

UNDERSTANDING THE PERCEPTUAL AND COGNITIVE PRECURSORS TO
THE ACQUISITION OF LANGUAGE: AN EXAMINATION OF INFANTS'
PERCEPTION AND USE OF MANUAL GESTURES AND SIGNS

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Several perceptual and cognitive abilities have been argued to guide language development and in particular, early word learning. This dissertation sought to determine whether these abilities extend to a signed language, like American Sign Language (ASL). A series of habituation-dishabituation experiments were conducted examining infants' ability to (1) discriminate between the visual contrasts of ASL signs and (2) form associations between words, gestures, or both paired with objects.

Chapter 2 describes an experiment examining ASL-naïve 6- and 10-month-olds' abilities to discriminate between the contrasts (i.e., handshape, movement, location, and facial expression) of 2-handed signs. Infants were habituated to a 2-handed sign and tested with additional 2-handed signs that varied in only one parameter. Infants detected location and facial expression changes, but did not demonstrate detection of handshape and movement changes.

Similarly, *Chapter 3* describes two experiments examining ASL-naïve infants' abilities to discriminate between the contrasts of 1-handed ASL signs on the face. In Experiment 1, 6- and 10-month-olds' were habituated to a 1-handed sign and tested with additional 1-handed signs that varied in only one parameter. In Experiment 2, 6-month-olds were also habituated to a 1-handed sign, but were tested with 1-handed signs that varied in one or more parameters. Across both experiments, infants detected handshape and movement changes, but did not demonstrate detection of location changes.

Chapter 4 describes two experiments examining 12- and 14-month-olds' ability to form associations between objects and words, gestures, or both. In Experiment 1, infants were habituated to either gesture-object or word-object pairings. In Experiment 2, infants viewed words and gestures simultaneously paired with objects. Infants were tested with a trial that maintained a pairing and a trial that violated a pairing. Fourteen-month-olds only demonstrated the ability to form associations between words and objects. Twelve-month-olds only demonstrated the ability to form associations between words and gestures simultaneously paired with objects.

These findings reveal two prevalent themes. First, infants' possess general perceptual sensitivities that they can recruit for early word/sign learning tasks. Second, experience with a particular type of input (e.g., words) fine-tunes these sensitivities and abilities in a more specialized way.

BIOGRAPHICAL SKETCH

Makeba Parramore Wilbourn was born in Long Beach, California in 1973. She graduated from Long Beach Millikan High School in 1991 and subsequently received her Associates of Arts degree from Cypress College. After graduating with her Bachelors of Arts and Masters of Arts degrees at California State University, Fullerton in 2001, she went on to complete her Ph.D. in Developmental Psychology in the Department of Human Development at Cornell University in 2008.

To Shawn...

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TABLE OF CONTENTS

BIOGRAPHICAL SKETCH	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
LIST OF FIGURES	xii
LIST OF TABLES	xiii
CHAPTER	
1. OVERVIEW	1
PRECURSORS TO EARLY WORD LEARNING	2
LANGUAGE DEVELOPMENT ACROSS MODALITIES	4
SIGN LANGUAGE & MONOLINGUAL HEARING CHILDREN	8
SIGN LANGUAGE & PRELINGUAL HEARING INFANTS	12
CURRENT SET OF EXPERIMENTS	14
<i>PERCEPTUAL SENSITIVITY TO SIGN CONTRASTS</i>	16
CHAPTER 2	16
CHAPTER 3	16
<i>ASSOCIATIVE LINKS BETWEEN LINGUISTIC UNITS & OBJECTS</i>	18
CHAPTER 4	19
REFERENCES	22
2. DISCRIMINATING SIGNS: PERCEPTUAL PRECURSORS TO ACQUIRING A VISUAL-GESTURAL LANGUAGE	29
METHOD	33
PARTICIPANTS	33
STIMULI	34
APPARATUS	35
PROCEDURE	37
RESULTS	38
DISCUSSION	39
REFERENCES	44
3. THE UPPER HAND: INFANTS' ABILITY TO DISCRIMINATE BETWEEN ONE-HANDED AMERICAN SIGN LANGUAGE SIGNS	47
<i>EXPERIMENT I</i>	55
METHOD	55
PARTICIPANTS	55
STIMULI	56
APPARATUS	57
PROCEDURE	59
RESULTS	60
DISCUSSION	62

3. (CONT) <i>EXPERIMENT 2</i>	66
METHOD	66
PARTICIPANTS	66
STIMULI	67
APPARATUS & PROCEDURE	72
RESULTS	72
DISCUSSION	77
GENERAL DISCUSSION	78
REFERENCES	88
4. DEVELOPMENTAL CHANGES IN INFANTS' ABILITY TO FORM LABEL-OBJECT ASSOCIATIONS USING WORDS AND GESTURES	93
<i>EXPERIMENT 1</i>	102
METHOD	103
PARTICIPANTS	103
STIMULI	104
APPARATUS	108
PROCEDURE	108
RESULTS	110
DISCUSSION	116
<i>EXPERIMENT 2</i>	118
METHOD	120
PARTICIPANTS	120
STIMULI	121
APPARATUS & PROCEDURE	121
RESULTS	123
GENERAL DISCUSSION	130
REFERENCES	143
5. SUMMARY	148
CURRENT SET OF EXPERIMENTS	149
PERCEPTUAL SENSITIVITIES TO ASL SIGN CONTRASTS	149
SENSITIVITY TO ASL CONTRASTS: TWO-HANDED SIGNS	150
SENSITIVITY TO ASL CONTRASTS: ONE-HANDED SIGNS	151
DEVELOPMENTAL CHANGES IN LABEL-OBJECTS ASSOCIATIONS	154
PREVALENT THEMES	158
FUTURE DIRECTIONS	161
REFERENCES	166

LIST OF FIGURES

CHAPTER

2	<u>Figure 2.1</u> Representative Photograph Examples of Events for Habituation and Test Trials	36
3	<u>Figure 3.1</u> Representative Photograph Examples of Events for Habituation and Test Trials	58
	<u>Figure 3.2</u> Mean Looking Times (in seconds) and Standard Errors to Test Events as a Function of Age	62
	<u>Figure 3.3</u> Photograph Examples of the Events for the <i>Handshape Change</i> Condition	68
	<u>Figure 3.4</u> Photograph Examples of the Events for the <i>Location Change</i> Condition	70
	<u>Figure 3.5</u> Photograph Examples of the Events for the <i>Movement Change</i> Condition	71
	<u>Figure 3.6</u> Mean Looking Time (in seconds) and Standard Errors to Each Test Trial	74
	<u>Figure 3.7</u> Mean Looking Times (in seconds) and Standard Errors (in seconds) to Each Test Trial Compared to the Familiar Test Trial as a Function of Condition	76
4	<u>Figure 4.1</u> Photograph Examples of Novel Objects and Novel Gestures	105
	<u>Figure 4.2</u> Mean Looking Times (in seconds) and Standard Errors to Test Events as a Function of Age Group	113
	<u>Figure 4.3</u> Mean Looking Times (in seconds) and Standard Errors to Test Events as a Function of Age Group	114
	<u>Figure 4.4</u> Photograph Examples of Habituation and Test Trials for Experiment 2	122
	<u>Figure 4.5</u> Mean Looking Time (in seconds) and Standard Error to Test Events as a Function of Age Group	124
	<u>Figure 4.6</u> Mean Looking Time (in seconds) and Standard Error to Habituate as a Function of Age Group and Condition	12

LIST OF TABLES

<u>Table 1.</u> Infants' Mean Looking Time (in seconds) and Standard Deviations to the Two-Handed Signs Test Events as Function of Age	3
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CHAPTER 1

OVERVIEW

Over the last 40 years, our understanding of children's ability to acquire language has greatly expanded. We know substantially more now about *what* aspects of language children acquire and *when* they typically acquire them. However, there is considerable debate surrounding *how* children acquire language. From brain modules to connectionist models, the field is far from a consensus on whether language is an innate ability afforded to humans by language specific modules or acquisition devices (Chomsky, 1988; Fodor, 1983; Pinker, 1984) or rather a product of a general ability to learn through interactions and experiences with the environment as a function of perceptual, cognitive, and/or social development (Bates, O'Connell, & Shore, 1987; Piaget, 1955; Vygotsky, 1986). Thus, conversations about "domain specificity" versus "general learning mechanisms" have now replaced the seemingly archaic terms of "nature" versus "nurture". Of particular interest is whether infants' preexisting knowledge or abilities are the necessary precursors to language acquisition or provide the scaffolding for subsequent language learning. Specifically, research has now focused on whether this preexisting knowledge or these precursory abilities may be specific to language or rather a result of more general cognitive abilities.

There is still much debate and no widespread agreement regarding the characteristics or abilities that are the prerequisites of language acquisition (Bonvillian, Orlansky, & Folven, 1990; Reilly, McIntire, & Bellugi, 1991), or if prerequisite skills are even necessary (Pinker, 1984). For example, Bates and Dick (2002) have argued that the development of general perceptual and cognitive abilities ultimately drives language learning. More specifically, they contend that infants' *prelinguistic* sensitivities in perception and attention in addition to their skills in

observational learning and imitation provide the foundation by which language develops. Thus, the acquisition of “language is a new machine built out of old parts” (Bates & Dick, 2002, p. 2). Likewise, Echols and Marti (2004) posit that early perceptual sensitivities to various types of speech contrasts and a predisposition to attend to elements in the environment (e.g., words and objects) that co-occur are the abilities that provide the scaffolding for language development, and in particular early word learning.

Precursors to Early Word Learning

A particular aspect of language acquisition that has received an enormous amount of empirical attention is how children learn the meaning of words. The route to word learning is no easy feat. Long ago, Quine (1960) argued that children’s route to referential or symbolic word learning is particularly challenging. Many have argued that there are several necessary precursory steps to children’s understanding that a word or label refers to or “stands for” a referent. For example, Oviatt (1980) contends that before a child can truly understand that a word or label stands for or is a symbol for a referent (i.e., referential understanding), they must first understand that a word is linked or associated with a referent (i.e., recognitory understanding). Such a distinction between children’s referential and recognitory understanding is essential in the study of word learning as particular cognitive and perceptual abilities may contribute differently to each type of understanding (Hirsh-Pasek & Golinkoff, 1996; Oviatt, 1980; Werker, Cohen, Stager, Casasola, & Lloyd, 1998).

