shown in events to decide on verb meaning, performance in the transitive condition should decline as two characters appeared in each scene. Results showed that children did not consider the bystander an actor in the event. They continued to watch the matching transitive event. These results corroborated research using the habituation paradigm that showed that 16-month-old infants expected to hear an intransitive sentence when shown a single-participant event and were surprised to hear a transitive sentence (Brandone, Addy, Pulverman, Golinkoff, & Hirsh-Pasek, 2006). Thus, the research using the IPLP on how children learn initial verb meanings is shedding light on the processes used to glean verb meaning and possibly on their origins.

Morphological and closed-class words offer grammatical information. Closed-class functional words and morphological inflections could also serve as input to a syntactic

bootstrapping mechanism. Hearing "*the* rup" informs the child that *rup* is likely a noun. "Sally's raff*ing*" suggests, both because of the /ing/ ending and the word's position after a proper noun, that *raffing* is a verb. Because closed class words and morphological inflections are not produced early, researchers initially assumed that they were not available to young children. Pinker (1984), for example, concluded, "as it would suit my purposes to claim that Stage I children have latent control over the morphemes whose presence defines the categorization of certain constituents, it does not seem to be tenable given available evidence" (Pinker, 1984, p. 103) (see also Radford, 1990 for a pessimistic view).

However, using the IPLP, research revealed that children are indeed sensitive to these potentially informative elements in the language stream. For example, Hirsh-Pasek, Golinkoff, and Naigles (1996) presented children with an intransitive sentence in an IPLP study in which the use of the preposition "with" indicated that the characters were doing an action together. In familiarization, children saw a transitive and an intransitive scene with Big Bird and Cookie Monster. At test, 24-month-old children heard, "Where is Big Bird glorping *with* Cookie Monster?" Girls reliably watched the intransitive action, recognizing the grammatical function of the preposition "with." Boys, however, apparently indifferent to the presence of the *with*, watched the transitive action, acting as if the with-sentence was an active transitive sentence.

Kedar, Casasola, and Lust (2006), building on Gerken and McIntosh (1993), presented 18- and 24-month-olds with images of 16 familiar nouns (e.g., a book vs. a ball) in the IPLP in one of four conditions: 1) Grammatical - "Can you see *the* ball?; 2) Ungrammatical – "…*and* ball?"; 3) Nonsense – "…el ball?"; and 4) Null – "…ball?" Children at both ages were best at finding the target in the grammatical condition. Furthermore, as evidence that infants expect to hear determiners like "the," children were significantly slower in orienting to the visual target in the

absence of an article in comparison to the grammatical sentences. Using the LWL, Zangl and Fernald (2007) found the same pattern of results in 36-month-old children.

In Spanish, nouns have obligatory gender marking on the articles that precede them (e.g., *la* and *el*, the feminine and masculine forms of "the," respectively). Using the LWL, Lew-Williams and Fernald (2007) presented 34- to 42-month-old Spanish-learning children pairs of pictures with names that had either the same grammatical gender (*la pelota* - ''ball''; *la galleta* - ''cookie'') or different grammatical genders (*la pelota*; *el zapato* - ''shoe''), and asked them to find the target. Children were faster to look at the target on *different*-gender trials. When gender-marking morphology is informative, it assists children in language processing. The use of the IPLP and its offshoot, the LWL, permits researchers to observe the *actual time course* of language processing, thereby getting closer to the way in which particular grammatical elements influence how children extract the meaning of the sentence.

Jolly and Plunkett (2008) investigated children's sensitivity to the plural morpheme using the IPLP. They showed 24- and 30-month-olds a pair of novel images, one of which contained a single object while the other showed a pair of objects. The images were accompanied by a sentence containing a novel word with or without the English plural inflection /s/ (e.g., "Look at the jeel/jeels!). Thirty-month-olds looked at the image that matched the presence or absence of the plural morpheme. Even 24-month-olds successfully find a target image by using the presence or absence of the English plural morpheme (Kouider, Halberda, Wood, & Carey, 2006).

Children can even use syntax to glean the meaning of a novel preposition. For example, consider a scene in which an object (perhaps a pencil) is on top of a box. A speaker might say, "It's *on top of the box,*" referring to the pencil with the pronoun "it," and the relation to the box as "on top of." Fisher, Klingler, and Song (2006) showed that 2.5-year-olds could indeed use the

syntactic frame surrounding a new word to decide whether to treat it as a novel preposition (as in "It's acorp my box") or a novel noun (as in "It's a corp").