Many have proposed that a general learning mechanism is responsible for children’s recognitory understanding or ability to associate words with objects (Werker et al., 1998). Proponents of this view argue that young children’s ability to rapidly form associative links between words and objects (Werker et al., 1998), causal relation words and actions (Casasola & Cohen, 2000) and spatial prepositions and

spatial relations (Casasola & Wilbourn, 2004) is also demonstrated in their ability to form associative links with non-linguistic input such as object form-function correlations (Younger & Cohen, 1986) and facial features (Cohen & Cashon, 2001). It is important to bear in mind that although most agree that this type of associative learning is fundamental and pervasive in early word learning, some have argued that associative learning, in and of itself, is not enough (Woodward, 2004).

Echols (1993) and Echols and Marti (2004) agree that associative learning is not enough and further suggest that there are several precursory perceptual and cognitive abilities that children must possess before they are able to associate labels with objects. Specifically, Echols and Marti (2004) state that when children are at the beginnings of word learning, they are confronted with several fundamental challenges. One of these challenges is determining how to associate words with their appropriate referents (i.e., recognitory understanding). However, before children are able to form associative links between words and referents, they face the initial challenge of being able to identify or segment words or linguistic units from the speech stream and discriminate between relevant speech contrasts.

Echols and Marti (2004) suggest that a similar framework may assist children in dealing with each of these challenges. For instance, children may enter the task of language learning with a set of predispositions, biases, or tendencies that prepare the perceptual system for linguistic input from the environment (Echols & Marti, 2004; Werker & Yeung, 2005). With regard to segmenting linguistic units and discriminating speech contrasts, children appear to possess tendencies to attend to perceptually salient language patterns (e.g., intonation, stress, pitch, first syllables, tones, statistical regularities), which assist them in the task of parsing speech sounds and linguistic units from the speech stream (Saffran, Aslin, & Newport, 1996; Saffran, Johnson, Aslin, & Newport, 1999; Werker & Yeung, 2005). Then, when associating

these units with referents, children's early tendencies to attend to objects and consistency may ultimately assist them in their ability to form label-object associations (Echols & Marti, 2004).

Initially, the prelinguistic child may possess general perceptual biases that help guide them in the early stages of word learning. However, these biases may then interact with and be expanded by the specific characteristics of the child's ambient language (Echols & Marti, 2004; Werker & Yeung, 2005). Hence, with more experience with their native language, children may come to rely on more language specific cues, such syntax and grammatical structure, for insights into word identification and meaning. Ultimately, the later reliance on syntactic cues may assist in children's identification and understanding of verbs, adjectives, and spatial prepositions. Thus, through development, experience with one's ambient language may provide a language-specific reorganization of the perceptual system (Werker & Fennell, 2004; Werker & Tees, 1984; Werker & Yeung, 2005).

In spite of the extensive literature on the possible precursors to language development in general, and word learning specifically, the majority of the empirical support for the proposed theories or hypotheses have focused solely on spoken language. To what degree do these precursory abilities extend to language development across modalities, as in the case of visual-gestural or signed languages? Bonvillian and colleagues (1990) have long argued that the "language modality is an important factor in the acquisition process" (p. 221) and is an area of research often left out of the discussion surrounding the mechanisms that drive language development.

Language Development Across Modalities

Investigating the development and acquisition of language (e.g., word and sign learning) across modalities serves to broaden linguistic theory by increasing our

knowledge base as well as focus theory to include both the similarities and differences between spoken and signed languages (Lillo-Martin, 1999). The comparison of language development of signed and spoken languages allows for cross-modal and cross-linguistic comparisons that provide insight into domain general and specific characteristics (Bonvillian & Siedlecki, 1998; Volterra & Iverson, 1995). How does modality of input affect language learning, and specifically early word/sign learning?

To examine this question, the hearing children of deaf parents may be one of the most insightful populations to study. These children represent a bilingual unique population because not only are these children typically learning two languages (e.g., ASL and English) but they are also learning these languages in two very different sensory modalities (Abrahamsen, Cavallo, & McCluer, 1985). Most importantly, they typically have received visual-gestural linguistic input from birth. This type of language development across modalities provides insights into the potential language specific and domain general mechanisms at play in the acquisition of language (Guttentag & Schaefer, 1987). One way in which this type of investigation sheds light on these issues is that we are able to assess children's linguistic and non-linguistic abilities as a function of the type of input they have received. For example, many researchers have claimed that children exposed to a visual-gestural language, which represents linguistic concepts visually and within a particular spatial context, greatly benefit from this type of input in various cognitive and linguistic domains (Acredolo, Goodwyn, & Abrams, 2002; Bellugi et al., 1990; Bonvillian & Siedlecki, 1998; Caselli et al., 1998; Cattani, Clibbens, & Perfect, 2007; Daniels, 1994a, 2001, 2004).

To date, there has not been a great deal of research exploring how this type of input may affect infants' *prelingual* perceptual and cognitive skills or their *comprehension* of language. However, we do have some insights from the research on how this type of input affects infants' *production* of language. Although, the

mechanisms driving the comprehension and the production of language may be very different, assessing how this type of input affects production is at the least a reasonable starting point. For instance, in a longitudinal study, Bonvillian and collaborators (1990) explored the language production of hearing children of deaf parents and whether the precursory abilities argued to be the necessary perceptual skills required for the acquisition of a spoken language are similar to necessary skills for the acquisition of a signed language. Bonvillian et al. (1990) found that the hearing children in their study attained linguistic milestones in the production of American Sign Language (ASL) signs during earlier stages of symbolic development than reported of children's linguistic milestones in the production of English words. These findings are in line with the research that has documented that infants exposed to a visual-gestural language from birth typically produce their first recognizable sign at about 8.2 months compared to hearing infants exposed to only a spoken language from birth who typically produce their first recognizable word between 11.5 and 13.5 months (Prinz & Prinz, 1979a; Orlansky & Bonvillian, 1985; Bonvillian & Folven, 1987; Meier & Newport, 1990, but also see Pettio et al., 2001).

Bonvillian et al. (1990) contend that the type of attentional and imitation skills required to learn ASL (i.e., establish joint attention, maintain eye contact, and imitate manual signs) may actually bolster children's sensorimotor and symbolic development; two forms of development that Piaget (1955) proposed to be fundamental aspects of children's spoken language acquisition. Bonvillian et al. (1990) claim that many of the necessary cognitive and social precursory skills required for learning spoken language may actually develop as a result of infants' exposure to a visual-gestural language from birth considering the "high degree of correspondence" between parent and child as well as the child's intention and cognition required for effective sign language communication does not exist in spoken languages (Bonvillian

et al., 1990, p. 227). As a result, Bonvillian et al. (1990) argue that the initial steps of sign language learning might be achieved more rapidly and readily than the initial steps of spoken language learning.

One particular challenge in generalizing the findings of Bonvillian et al. (1990) to a broader population is that they investigated a very unique and small population of children (i.e., hearing children of deaf parents, $N < 15$). In addition, the parental reports or diary studies of deaf parents with hearing children must be interpreted with caution because deaf parents of hearing children may not be as accurate at assessing their hearing child's spoken language development as they are in assessing their hearing child's sign language development. However, two influential studies addressed this particular concern by examining hearing children born to at least one hearing parent (Prinz & Prinz, 1979a, 1979b, 1981; Holmes & Holmes, 1980). For instance, Prinz and Prinz (1979a, 1979b, 1981) documented the sign (i.e., ASL) and spoken (i.e., English) language development of a typically developing hearing female born to a deaf mother and hearing father. Likewise, Holmes and Holmes (1980), two hearing signed language interpreters, documented the language development of their hearing son, who was exposed to Signed English (i.e., Siglish)¹ from birth.

Both studies found that both children had significantly more signs in their productive vocabularies compared to words (Holmes & Holmes, 1980; Prinz & Prinz, 1979a, 1979b). Both sets of researchers concluded that signs seemed to augment or facilitate their children's verbal repertoire rather than compensate for verbal difficulties. Although insightful, both the Holmes and Holmes (1980) and Prinz and Prinz (1979) studies only documented the development of one child and employed more naturalistic methods of data collection (i.e., parental report or diary studies). This

¹ Siglish is a visual-gestural language that uses ASL signs but in an English-based syntax or grammatical structure.

small sample size and methods of data collection also makes it difficult to generalize and determine how this type of visual-gestural linguistic input may affect a broader population of hearing children's language development.

Sign Language & Monolingual Hearing Children

The Prinz and Prinz (1979a, 1979b, 1981) and Holmes and Holmes (1980) studies were in many ways the impetus for much of the more recent research exploring the effects of sign language or sign-accompanied speech (i.e., baby signs) input on typically developing hearing monolingual children or hearing infants born to hearing parents (Acredolo et al., 2002; Garcia, 2002). Despite the commercial use and promotion of this work (e.g., Baby Signs®, Sign with your Baby®), the study of sign language input and sign and spoken language development in hearing infants born to hearing parents provides valuable scientific insight into language acquisition because it provides an additional method for assessing young children's linguistic abilities and language comprehension (Acredolo & Goodwyn, 1990; Thompson, Cotnoir-Bichelman, McKerchar, Tate, & Danco, 2007). Furthermore, some have proposed that language fundamentals acquired through the manual/visual modality are ultimately transferred to the oral modality as motor development (i.e., tongue, lip, and mouth coordination) and phonetic development progress (Johnston, Durieux-Smith, & Bloom, 2005).

Daniels (1993, 1994a, 1994b, 1996a, 1996b, 1997, 2001, 2003, 2004) has repeatedly demonstrated that young language learners who are exposed to ASL and sign-accompanied speech have an advantage in overall language development (e.g., vocabulary growth, spelling, literacy) over young language learners who have not been exposed. Daniels (2001) has conducted a series of studies that address numerous anecdotal reports from ASL interpreters for deaf parents of hearing children who worked in different locations across the country. The interpreters observed and

reported that the hearing children born to deaf parents had “an unusual facility with English and unexpectedly larger vocabulary than their peers who do not sign” (Daniels, 1993, p. 23).

Daniels (1994a, 1994b, 1996) set out to investigate the possibility that exposure to bimodal (signed and spoken) linguistic input affords hearing children with a greater proficiency in a spoken language (i.e., English). She examined English vocabulary development in normally developing hearing children born to hearing parents. The children were exposed to bilingual/bimodal linguistic input during an ASL intervention program at school. The Peabody Picture Vocabulary Test-Revised (PPVT-R) was administered to each classroom before and after the intervention.

Initially, the intervention program began by exposing the preschoolers and kindergarteners to signed-accompanied speech (i.e., English phrases accompanied with ASL signs). For example, the English sentence “This *bird* likes a very special *tree*” was conveyed with the ASL signs for BIRD and TREE simultaneously presented with the spoken words. As the intervention progressed, the children were exposed to ASL alone (i.e., ASL grammar). In sum, the students were exposed to ASL signs embedded within English phrases for approximately 50% of the time, spoken English alone for 25% of the time, and ASL alone for the remaining 25% of the time. This distribution of exposure was done to present the children with truly bimodal and bilingual linguistic input. By the end of the program, the majority of the students were using both ASL and English interchangeably with increasing proficiency.

The findings revealed that the average vocabulary gain for the children who participated in the ASL program was significantly higher than the average vocabulary gain for those children who did not. Surprisingly, these gains remained over a three-year period, even when no additional sign language exposure was provided (Daniels, 1996b). Daniels (2001) concluded that visual linguistic input adds an additional

sensory channel for young language learners, which ultimately enhances their ability to understand and learn more words.

Similarly, Heller and colleagues (Heller, Manning, Pavur, & Wagner, 1998) documented language development of 54 deaf and hearing 3-year-olds in a 2-year long English Sign Language (ESL) training program. The teachers integrated ESL in their entire curriculum and used signing concurrently in all communications with the children. As in the Daniel's (2001) studies, the children in ESL training program yielded significantly higher scores on the PPVT than their same age peers who were not in the training program.

Likewise, in a similar yet more comprehensive program in the United Kingdom, researchers implemented a British Sign Language (BSL) training program with both deaf and hearing toddlers. The children were in an integrated classroom with a deaf teacher one day a week. Surprisingly, the hearing children attained a level of BSL proficiency comparable to that of their deaf peers with such minimal exposure. What is equally remarkable about these findings is that the children also demonstrated a significant increase in their national test scores in both reading and spelling (Daniels, 2004).

Based on these findings, Daniels conducted a subsequent study with hearing kindergarteners in rural Vermont (Daniels, 2004). As in the previous studies (Daniels, 1994a, 1994b, 1996a, 1996b), kindergartners were exposed to ASL throughout the academic term. Again, the intervention began with sign-accompanied speech and concluded with ASL with no voicing during academic lessons. In addition, the teacher used the manual alphabet and fingerspelling to enhance the children's phonemic awareness. Specifically, the teacher would verbally articulate the letter names or the sound of the letter as she manually articulated the corresponding letter. In addition, when reading was being taught to the children, the teacher would use ASL signs in

English word order with all relevant vocabulary words being articulated in both English and ASL.

Before and after the program, the children's English receptive and productive vocabulary was assessed in addition to their emergent reading level. Also, at the end of the school term, the children's proficiency in ASL, including ASL phonology, morphology, and syntax was assessed. The findings revealed that the children attained a two-year vocabulary growth as evidenced by the comparison of their pre- and post-test vocabulary scores. In addition, the children in the ASL training program scored higher than their non-exposed peers on standardized reading measures.

One significant limitation of the above mentioned research is that it explored the effects of exposure to a visual-gestural language on the language development of preschoolers and kindergarteners. By the preschool and kindergarten years, most typically developing toddlers have already begun to produce symbolic labels verbally and are in many ways already expert language learners. Hence, most of the children had already acquired their native language before they were exposed visually to linguistic input. These findings leave open the question of whether younger *prelingual* children will also benefit in similar ways from such gestural input.

Sign Language & Prelingual Hearing Infants

To explicitly investigate this question Acredolo et al., (2002) conducted numerous studies exposing typically developing prelingual hearing infants to gestural input. Goodwyn and Acredolo (1993) posited that if a gestural advantage is truly robust, then prelingual hearing children born to hearing parents who receive incomplete or less structured visual-gestural input (i.e., symbolic signs as opposed to a complete signed language) should demonstrate a similar gestural advantage in language production to the hearing children born to deaf parents in the previous studies (Prinz & Prinz, 1979a; Orlansky & Bonvillian, 1985; Bonvillian & Folven,

1987). In their study, Goodwyn and Acredolo (1993) addressed whether or not a preference for signs over speech in language production was evident in hearing children born to hearing parents who were exposed to verbal linguistic input and simultaneously presented with symbolic signs or signs. They sought to eliminate the limitations of the previous studies by using a larger sample size and by using a population of prelingual infants that received a great deal of verbal linguistic input (monolingual hearing infants born to hearing parents).

The parents of 22 11-month-old infants were trained with “target” signs (e.g., arm-flapping for bird, open-close hand for frog, lip-smacking for fish) and were instructed to present these signs simultaneously with the appropriate verbal labels (i.e., “bird”, “frog”, “fish”). Parents were asked to expose their infant to these symbolic signs daily and incorporate them into the child’s everyday routines. The parents were also encouraged to create and add signs once they were comfortable incorporating the eight targets signs into their everyday routines.

The findings revealed a small, but reliable advantage for signs over spoken words for the infants in the study. Seventeen of the 22 infants demonstrated a preference for signs over words for their first productive label. To address the criticism that the first symbolic production alone, either manual or vocal, is not indicative of a preference for one modality over another for symbol use, the researchers compared the age at which the first 5 gestural labels appeared in the infant’s vocabulary to the age at which the first 5 verbal labels appeared. The results again appeared to favor signs over words, but only marginally.

The researchers posit that recruiting manual signs to label objects appears to be easier for infants than recruiting the appropriate vocal abilities to label objects. In a subsequent longitudinal study, Goodwyn, Acredolo, and Brown (2000) found that prelingual hearing infants who were exposed to signed-accompanied speech or “baby

signs” demonstrated a significant linguistic precocity over their peers on multiple language assessment measures. Furthermore, evidence from this study indicates that this precocity remains throughout early childhood (Acredolo et al., 2002).

As a result of the work of Acredolo and collaborators (2002), as well as Garcia (2002), a countless number of “baby sign” language programs and products have been developed capitalizing on parents’ and caregivers’ desire and enthusiasm for facilitating their infant’s language and cognitive development. The majority of these well-publicized programs and products for parents claim that the use of baby signs (e.g., *Baby Signs, Inc.*®; Acredolo et al., 2002) or early exposure to ASL (i.e., *Sign with your baby*™; Garcia, 2002) will facilitate language development, reduce parent-child communicative frustrations, increase social bonding, and enhance cognitive development and IQ (Acredolo et al., 2002). However, it is unclear whether the claims made by many of these companies are completely justified by the cited research (Johnston, Durieux-Smith, & Bloom, 2005).

To further investigate the claims made by Acredolo and colleagues (2002), Thompson and colleagues (Thompson et al., 2007; Thompson, McKerchar, & Danco, 2004) investigated whether signs acquired during controlled experimental conditions as well as during naturalistic conditions would continue to be used in naturalistic environments across multiple listeners and reinforcers. The researchers initiated a sign-training program and documented the acquisition of a particular ASL sign (e.g., <PLEASE>, <MORE>) with 5 infants ranging in age from 6- to 13-months. Overall, Thompson et al. (2004, 2007) found that with training in both experimental and naturalistic settings and with different experiments and reinforcers, infants not only were able to quickly learn and use the sign (i.e., less than 4 hours exposure), but also maintained a high rate of independent use without prompting or reinforcement.

Thompson and colleagues (2004, 2007) conclude that prelingual infants are able to learn and appropriately use an ASL sign in naturalistic settings (e.g., home, school) with relative ease. It is important to note that the youngest infant studied in the Thompson et al. (2007) study was 6 months; an age well before the typical age of onset of communicative signs or words (Bonvillian et al., 1990; Meier & Newport, 1990). These findings provide further support for previous claims that exposure to a sign language or sign-accompanied speech may facilitate language development, and in particular early word or sign learning (Acredolo et al., 2002; Daniels, 2001), however the mechanisms responsible for this facilitation have only been left to speculation.

Current Set of Experiments

The overarching goal of the current set of experiments is to explore whether some of the previously proposed perceptual and cognitive mechanisms for early word learning (Echols & Marti, 2004) extend to visual-gestural and bimodal input in the form of ASL signs and manual gestures simultaneously presented with auditory words. Although there is not widespread agreement on the nature or development of the precursors or prerequisite skills required to acquire language, it is important to explore the previously proposed models (e.g., Echols & Marti, 2004) and claims with diverse types of input.

The majority of the research conducted thus far examining children's language development as a function of input has focused primarily on describing and explaining the children's *production* of language. However, the mechanisms driving children's early *production* of various types of linguistic labels (e.g., signs, words) may be very different than the mechanisms driving children's early *comprehension* of these linguistic labels. For instance, if the path to word (or sign) learning is different for visual versus auditory input or the combination of both, this suggests that the

mechanisms guiding this process might be different. Thus, the exploration of children's precursory abilities related to the comprehension of labels using various types of input is warranted. Are the perceptual cognitive prerequisites for the comprehension of signs and words similar whether the input is visual or auditory?

Echols and Marti (2004) have argued that one particular cognitive requirement of word learning in early development is the perception of relevant linguistic contrasts. The development of this highly complex human ability has received a substantial amount of empirical attention with regard to spoken language, however it has received substantially less attention with regard to signed languages. It has been well documented that from a very early age, hearing infants possess remarkable perceptual sensitivities to both native and non-native speech contrasts (Werker & Tees, 1984). Considering that typically developing children readily acquire language whether that language is spoken or signed, it is only logical to assume that infants also possess similar perceptual sensitivities to visual contrasts. Yet, very little research has been conducted examining hearing infants' abilities to distinguish between relevant sign contrasts (Baker, Golinkoff, & Petitto, 2006; Carroll & Gibson, 1986; Schley, 1991).

Perceptual Sensitivities to Sign Contrasts - Chapter 2. This particular chapter explores hearing ASL-naïve infants' abilities to visually discriminate between the relevant contrasts of ASL. Specifically, the study presented in this chapter examined hearing ASL-naïve 6- and 10-month-olds' abilities to visually discriminate between the ASL sign contrasts of handshape, movement, location, as well as a grammaticized facial expression used in ASL. Infants were habituated to one 2-handed symmetrical (hands mirroring one another) sign articulated in neutral space (in front of the torso) and tested with additional 2-handed symmetrical signs that varied in handshape, location, movement, or facial expression (i.e., furrowed brow).