Given that grammar is the sine qua non of language, these findings suggest something about the process by which toddlers discover it. Inflectional morphology, closed class items, and the syntactic organization of the sentence offer valuable information about word and sentence meaning. Studies using the IPLP strongly suggest that English-reared children utilize this information to learn language. As the IPLP is now used in many labs all over the world, studies are being conducted in other languages as well. For example, Legendre, Barriere, Goyet, and Nazzi (2010) showed that 30-month-olds, but not 24-month-olds, distinguished between singular and plural agreement markers in French, watching the screen that matched the language they heard. Imai et al. (2008) explored novel verb and noun learning in Chinese, Japanese, and English, discovering intriguing differences in the use of extralinguistic, social information by Chinese children whose language lacks morphological inflection. The IPLP will undoubtedly continue to provide researchers with a powerful tool to explore word and sentence processing and tap into young children's burgeoning linguistic knowledge, despite the fact that it has its shortcomings.

Limitations of the IPLP

The IPLP and its offshoots are not perfect. While on the one hand they reveal the "cutting edge" of children's language ability, they may occasionally overestimate children's knowledge. This is because they suffer from the "A not A" problem. When presented with two alternatives in the IPLP, children may solve the task by a process of elimination: That one is wrong so it must be this one. Actually, children are able to use the Disjunctive Syllogism to find the referent of a new word (e.g., Halberda, 2006; Markman & Wachtel, 1988). For this reason, using collateral

measures, such as the MCDI or independent measures of the same language structures, may result in a more consistent picture of what young children know about language.

Additionally, because the IPLP requires the creation of visual representations of lexical and syntactic concepts, it is difficult to use to examine children's comprehension of abstract words such as nouns like *love* or verbs like *promise*. However, Onishi, Baillargeon, and Leslie (2007) employed children's looking behavior to study children's assessment of the beliefs of others – without words. Finally, not all children sit through the procedure. As Lewis and Cherry (1977) argued, children who "fuss out" of the procedure might have language or processing issues that will remain hidden until they are older. This is another reason why convergent measures are a useful addition to the IPLP. We predict that the IPLP will be combined with emerging neuroscience research methods. With the advent of measures such as cortical evoked potentials (ERPs) (e.g., Kuhl & Rivera-Gaxiola, 2008; Mills, Plunkett, Prat, & Schafer, 2005), or the measurement of cranial blood flow (NIRS) (Bortfeld, Fava, & Boas, 2009), or the use of MEG scans (Imada et al., 2006), designs that utilize the IPLP may well continue to deepen our understanding of language acquisition. Furthermore, the IPLP is increasingly coming to the attention of researchers as a means of assessment and prediction.

Applications of the IPLP for Prediction and Assessment

Because the IPLP makes minimal demands on young children, it is beginning to be used as a way to tap into important individual differences. Using the LWL, for example, Lew-Williams and Fernald (2007) showed that children's word recognition ability was correlated with their productive vocabularies and grammatical competence contemporaneously. Longitudinal studies showed that children who were faster and more accurate in online word recognition at 25 months of age showed faster and more accelerated growth in expressive vocabulary across the second

year (Fernald et al., 2006), and better cognitive skills (e.g., working memory) at 8 years of age (Marchman & Fernald, 2008). LWL research also showed that 1- to 3-year-old Latino children's word recognition speed is related to their family's socio-economic status (Hurtado et al., 2007). Despite the fact that these findings are correlational, they might be used to study the impact of interventions. Thus, children's performance in the LWL appears to be able to predict their later linguistic and cognitive development.

Using a computer-administered task via the use of a touch-screen computer, Brandone, Golinkoff, and Hirsh-Pasek (2008) tested preschoolers' (M = 3.60 years) verb vocabulary and comprehension of plural morphology, negation, and noun-verb agreement. Moreover, analyses revealed significant correlations among performance on the computer-based language assessment, age, and performance on the Preschool Language Scale-4. Friend and Keplinger (2008) tested 16- and 20-month-olds' word knowledge with a standard picture book task and the same task administered on a touch-sensitive screen in an IPLP setup. The computerized task improved task attention, compliance, and performance. These data support the notion that a computer-administered language assessment that is based on the IPLP is methodologically feasible and can provide a practical and valid means to assess early language abilities.