The findings from this study provide insight into the perceptual sensitivities that ASL-naïve infants bring to the task of sign discrimination, arguably a necessary precursor to the acquisition of a signed language. In general infants demonstrated the ability to detect changes in location and facial expression, but failed to provide evidence of detecting changes in handshape or movement. However, one important possibility to consider is that infants' abilities vary as a function of the (1) number of hands used to articulate the signs and (2) where in the signing space signs are produced. So to investigate this possibility, a second study was conducted that varied (1) the number of hands used to produce the signs, (2) where in the signing space the signs were produced and well as (3) the number of parameters (i.e., “phonemes”) that varied and which remained constant. And thus, the set of experiments in Chapter 3 addressed these issues.

Chapter 3. This particular chapter comprises two experiments that were conducted examining ASL naïve infants' ability to discriminate between the relevant contrasts of one-handed ASL signs articulated near the face. In the first experiment, hearing ASL-naïve 6- and 10-month-olds were habituated to a one-handed ASL sign articulated near the face. After habituation, the infants were tested with different one-handed signs also articulated near the face that varied in handshape, movement, location, or grammatical facial expression.

The findings of Experiment 1 revealed that infants can detect changes in handshape and movement, but failed to provide evidence of detecting changes in location and facial expression. However, due to methodological constraints, limited ecological validity (i.e., created signs used with a non-native signer), and an unexpected effect of gender, a second study was conducted. Experiment 2 was specifically conducted to (1) minimize any methodological confounds (i.e., signer's hand covering eyebrows), (2) increase ecological validity, and (3) further explore a

possible sex difference in abilities.

In Experiment 2, again 6- and 10-month-olds were habituated to a one-handed ASL sign articulated near the face by a native signer. However, infants were tested with ASL signs that varied in one or more parameters (e.g., handshape or handshape + movement). This was done to assess the degree of change from the habituation sign that infants were able to detect and which parameter or combinations of parameters were particularly salient to ASL-naïve infants. In addition, actual ASL signs were used instead of created or modified signs in order to increase the ecological validity of the study. Interestingly, the findings from Experiment 2 replicated the findings from Experiment 1 with infants providing evidence of detecting changes in handshape and movement and failing to provide evidence of detecting changes in location (note: facial expression was not assessed in this experiment). This project provided important insights into the nature of infants pre-existing perceptual sensitivities to the sign contrasts relevant to ASL and an another small piece of evidence to the extant literature on infants' perception of visual-gestural signs.

Associative Links Between Linguistic Units and Objects. Another very important step along the path to label or symbol learning, proposed by Echols and Marti (2004), is the ability to form associative links between the perceived linguistic units (e.g., words) and their respective referents. Before children are able to learn that a word (or sign) *represents* an entity, they must first be *sensitive* to the co-occurrence of the label and referent in their environment. Others have argued that the ability to form word-referent associations requires a less cognitively advanced skill (e.g., recognitory memory) than the ability to understand that a word *stands for* or *represents* a referent (i.e., referential memory; Oviatt, 1980). A number of studies have explicitly tested prelingual infants' ability to link words with objects (Schafer & Plunkett, 1998; Werker et al., 1998; Woodward, Markman, & Fitzsimmons, 1994).

Yet, very few studies have examined infants' ability to form linkages between signs or gestures and referents (see Namy & Waxman, 1998).

Namy & Waxman (1998) examined toddlers' willingness to accept either an auditory word or a visual gesture as a label for an object. Using word-learning paradigm rich with social cues, the researchers found that 18-month-olds readily learned both gestural and auditory labels for objects, whereas 26-month-olds readily learned the auditory labels but required further training to learn the gestural labels. However, it is important to consider that the ability tested in this study was more symbolic in nature (i.e., referential memory, Oviatt, 1980) and may have been more cognitively demanding in that the toddlers were required to map and generalize the label (either gestural or verbal) to both familiar and novel referents.

To explicitly investigate prelingual infants' ability to form associative links between words and objects without the benefit of social support, Werker and colleagues (1998) tested 12- and 14-month-olds infants' ability to form word-object associations in a controlled experimental setting without social cues. They found that 14-month-olds, but not 12-month-olds, could rapidly form associative links between words and objects in an experimental setting. These findings complement the work of both Oviatt (1980) and Woodward et al., (1994), demonstrating that by the age of 14 months, infants are able to recruit the appropriate cognitive abilities necessary to learn new words (Werker et al., 1998). However, several questions remain. First, why do 12-month-olds fail to demonstrate this ability and can gestural labels help? Given, that a great deal of research suggests that gestural labels may in fact be easier to acquire than auditory labels (Bonvillian et al., 1990), it is possible that infants as young as 12 months are able to form associative links between gestures and objects before they can form links between words and objects. Second, do 14-month-olds' abilities to rapidly form associative links, without the benefit of social support, extend to gestural labels

as well?

To date no such studies have directly examined hearing infants' ability for form associative links between gestures with objects or words and gestures with objects without the benefit of social support. The majority of work has focused on children's understanding and use of symbolic gestures in naturalistic settings or environments rich with social cues (Acredolo & Goodwyn, 1988; Namy & Waxman, 1998). Thus, the goal of the third and final project was to examine infants' ability to form associative linkages with various types of input and in particular, manual gestures².

Chapter 4 describes a study testing prelingual infants' ability to form associative links between words or gestures with objects. In addition, infants' ability to form a 3-way association with words and gestures with objects (i.e., bimodal input) was tested. In the Experiment 1, 12- and 14-month-olds' ability to form associative links with words and objects or gestures and objects was examined. Using the same modified habituation paradigm as Werker et al. (1998), infants were habituated to two different word-object or gesture-object pairings (depending on which condition they were in). During the test trials, infants viewed one trial that maintained a previously presented pairing (i.e., same trial) and another trial that violated one of the previously presented pairings (i.e., switch trial). If infants had formed associative links with various types of input, without the aid of social cues, they should have demonstrated a visual recovery to the novel pairing during the test trials. The results revealed that 14-month-olds, but not 12-month-olds demonstrated the ability to form word-object associative linkages, replicating Werker et al.'s (1998) findings. However, neither group provided evidence of forming associative linkages between the gestures and the

² The term "gestures" is used throughout Chapter 4 to explicitly distinguish between the input used in Chapters 2 and 3, which were actual ASL signs, compared to the input used in Chapter 4, which were gestures derived from ASL signs but were used as "nonsense" gestural labels in the experiments.

objects.

Based on the work of Daniels (2001) and Acredolo and colleagues (2002) revealing that gesture-accompanied speech can facilitate language development in young language learners, the primary goal of Experiment 2 was to determine whether multiple sources of input (gestures and words) presented simultaneously across two sensory modalities would affect infants' ability to form associative linkages between words, gestures, and objects. Using the identical paradigm as in Experiment 1, in Experiment 2 infants viewed simultaneous presentations of both words and gestures (i.e., synchronous bimodal input) paired with objects. Specifically, 12- and 14-month-olds infants were presented with two alternating word-gesture-object combinations and tested with a "switch" trial that violated only one aspect of the combination (e.g., the word switched). Again, if infants were able to attend to the combination of words, gestures, and objects, they should have looked longer at this switch trial. The findings revealed that contrary to Experiment 2, 12-month-olds, but not 14-month-olds demonstrated the ability to form associative linkages between both words and gestures presented simultaneously with the objects.

The findings from this study provide some of the first evidence that 12-month-olds possess the ability to form associative links between various types of input (gestures and words) and objects in an experimental setting without the benefit of social support. In addition, the results are the first to directly replicate the findings of Werker et al. (1998). These findings in conjunction with the findings of Werker et al. (1998) support the contention that the period between 12 and 14 months of age is one of great transition in early word learning, and specifically in infants' precursory abilities that lay the foundation for subsequent language learning. Moreover, the findings from the current study reveal that this period may be more of a general-to-specific transition rather than a transition from less-to-more advanced associative

learning abilities as previously proposed by Werker et al. (1998). In particular, the results of the current study suggest that by 14 months, hearing infants exposed from birth to spoken language may become more specialized toward auditory words than other types of input in the form of gestures or gesture-accompanied speech. Thus, it is not that 12-month-olds require and can only rely on social cues to form associative links, but rather are able to rely on additional sources of input (e.g., *both* words and gestures) to attend to the relevant linkages.

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CHAPTER 2

DISCRIMINATING SIGNS: PERCEPTUAL PRECURSORS TO ACQUIRING A VISUAL-GESTURAL LANGUAGE

Abstract

We tested hearing 6- and 10-month-olds' ability to discriminate among three American Sign Language (ASL) parameters (location, handshape, and movement) as well as a grammatical marker (facial expression). ASL-naïve infants were habituated to a signer articulating a two-handed symmetrical sign in neutral space. During test, infants viewed novel two-handed signs that varied in only one parameter or in facial expression. Infants detected changes in the signer's facial expression and in the location of the sign but provided no evidence of detecting the changes in handshape or movement. These findings are consistent with children's production errors in ASL and reveal that infants can distinguish among some parameters of ASL more easily than others.

DISCRIMINATING SIGNS: PERCEPTUAL PRECURSORS TO ACQUIRING A VISUAL-GESTURAL LANGUAGE

Infants possess remarkable perceptual abilities that are pivotal in the acquisition of language. For hearing infants, the ability to discriminate between speech contrasts plays an essential role in the acquisition of spoken language. Until about 6 months of age, infants are able to discriminate between speech contrasts from non-native languages (e.g., /t a/ versus /ta/ in Hindi) and their native language (e.g., /ba/ versus /da/ in English; Werker & Tees, 1984). Thus, infants' perceptual abilities, early in their first year, allow for "language-universal phonetic discrimination", even though by 12 months, infants' ability to discriminate between non-native speech contrasts begins to decline (Werker & Tees, 1999, p. 515). These findings raise the question of whether infants' perceptual abilities play an analogous role in the acquisition of a visual-gestural language. To date, we know substantially less about hearing infants' sensitivity to and discrimination of the linguistic properties of a visual-gestural language, such as American Sign Language (ASL). The purpose of the present study is to explore how hearing infants' perceptual sensitivities to the linguistic properties of ASL may aid them in acquiring a visual-gestural language.

The linguistic properties of visual-gestural languages, such as ASL, are notably similar to the phonological structure of spoken languages. Stokoe (1960) and Stokoe, Casterline, & Croneberg (1965) outlined three primary parameters³ that distinguish signs: (1) the *location* where the sign is articulated; (2) the shape of the hand(s) or *handshape*; and (3) the *movement* of the hand(s). Also similar to a spoken

³ Stokoe and colleagues (1960; Stokoe, Casterline, & Croneberg, 1965) also included *palm orientation*, the direction of the palm in relation to the signer's body (e.g., palm out, palm down) as a parameter of ASL, however in the current study this distinction was not directly examined and was held constant in each of the sign presentations (i.e., palm out and palm in).

language, ASL has minimal pairs of signs (i.e., contrasts) that differ in only one parameter. For instance, the signs <SUMMER> and <UGLY> vary with respect to location but maintain the same handshape and movement (Klima & Bellugi, 1979). Although manually articulated, these parameters serve the same essential function as phonemes in spoken languages.

Likewise, the use of facial expressions in ASL serves a similar function to intonation in English; particularly, in the contrasts that denote yes/no questions from wh-questions. In English, yes/no questions are typically pronounced with a rising intonation whereas wh-questions are pronounced with a falling intonation, a distinction that is essential for effective communication (Frishberg, 1975). Similarly in ASL, yes/no questions are articulated with raised eyebrows whereas wh-questions are articulated with a furrowed brow (Sternberg, 1998). This distinction is critical, grammatically, in that questions missing the appropriate facial expression can be completely uninterpretable (Campbell, Woll, Benson, & Wallace, 1999).

The similarities between English and ASL raise the question of what role hearing infants' perceptual abilities plays in their acquisition of a visual-gestural language. Just as infants' acute perceptual sensitivities form the necessary building blocks to acquire a spoken language, it seems plausible that these sensitivities serve an analogous function in the acquisition of a visual-gestural language, such as ASL (Holmes & Holmes, 1980; Prinz & Prinz, 1979). There have been only a few studies that have explored this issue by examining hearing infants' ability to discriminate ASL contrasts (Carroll & Gibson, 1986; Schley, 1991). Schley (1991), for example, examined ASL-naïve hearing 3.5-month-olds' discrimination of two different types of movement contrasts in ASL. Infants were habituated to one particular type of movement (e.g., cyclicity) and tested with signs that had a different type of movement (e.g., direction). She found that ASL-naïve hearing infants were able to discriminate

between various movement contrasts in ASL. Similarly, Carroll and Gibson (1986) found that hearing 4-month-olds were able to discriminate between two ASL signs based on multiple movement dimensions (<TEN> vs. <OTHER>) as well as on a single movement dimension (<LEFT> vs. <LIBRARY>). Although these studies are some of the only investigations into hearing infants' sensitivities to visual-gestural languages (see also Masataka, 1995), the findings do not address hearing infants' ability to discriminate among the other ASL parameters, such as handshape and location. Do hearing infants discriminate between these parameters equally well?

Several lines of research with adults and children suggest that differences in how easily particular parameters of ASL are discriminated, even for experienced signers. For instance, adult native signers demonstrate more difficulty in discriminating and identifying changes in handshape (Stungis, 1981) and movement (Tartter & Fischer, 1982) than changes in location (Poizner & Lane, 1978). Likewise, 6- to 10-year-old Deaf children made more errors discriminating minimal pairs of signs that differed in handshape than in movement or location (Hamilton, 1986). These findings suggest that changes in handshape and movement are more difficult to discriminate than changes in location. Perhaps, novice ASL learners, such as hearing infants, may demonstrate the same pattern of difficulty as experienced ASL signers.

The suggestion that changes in handshape and movement may be more difficult to discriminate between than changes in location is also supported by previous research examining young signers' production errors during the early stages of ASL acquisition. For instance, research on the ASL production errors of Deaf and hearing infants and toddlers demonstrates that first signs are typically produced in the correct location but with incorrect handshapes and movement (Bonvillian & Siedlecki, 2000; Wilbur & Jones, 1974). Although these errors have been attributed primarily to motoric constraints (Conlin, Mirus, Mauk, & Meier, 2000), Bonvillian

and Siedlecki (2000; Siedlecki & Bonvillian, 1993) argue that these errors also may be due to difficulty in *perceiving* specific handshapes. Thus, early perceptual abilities may also play a role in children's production errors in ASL.

Bearing in mind that the ability to discriminate among the primary parameters of ASL plays an essential role in the acquisition of ASL, the current study sought to outline the degree to which hearing infants' perceptual abilities provide the scaffolding needed to acquire this type of visual-gestural language. Specifically, we tested hearing ASL-naïve infants' ability to discriminate among three primary parameters (location, handshape, movement) as well as a grammatical marker (facial expression) in ASL. Six- and ten-month-olds were tested in order to explore possible developmental changes in these abilities. The infants were habituated to a single sign (i.e., a two-handed symmetrical sign) and tested with novel signs that varied in only one parameter (i.e., handshape, movement, location, or facial expression). Two-handed symmetrical signs (both hands mirroring one another) were used because they are representative of the first signs children typically produce as well as signs typically articulated in neutral space (Frishberg, 1975).

Method

Participants. Participants were recruited at a local hospital at the time of their birth. At that time, parents were given a letter and subsequently contacted to participate. Fifteen 6-month-olds (± 2 weeks, 7 females) and 12 10-month-olds (± 2 weeks, 6 females) participated. Infants were full-term, of normal birth weight, and had no auditory or visual problems. Infants who had been previously exposed to ASL or "baby signs" were excluded. Six additional infants were excluded (one 6-month-old and five 10-month-olds) because they failed to meet the habituation criterion (described below). Four additional infants (two at each age) were excluded because they demonstrated extreme looking times ($+2$ SD) to the familiar event.

Stimuli. Figure 2.1 depicts representative examples of the stimuli⁴. The stimuli were videotaped dynamic events that depicted a female signer producing a two-handed symmetrical sign in front of her torso (i.e., neutral space). The habituation event depicted the signer slowly lifting her hands up from her lap and producing the ASL sign, <FINISH>. This sign was produced twice in rapid succession to ensure that infants had sufficient exposure to the sign. As she produced the sign, the signer raised her eyebrows while signing, which is a grammatical marker in ASL used to indicate a yes/no question.

Test events were created that depicted novel signs in which one parameter differed from the habituation sign. More specifically, these novel signs depicted a change in handshape, location or movement while maintaining the other parameters in the habituation sign. Each novel sign was based on an actual ASL sign but was modified slightly to ensure that only the relevant parameter differed from the habituation sign. In the *novel handshape* event, the signer's hands changed from all of the fingers being extended (open 5-hand) to where only the thumb and pinky finger were extended (Y-hand). This change yielded a sign that resembled the ASL sign for <PLAY>, yet differed slightly in that the Y-hands faced out instead of down (Sternberg, 1998). Because the ASL sign for <PLAY> presented a change in more than one parameter (i.e., handshape and palm orientation), this modified version was used instead.

The *novel location* event depicted the sign <FINISH> produced above the signer's forehead instead of in neutral space. This sign resembled the ASL sign for <GREAT>. However, this modified sign differed in movement slightly from the actual ASL sign for <GREAT>, which is typically articulated by having the hands

⁴ Representative examples of the stimuli are presented because the signer did not grant her permission for us reproduce her videotaped image, thus we have used a different signer to exemplify the videotaped dynamic events.

move up and out (Sternberg, 1998). The *novel movement* event depicted a change in the rotating-type movement used in the <FINISH> sign to, instead, having the hands in closed fists, and then quickly opening and extending the fingers, similar to the ASL sign, <MANY> (Sternberg, 1998). For the *novel facial expression* event (hereafter, novel expression), the only change was that the signer presented <FINISH> with a furrowed brow rather than raised eyebrows.

In order to determine the extent to which the modified signs varied from the actual ASL signs, four Deaf native signers rated the modified ASL signs on a 1 (unrecognizable) to 5 (native-like) scale. The habituation sign <FINISH> received an average rating of 4.6, the *novel movement sign*, <MANY> received an average rating of 4.4, and the *novel handshape sign*, <PLAY> and *novel location sign*, <GREAT> received average ratings of 2.3. Hence, <FINISH> and <MANY> were more native-like in their articulation, whereas <PLAY> and <GREAT> were sufficiently modified so that they only resembled the actual ASL signs. Although these modifications reduced the ecological validity of the ASL signs, they allowed us to increase the internal validity to pinpoint the basis of infants' discrimination of each parameter.

For both the habituation and test events, the signs were produced twice rapidly with a 1/2-second pause between each presentation before the signer returned her hands to her lap. This double presentation was looped 10 times without pauses to create a 30-second trial.

Apparatus. Infants were seated on their parent's lap approximately 127 cm from a 20-inch computer monitor. Below this monitor was a camera that was connected to another monitor and VCR in an adjoining room, where an experimenter observed and recorded the infants' looking times during the habituation and test trials.

Example of Habituation and Familiar Test Event - ASL Sign <FINISH>



Example of Novel Handshape Test Event - ASL Sign <PLAY>



Example of Novel Movement Test Event - ASL Sign <MANY>



Example of Novel Location Test Event - ASL Sign <GREAT>



Figure 2.1 Representative Photograph Examples of the Dynamic Events Presented for the Habituation and Test Trials

The presentation and recording of each trial was done using G5 Macintosh computer and Habit 2000 software (Cohen, Atkinson, & Chaput, 2000).

Procedure. After parental consent was obtained, the infant and their parent were seated in the testing room. Parents were asked to remain silent and neutral during the testing session. From the adjoining room, an experimenter depressed a key on the computer to begin the testing session. Prior to each trial, an attention-getter (a green chiming expanding circle) was used to focus the infant's attention. Once the infant's attention was focused on the monitor, the experimenter depressed a key to begin a trial. To record looking time, the experimenter held down a key for as long as the infant attended to the trial. A trial played until the infant either looked away for more than 1-second or until the 30-second trial ended.

Pretest & Habituation Phase. The pretest trial (a hand moving a stuffed pig) was presented first to introduce the procedure. After the pretest, the habituation phase began. During habituation, infants viewed the signer producing the sign <FINISH>. The habituation criterion was met when an infant's looking time across three habituation trials decreased by 50% from the first three habituation trials. Habituation trials ended when this criterion was met or when 20 habituation trials had been presented.

Test Phase. Following habituation, infants viewed five test trials. One familiar trial presented the same event seen during habituation (i.e., the sign <FINISH>), and four trials presented a novel handshape, a novel movement, a novel location, or a novel expression. The presentation order of the five test trials was counterbalanced across participants. An independent observer coded the looking times of eight randomly chosen infants from the recorded sessions, yielding an inter-rater reliability of .996 (range = .989 - .999).