Conclusions

Since its invention, the IPLP and its offshoots have improved our understanding of what young children know about language, the processes by which they learn it, and the conceptual underpinnings required for making mappings from language to elements and events in the world. Compared with other methods (e.g., pointing, verbal elicitation, or observation), the IPLP and its offshoots appear to reveal children's incipient language knowledge, capturing their budding abilities well before they are manifested in language production. Finally, the IPLP and its

extensions may also have significant practical value for predicting infants' linguistic and cognitive development and diagnosing possible developmental difficulties.

Footnote

The IPLP is not the only method that has contributed to our understanding of language growth. Aside from the sucking response used with infants less than four months of age to access phonological discrimination (e.g., Eimas, Siqueland, Jusczyk, & Vigorrito, 1971), other methods have appeared that utilize visual fixation or head turning as dependent variables, such as the habituation method (Shi, Werker, & Cutler, 2006), the switch design (e.g., Werker, Cohen, Lloyd, Casasola, & Stager, 1998), the head turn preference procedure (e.g., Fernald, 1985; Hirsh-Pasek, Jusczyk, Kemler Nelson et al., 1987; Jusczyk, Hirsh-Pasek, Kemler Nelson, Kennedy, Woodward, & Piwoz, 1992), and the conditioned head turn procedure (e.g., Kuhl, 1983: Werker, Polka, & Pegg, 1997) (see Golinkoff & Hirsh-Pasek, 2011; Hoff, 2011, for reviews).

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Table 1.

The Video Events and Linguistic Stimuli for One Block of Trials

Left screen	Linguistic stimuli	Right screen
	Salience trial	
Blank screen	{Center light}	Blank screen
	"Wow, what's happening?"	
Woman kissing a ball…	"What are they doing?"	Woman kissing keys…
	Test trials	
Blank screen	{Center light}	Blank screen
	"Hey, she's kissing the keys!"	
Woman kissing a ball…	"Wow, she's kissing the keys!"	Woman kissing keys…
Blank screen	{Center light}	Blank screen
	"Where is she kissing the keys?"	
Woman kissing a ball…	"Oh! She's kissing the keys!"	Woman kissing keys…

Figure Captions

Figure 1. The preferential looking paradigm (Hirsh-Pasek & Golinkoff, 1996). The infant is seated on a blindfolded parent's lap in front of two televisions or one large television (as shown here). The television plays a linguistic stimulus that matches only one of the displays shown on the screen. To allow for offline coding, a hidden camera records infants' visual fixation. Parents' potential influence on children's responses is neutralized by blocking their vision in a variety of ways (e.g., eye closure).

Figure 2. The interactive intermodal preferential looking paradigm (Hollich et al., 2000). Children sit on a parent's lap (the parent keeps her eyes closed) in front of a rotating board (Fagan, 1971) that can flip over to reveal a pair of objects affixed with Velcro. The experimenter stands behind the board, and using a tightly controlled script, presents the linguistic stimuli. A hidden camera records children's looking preferences toward the two objects on the board.

Figure 3. Children's responses over time, separated by condition and by whether children fixated the target or the distractor picture at the onset of the spoken target word. The y-axis indicates the proportion of trials on which children were (at that moment) fixating a different picture than the one they fixated at the onset of the target word. The dashed vertical line indicates the average offset of the target word (Swingley & Aslin, 2000; p. 158).

Figure 1.

Figure 2.