Results

To ensure that infants did not meet the habituation criterion as an artifact, an analysis was conducted comparing infants' average looking time during the first three habituation trials to the familiar test event (i.e., habituation event). A 2 (Age: 6 months, 10 months) by 2 (Sex: males, females) by 2 (Trials: average of first three habituation trials, familiar test trial) mixed-model analysis of variance (ANOVA) was conducted and revealed a significant main effect of Trials, $F(1, 23) = 67.21, p < .001, \eta_p^2 = .75$. Infants looked significantly longer at the habituation event during the first three trials of habituation ($M = 18.5$ s, $SD = 6.7$ s) than at the same event when it was presented as a test trial ($M = 6.2$ s, $SD = 3.2$ s). No other significant main effects or interactions emerged, all p 's $> .05$.

Table 1 presents infants' mean looking times and standard deviations to each event during the test trials. To address whether infants discriminated each novel event from the familiar test event, a 2 (Age) by 2 (Sex) by 5 (Test Event: familiar, novel handshape, novel movement, novel location, novel expression) ANOVA was conducted. Simple contrasts revealed that infants looked significantly longer at the *novel location* event relative to the familiar event, $F(1, 23) = 11.76, p < .01, \eta_p^2 = .34$. That is, infants looked significantly longer at the sign when it was produced above the head rather than in its familiar location in neutral space. Infants also discriminated between the *novel expression* with the furrowed brow and the familiar expression with the raised eyebrows, $F(1, 23) = 4.94, p < .05, \eta_p^2 = .18$, although the effect size for this result was small. However, infants did not provide evidence of discriminating between the *novel handshape* event and the familiar event, $F(1, 23) = 3.10, p > .05, \eta_p^2 = .12$ nor between the *novel movement* event and the familiar event, $F(1, 23) = 2.55, p > .10, \eta_p^2 = .09$. No other significant main effects or interactions emerged, all p 's $> .05$.

Table 1 Mean Looking time (in seconds) and Standard Deviations to the Two-Handed Sign Test Events as a Function of Age			
<i>Test Event</i>	<i>6-month-olds</i>	<i>10-month-olds</i>	<i>Total Sample</i>
Familiar	5.96 (3.69)	6.50 (2.81)	6.20 (3.27)
Nov. Handshape	8.73 (7.02)	8.01 (3.63)	8.41 (5.68)
Nov. Movement	7.60 (5.02)	9.33 (6.97)	8.37 (5.91)
Nov. Location	10.15 (6.74)	15.45 (10.89)	12.5 (9.05)
Nov. Expression	9.19 (7.22)	9.76 (5.95)	9.44 (6.57)

Discussion

The current study demonstrated that when ASL-naïve hearing six- and ten-month-olds were habituated to a two-handed symmetrical sign and tested with signs that varied in only handshape, location, movement, or facial expression, they detected the change in location and facial expression. Specifically, infants detected the change from a raised brow to a furrowed brow. Infants were especially attentive to the change in the location from the sign <FINISH>, articulated in front of the signer’s torso, to the sign <GREAT>, articulated above the signer’s head, a result that yielded a stronger effect relative to that obtained for the change in facial expression. However, infants did not provide evidence of detecting the changes in handshape (open 5-hand vs. Y-hand) or movement (<FINISH> vs. <MANY>).

The present results are consistent with previous findings on children’s early production errors in ASL. For instance, Wilbur and Jones (1974) report that hearing infants exposed to ASL from birth typically produce their first signs in the correct

location but with incorrect handshapes and movement. Likewise, Bonvillian and Siedlecki (2000) found that children in their longitudinal study produced signs in the correct location 84% of time, with the correct movement and handshape, 61% and 50% of the time, respectively. Conlin et al. (2000) contend that these early production errors are due to developing motor abilities that constrain children's ability to produce particular types of signs or parameters correctly. However, the findings from the current study provide some support for the suggestion that young children's errors in the production may not be solely a function of their inability to produce certain parameters accurately, but also a function of their ability to *perceive* certain parameters accurately (Bonvillian & Siedlecki, 2000). Hence, the current study lends insight into the specific role perceptual abilities (and not just motor abilities) may play in children's acquisition of a visual-gestural language, like ASL.

But why would some parameters be more perceptually distinct than others? To address whether some parameters are more distinct on a psychophysical basis, we documented the degree to which hearing adults' discrimination of the signs would be similar to hearing infants' discrimination of the signs. We asked 10 hearing adults, who were naïve to any visual-gestural language, to compare each of the novel signs to the sign <FINISH>. Adults rated the similarity of each novel sign to <FINISH> on a scale of 1 (highly similar to <FINISH>) to 5 (low similarity to <FINISH>). Adults rated the sign <MANY> (i.e., the change in movement) as most different ($M = 4.1$, $SD = .71$), but also rated the sign <GREAT> (i.e., the change in location, $M = 3.3$, $SD = 1.74$) and the sign <PLAY> (i.e., the change in handshape, $M = 3.1$, $SD = .86$) as being fairly different from <FINISH>. In contrast, the raised versus furrowed eyebrows were rated as highly similar ($M = 1.3$, $SD = .48$). Therefore, adults viewed the change in movement as the most different, the change in location and handshape to be equally different, and considered the change of face to be the least salient

change. Interestingly, the adult ratings of the perceptually similarity between ASL signs (i.e., parameters) are different than what the infants' were able to perceptually discriminate. Recall, that the infants did not demonstrate that they detected the change in movement, which was the most perceptually dissimilar parameter for the adults. In addition, infants did discriminate the change in location but did not discriminate the change in handshape whereas the adults indicated that both of these parameters were equally different from the sign <FINISH>. Lastly, the infants did discriminate the change in facial expression whereas the adults rated this change as the least perceptually distinct. Hence, ASL-naïve infants appear to perceive ASL parameters differently than ASL-naïve adults, indicating that in infancy, the discrimination of ASL signs may be more than just a psychophysical ability.

Another reason that some parameters may be more perceptually distinct than others for the infant may have had to do with the specific signs selected. The rapid “flicking-type” motion (i.e., outward rotation of the wrists and hands) of the sign may have made it more difficult for infants to attend to changes in movement, since there was such a high degree of motion with both hands. The previous studies that have examined infants' sensitivity to ASL movement contrasts used one-handed ASL signs (Carroll & Gibson, 1986; Schley, 1991) and not two-handed signs as in the current study. Therefore, infants' sensitivity to movement contrasts may vary depending of the number of hands articulating the sign or alternatively, the specific two-handed sign presented, a possibility not tested in the present study. In addition, the changes in location may have been more perceptually salient regardless of the increased motion of the hands, because the degree of change in location from the sign, <FINISH> to the sign <GREAT> was larger (in front of the signer's torso v. up over the signer's head), than the changes in movement or handshape. These explanations remain to be tested with studies that vary not only the number of hands used to articulate the sign, but

also in the degree of change in each parameter.

Another possible explanation as to why the novel location sign (i.e., <GREAT>) was perceptually distinct for infants is that it deviated much more from its corresponding ASL sign compared to the novel movement and novel handshape signs and their corresponding ASL signs (i.e., <MANY> and <PLAY>, respectively) as rated by the Deaf native signers. This raises the concern that the infants' discrimination between the habituation sign <FINISH> and the novel location sign, <GREAT> is due to a spurious stimulus difference. Although possible, this explanation is unlikely for the following reasons. First, all of the infants were naïve to ASL, which eliminated the likelihood that they were using as a basis of comparison the difference between the created novel location sign used in the study and the actual ASL sign <GREAT>. Therefore, even though the Deaf native signers rated this created novel location sign as being less native-like compared to the other created signs used in the study, the ASL-naïve infants could not have been influenced by this deviation. Secondly, the ratings from the ASL-naïve hearing adults also suggest that infants' ability to discriminate the change in location was not due to a spurious stimulus difference

The current finding that infants were sensitive to the ASL contrasts articulated on the face (raised vs. furrowed brow) is not surprising in that faces, in general, are salient for young infants. Research has demonstrated that infants, as young as 23 hours, are able to discriminate between various facial expressions (Walker-Andrews, 1997). Thus, not only are hearing infants able to use their perceptual abilities in order to acquire their ambient language, but also are able to use these abilities to detect changes in ASL contrasts articulated on the face, a grammatical distinction not used in English (Reilly, McIntire, & Bellugi, 1991). However, it is important to consider that the effect size for this result was small, indicating that this change may not have been

as salient for the infants as the change in location.

The findings from the current project underscore that infants were able to recruit their perceptual abilities to detect changes in certain ASL parameters. This ability provides the building blocks necessary to acquire a visual-gestural language, such as ASL. Since the infants in the current study were unfamiliar with ASL, it seems unlikely that they viewed these signs as linguistic, suggesting that infants may have used a more general perceptual mechanism rather than a mechanism specific to language. Finally, there was no evidence to show developmental change between six and ten months in infants' ability to discriminate among the non-native ASL contrasts. Both the six- and the ten-month-olds demonstrated sensitivity to the parameter change of location and grammatical contrasts on the face.

Given that modified rather than actual signs were used, can these findings be used as an indicator of infants' ability to discriminate between the primary parameters of ASL? Increasing the internal validity led to a decrease in the ecological validity of the signs. Nonetheless, the modification of the signs made it possible to assess infants' discrimination of the *specific* changes in handshape, location, or movement. However, the use of modified signs may have made the task slightly more difficult for infants in that they were less naturalistic. On the other hand, if hearing infants are able to discriminate changes in ASL parameters with modified signs, then it is plausible that they can do so with unmodified ASL signs as well. Nevertheless, a task for future research is to document the degree to which the current results are replicable with more naturalistic signs.

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CHAPTER 3

THE UPPER HAND: INFANTS' ABILITY TO DISCRIMINATE BETWEEN ONE-HANDED AMERICAN SIGN LANGUAGE SIGNS

Abstract

We conducted two experiments that directly examined prelingual hearing infants' sensitivity to relevant American Sign Language (ASL) parameters (location, handshape, and movement). In Experiment 1, we also explored infants' sensitivity to an ASL grammatical marker (facial expression). ASL-naïve infants were habituated to a native signer presenting a one-handed ASL sign near the face. During test, infants viewed novel one-handed signs that varied in only one parameter or in facial expression. In Experiment 2, infants were habituated to a one-handed ASL sign near the face and tested with one-handed ASL signs that varied in one, two, and all three parameters. Infants failed to provide evidence of detecting changes in facial expression in Experiment 1. However, across both experiments, infants detected changes in handshape and movement, but did not provide evidence of detecting changes in location.

THE UPPER HAND: INFANTS' ABILITY TO DISCRIMINATE BETWEEN ONE-HANDED AMERICAN SIGN LANGUAGE SIGNS

Infants are universal language learners, equipped and able to acquire their ambient language, whether that language is signed or spoken. To acquire a spoken language, infants must be able to perceive and discriminate between minimal pairs of speech contrasts (e.g., /ba/ vs. /da/ in English, Werker & Tees, 1984). Undoubtedly, to acquire a signed language, infants must also possess the ability perceive and discriminate between sign contrasts. However, there has been very limited research exploring hearing infants' ability to perceive and discriminate between sign contrasts. And thus, the purpose of the current project is to directly examine hearing infants' sensitivity to the relevant contrasts of a signed language, such as American Sign Language (ASL).

Over 30 years of research on hearing infants' speech perception has demonstrated that from birth, infants possess remarkably impressive perceptual sensitivities (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Werker & Yeung, 2005). These perceptual sensitivities are the necessary prerequisites for the acquisition of spoken language. Werker and Yeung (2005) argue that infants' perceptual capabilities ultimately prepare their perceptual system for subsequent speech input from their native language environment. For spoken languages, this input is typically in the form of words. Therefore, infants' perceptual systems must be capable of discriminating between relevant speech sounds and spoken words. However, for signed languages, linguistic input is typically in the form of manual signs. Thus, in order to acquire a signed language such as ASL, infants' must possess a comparable set of perceptual abilities which allow them to visually discriminate between relevant sign contrasts and manual signs (Carroll & Gibson, 1986).

The linguistic properties of ASL are notably similar to the linguistic properties of English (Stokoe, 1960). More specifically, in ASL there are three major formational parameters or “phonemes” which distinguish signs (Stokoe, Casterline, & Croneberg, 1965). These primary parameters⁵ are (1) the *handshape* or way the hands are formed when articulating the sign, (2) the *movement* of the sign, and (3) the *location* or where in the signing space (i.e., signers’ head and torso and extends approximately 12 inches to the left and right sides of his or her body; Sternberg, 1998) a sign is articulated (Klima & Bellugi, 1979; Stokoe, Casterline, & Croneberg, 1965). These parameters comprise minimal pairs or contrasts similar to English. For example, the ASL signs <FATHER>⁶ and <MOTHER> vary in their location, but maintain the same handshape and movement (Poizner, Klima, & Bellugi, 1987). This distinction is analogous to the English words, “bat” and “pat”. Thus, English and ASL are similar in that their “phonologies” involve a sublexical structure and minimal pairs however the two languages differ in the way in which these phonologies are articulated (Emmorey, Borinstein, & Thompson, 2005).

One unique aspect of ASL is that facial expressions are used as grammatical markers (Bettger, Emmorey, McCullough, & Bellugi, 1997). These grammatical facial expressions differ from affective facial expressions, particularly in their timing. Grammatical facial expressions have very distinct onset and offset and are temporally coordinated with specific aspects of the signed communication (Bettger et al., 1997; Reilly, McIntire, Bellugi, 1990, 1991). These facial expressions serve a similar function in ASL as vocal intonation does in English. For example, in English, yes/no questions are typically pronounced with a rising intonation whereas wh-questions are

⁵ *Palm Orientation*, the direction of the palm in relation to the signer’s body (e.g., palm in, palm up, etc.) is another parameter of ASL (Emmorey et al., 2003). However, in the present experiment we attempted to keep palm orientation constant and thus did not examine infants’ discrimination of palm orientation.

⁶ By convention, English glosses for ASL signs are denoted by uppercase letters.

pronounced with a falling intonation, a distinction that is essential for effective communication (Frishberg, 1975). Similarly in ASL, yes/no questions are articulated with raised eyebrows whereas wh-questions are articulated with a furrowed brow (Sternberg, 1998). Attending to these types of distinctions is critical in ASL and English as questions missing the appropriate facial expression or intonation can be easily misinterpreted (Campbell, Woll, Benson, & Wallace, 1999). Although, we know a great deal about infants' sensitivity to vocal tones and intonations (Nazzi & Ramus, 2003; Stern, Spieker, & MacKain, 1982; see also Masataka, 1995) as well as infants' sensitivity to affective facial expressions (Walker-Andrews, 1997), we know substantially less about their sensitivity to the grammatical facial expressions used in ASL.

To successfully process and interpret a signed language like ASL, infants must be able to visually discriminate between the parameters of ASL (e.g., handshape, movement, and location) as well as linguistically relevant facial expressions (e.g., furrowed brow vs. raised eye brow). However, the degree to which experience is required for such visual discrimination is somewhat uncertain. With spoken languages, we know that prelingual infants, younger than 12 months, do not require experience with a spoken language to demonstrate the ability to discriminate between speech contrasts (Nazzi, Jusczyk, & Johnson, 2000; Werker & Tees, 1984, 1999). Intuitively, it seems as though hearing infants' perceptual abilities must provide the necessary foundation required for the acquisition of a signed language, just as their perceptual abilities do for the acquisition of a spoken language (Holmes & Holmes, 1980; Prinz & Prinz, 1979). However, the question remains as to whether these perceptual abilities develop and function in an analogous way for both signed and spoken languages, particularly at the level of sign and speech perception.

To date, very little research has been conducted investigating hearing infants'

ability to discriminate among ASL contrasts (Carroll & Gibson, 1986; Schley, 1991; Wilbourn & Casasola, 2007). Of this research, the majority has studied infant's sensitivity to movement contrasts in ASL. For example, Schley (1991) found that hearing 3.5-month-olds detected changes in the movement of one-handed ASL signs articulated in neutral space (i.e., in front of the torso) when habituated to one particular type of movement (e.g., directional/left-right) and tested with another (e.g., cyclicity). Likewise, Carroll & Gibson (1986) also presented hearing 4-month-olds with one-handed ASL signs, articulated in neutral space, and found that they could discriminate between movement contrasts on the basis of varying dimensions. Infants detected movement changes on multiple dimensions (e.g., ASL sign, <TEN> vs. <OTHER>) as well as on a single dimension (e.g., <LEFT> vs. <LIBRARY>). However, infants did not provide evidence of detecting a change in movement when the sign's movement was repeated and articulated parallel to the infants' line of sign (e.g., <SCOLD> vs. <WHERE>). Although these studies provide compelling evidence that ASL-naïve hearing infants are sensitive to *particular* types of ASL movement contrasts, the findings left open the question of whether ASL-naïve infants are equally sensitive to the other parameters of ASL, namely handshape and location.

To explore this question, Wilbourn and Casasola (2007) examined prelingual infants' ability to discriminate among the ASL parameters of movement, handshape, and location. They also examined infants' ability to detect changes in the signer's grammatically relevant facial expressions (i.e., raised eyebrows vs. furrowed brow). Six- and ten-month-olds were habituated to the two-handed symmetrical (hands mirroring one another) ASL sign, <FINISH>. During test, infants viewed two-handed symmetrical signs that varied in only one parameter (handshape, location, movement) or facial expression. The results demonstrated that infants were able to detect changes in location and facial expression. Interestingly, the infants failed to provide evidence

of detecting changes in handshape and movement.

Although Wilbourn and Casasola (2007) concluded that infants are able to recruit the necessary perceptual abilities to detect changes in the ASL parameter of location and the signer's facial expression, the question of why infants failed to provide evidence of detecting changes handshape and movement remained largely unanswered. Previous research with adults and young children has shown that even for experienced signers, the parameters of handshape (Hamilton, 1986) and movement (Tartter & Fischer, 1982) may be more difficult to perceive than location (Poizner & Lane, 1978). Moreover, research has also demonstrated that handshape may be even more challenging to detect for experienced signers than movement (Hamilton, 1986). For example, Hamilton (1986) found that deaf children between the ages of six and ten years made significantly more errors detecting minimal pairs of ASL signs that varied in handshape than they did when the signs varied in movement or location. This finding is in line with research documenting the types of production errors made by both hearing and deaf children acquiring ASL.

In general, young signers' first signs are typically articulated in the correct location but with incorrect handshapes and movement (Bonvillian & Siedlecki, 2000; Wilbour & Jones, 1974). With regard to handshape in particular, Siedlecki and Bonvillian (1993) contend that although children's motoric constraints may play a role in these types of production errors (Conlin, Mirus, Mauk, & Meier, 2000), the possibility that these errors are attributable to children's difficulty in *perceiving* ASL handshapes cannot be overlooked. Hence, infants' early perceptual sensitivities may play a significant role in their subsequent production of ASL.

While it is possible that changes in location (Poizner & Lane, 1978) and facial expression (Walker-Andrews, 1997) are less challenging to detect than changes in handshape (Bonvillian & Siedlecki, 2000) and movement (Emmorey & Corina, 1990),

it is unclear as to why the ASL-naïve infants in the Wilbourn and Casasola (2007) study failed to detect changes in movement of the ASL signs when previous research has reported that infants are particularly sensitive to ASL movement changes (Carroll & Gibson, 1986; Schley, 1991). Wilbourn and Casasola (2007) noted that an important distinction between their study and previous work is that their study used two-handed symmetrical signs articulated in neutral space, whereas Carroll and Gibson (1986) and Schley (1991) used one-handed signs articulated in neutral space. Therefore, infants' ability to discriminate between particular types of movement contrasts, in addition to the parameters of handshape and location, may depend on the number of hands used to articulate the signs, a possibility not directly tested in previous research (Carroll & Gibson, 1986; Schley, 1991; Wilbourn and Casasola, 2007).

Another important factor that may significantly affect infants' abilities to discriminate between particular ASL parameters is where in the signing space signs are articulated. Emmorey and Corina (1990) found that deaf adults identified ASL signs significantly faster if they were articulated in neutral space as opposed to near the face. They also discovered that deaf adults were more accurate in their articulation of particular parameters over others (e.g., correct location but with incorrect movement) depending on where the signs were articulated in the signing space. Thus, it is possible that ASL-naïve infants' perceptual sensitivities vary depending on where the signs are articulated.