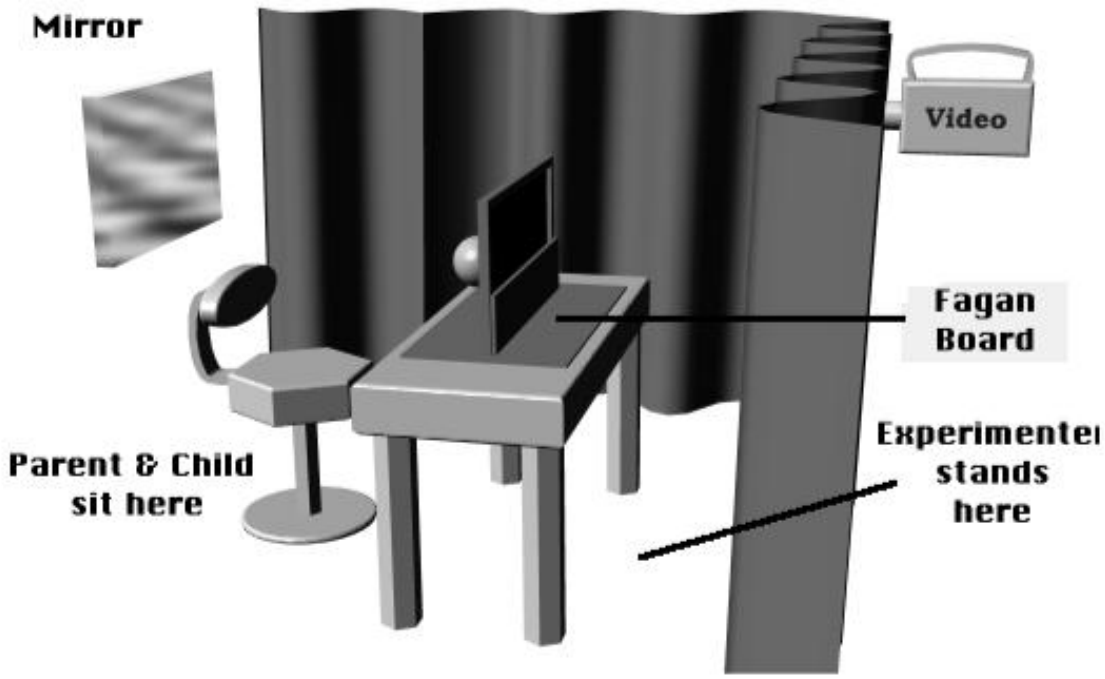
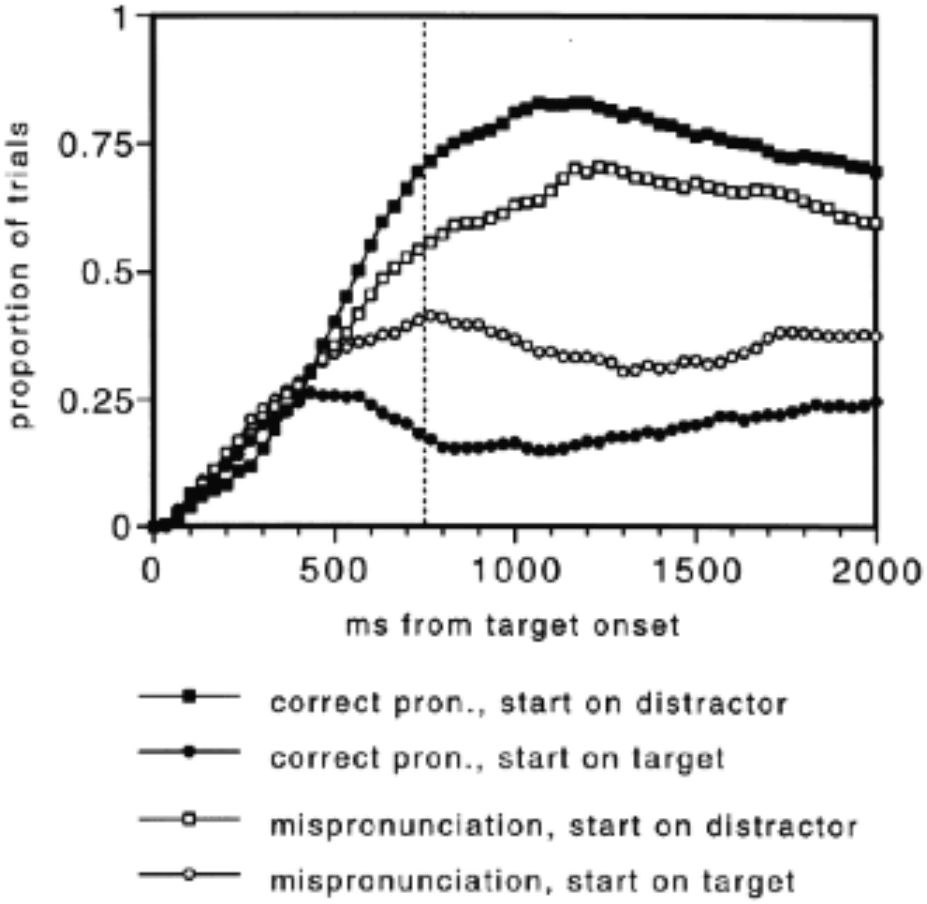

Mirror
Video
Fagan
Board
Experimenter
stands
here
Parent & Child
sit here

Figure 3.


1
0.75
0.5
0.25
0
proportion of trials
0
500
1000
1500
2000
ms from target onset
correct pron., start on distractor
correct pron., start on target
mispronunciation, start on distractor
mispronunciation, start on target