To assess infants' perceptual sensitivities to particular types of ASL signs, the current set of experiments were conducted. In particular, we sought to investigate ASL-naïve infants' perceptual sensitivities to one-handed ASL signs articulated near the face. We chose one-handed signs that were articulated near the face because (1) children's early signs are likely to be articulated by the face (Conlin et al, 2000) and

(2) previous research has investigated both one-handed (Carroll & Gibson, 1986; Schley, 1990) and two-handed signs (Wilbourn & Casasola, 2007) in neutral space and found somewhat conflicting results.

In Experiment 1, we tested six- and ten-month-old ASL-naïve infants' ability to discriminate between each of the ASL parameters as well as grammatical facial expressions using the same habituation paradigm as Wilbourn and Casasola (2007). In the current experiment, we used a within subjects design in which all infants were habituated to the same base sign (i.e., <FORGET>) and were tested with modified ASL signs that varied in only parameter or facial expression. We chose a within subjects design to allow for a direct comparison with the findings of Wilbourn and Casasola (2007). Yet, in choosing this type of research design there was an important trade off between increasing the internal validity and decreasing the ecological validity. Due to the fact that ASL signs tend to differ along more than one parameter (e.g., both handshape and movement), it was not possible to find one-handed ASL signs that allowed for minimal contrasts along each parameter from a base sign. For this reason, the signs used in this experiment were derived from actual ASL signs, but were sufficiently modified to allow for minimal pair contrasts varying only one parameter. Also similar to Wilbourn and Casasola (2007), a non-native signer was used to present these modified signs.

Bearing in mind that both of these factors (i.e., modified signs, non-native signer) may have made the task more challenging for infants due to the artificial nature of the sign presentations, we conducted a second study in order to reduce the effects of these potential confounds. In Experiment 2, a native signer was used to present unmodified ASL signs to ASL-naïve infants. In order to use unmodified signs, we had to utilize a between-subjects design where infants were placed in different groups and each group viewed a different base sign. Infants were then tested with

varying signs that changed either one, two or all three parameters.

Experiment 1

To directly assess ASL-naïve hearing infants' ability to discriminate between minimal pairs of one-handed signs articulated near the face, we tested six- and ten-month-olds using the same habituation paradigm as Wilbourn and Casasola (2007). We chose six- and ten-month-old hearing infants in order to explore potential developmental changes in the infants' sign perception abilities, since these particular age groups have been previously shown to differ in their speech perception abilities (Werker & Tees, 1984, 1999). All infants were habituated to the same one-handed base sign articulated near the face, derived from the ASL sign, <FORGET>. This modified sign was articulated on the signer's forehead and was presented with the signer's eyebrows raised, denoting a yes/no question in ASL (Klima & Bellugi, 1979). Infants were tested with one-handed signs articulated near the face that varied in location, movement, handshape, or facial expression. If the number of hands used to articulate the sign plays a significant role in infants' ability to discriminate between each ASL parameter than we would expect that infants will, at the least, detect changes in movement similar to the infants in the Carroll & Gibson (1986) and Schley (1991) studies and in contrast to the infants the Wilbourn & Casasola (2007) study with two-handed signs.

Method

Participants. The participants were recruited with a letter given to parents at the time of their infant's birth. Parents were subsequently contacted when the infant was within the appropriate age range. The final sample consisted of 13 infants (8 females) between the ages of 5.5 and 6.5 months ($M = 27.2$ weeks, $SD = 4.5$ weeks) and 12 infants (6 females) between the ages of 9.5 and 10.5 months ($M = 27.2$ weeks, $SD = 4.5$ weeks). Inclusion criteria were that infants were least 37 weeks gestational

age, of normal birth weight, had no reported history of visual or auditory problems and no previous exposure to “baby signs” or a visual-gestural language. Nine (five 6-month-olds, four 10-month-olds) additional infants were excluded from the final analyses for the following reasons: 2 six-month-olds failed to reach the habituation criteria, 2 six-month-olds and 2 ten-month-olds did not complete the testing session due to fussiness, and 1 six-month-old and 2 ten-month-olds demonstrated extreme (+2 SD) looking times to the familiar test event, indicating that they may not have truly habituated. All infants were given a small toy, book, or baby t-shirt in appreciation for their participation in the study.

Stimuli. The habituation trial and test trials were videotaped events of a non-native female signer, who was filmed, from the waist up, sitting against a white background and wearing a dark turtleneck sweater. Figure 3.1 depicts representative examples of the videotaped events⁷. For the habituation event, the signer slowly raised her right hand, palm facing inward, towards the left side of her forehead. She then quickly moved her hand laterally towards the right side of her forehead while closing the palm into a fist, producing a sign which is similar to the ASL sign for <FORGET> (Sternberg, 1998). This sign was presented with the signer’s eyebrows raised, indicative of a yes/no question in ASL.

Test events were created to present a change in only the handshape, location, movement or facial expression of the habituation sign. In the *novel handshape* event, the signer extended only her index finger on her forehead, similar to the ASL sign for <BLACK>, rather than extending all five fingers as she did in the habituation sign, <FORGET> (Sternberg, 1998). In the *novel location* event, the sign was produced over the woman’s mouth, just under her nose similar to the ASL sign, <BETTER>

⁷ Representative examples of the stimuli are presented because the signer did not grant permission for her videotaped image to be reproduced, thus we have used a different signer to exemplify the videotaped dynamic events.

instead of on her forehead as she did in the habituation sign (Sternberg, 1998). In the *novel movement* event, the sign started at the woman's forehead with the palm facing inward. Rather than move her hand laterally as she did in the habituation sign, instead, the woman quickly raised her hand directly above her head (see Figure 3.1). This sign was created to vary only the movement of the sign and simultaneously maintain the location and the handshape and thus, does not resemble an actual ASL sign. Finally, in the *novel facial expression* event (hereafter *novel expression*), the woman furrowed her eyebrows while articulating the habituation sign, <FORGET> instead of raising her eyebrows. All of these signs were articulated twice before the woman returned her right hand back to her lap. Each event was looped 6 times to create a 28 second trial. Hence, each sign was presented 12 times per trial.

The modified signs were rated by an independent sample (N = 4) of deaf native signers on a scale from 1 (unrecognizable) to 5 (native-like sign). On average, the habituation sign <FORGET> was rated 3.9, the sign <BLACK> was rated 3.8, the sign <BETTER> was rated 3.4, and the nonsense gesture received rating of 1.6. Hence, all of the signs, with the exception of the nonsense gesture, were rated as recognizable as ASL signs.

Apparatus. Infants were tested in a 3 m x 3 m experimental room that contained a chair situated 127 cm away from a 20-inch color monitor. A black wooden frame designed to reduce distraction enclosed this monitor. Approximately 22 cm below the monitor was a 9-cm circular opening in the wooden frame for the lens of a Panasonic video camera.

Example of Habituation Trial and Familiar Test Trial

Derived from the ASL sign <FORGET>



Example of Test Trials

Derived from the ASL sign <BLACK> – change in Handshape



Derived from ASL sign <BETTER> – change in Location



Example of created sign – change in Movement



Figure 3.1 Representative Photograph Examples of the Dynamic Events Presented for the Habituation and Test Trials

This camera was connected to a 15-inch monitor and Panasonic VCR in an adjoining control room. The camera, monitor, and VCR were used to record infants' online looking time to each event during a trial. A specially designed software program, Habit 2000 (Cohen, Atkinson, & Chaput, 2000), was used to present the events to the infants and record online infants' looking time during the testing session.

Procedure. Once parental consent was obtained, the infant and his or her parent were seated in the experimental room. The parent was asked to remain neutral and quiet throughout the testing session. In the adjoining control room, the experimenter depressed a key on the computer to begin the testing session. Prior to each trial, an attention-getter, a green chiming expanding circle was used to focus the infant's attention to the monitor. Once an infant directed their attention to the monitor, the experimenter depressed a different key to begin a trial. To record looking time during each trial, the experimenter held down a key on the keyboard for as long as the infant attended to the trial. A trial played until the infant either looked away for more than 1 continuous second or until the 28 s trial ended.

The first trial of the experimental session was a pretest trial that presented the event with the stuffed animal and was used to introduce infants to the testing procedure. Following this pretest, the habituation phase of the experiment began in which infants viewed the signer producing the habituation sign, <FORGET>. The habituation criterion was met when an infant's looking time across a block of three habituation trials decreased by 50% from the first three trials of habituation. The habituation trials ended when this criterion was met or when a maximum of 20 habituation trials had been presented. Infants then viewed five test trials. One test trial presented the same event seen during habituation (i.e., <FORGET>). The four additional trials presented test events that depicted a change in the handshape,

location, movement, or facial expression from the habituation event. The order of presentation of the five test trials was counterbalanced across participants. A second observer recorded the looking times of 6 randomly chosen infants off-line. The average correlation between on-line and off-line looking times was .996 (range = .987 - .999).

Results

For all statistical analyses, infants' looking times (in seconds) were converted to Log_{10} transformations to normalize the data (Neter, Kutner, Nachtsheim & Wasserman, 1996). However, for ease of interpretation the looking time scores (in seconds) for all of the transformed data are presented. The first analysis examined infants' looking times during the average of the first three habituation trials and the familiar test event in a 2 (Age: 6 months vs. 10 months) x 2 (Sex: males vs. female) x 2 (Trials: average of the first three habituation trials vs. the familiar test event) mixed-model analysis of variance (ANOVA). This analysis yielded a significant main effect for Trials, $F(1, 20) = 110.45, p < .001, \eta_p^2 = .85$. Infants looked significantly longer at the habituation event during the beginning of habituation ($M = 16.08$ s, $SD = 5.66$ s) than when this event was presented as the familiar test event ($M = 5.65$ s, $SD = 2.86$ s). Hence, infants demonstrated a significant decrease in looking time to the event from the time that they began the habituation phase to the time that they viewed this event during the test. No other significant main effects or interactions emerged.

Analyses of Looking During Test Events: Simple Contrasts. The next analysis examined infants' looking times during the test phase. Infants' looking time was examined in a 2 Age by 2 Sex by 5 (Test Event: familiar vs. novel handshape vs. novel location vs. novel movement vs. novel expression) mixed-model ANOVA. Simple contrasts comparing each novel test event to the familiar test event indicate that infants looked longer at the *novel handshape* ($M = 9.32$ s, $SD = 7.05$ s) than at the

familiar test event ($M = 5.65$ s, $SD = 2.86$ s), $F(1, 20) = 4.34$, $p = .05$, $\eta_p^2 = .18$. It is important to note that the pattern of results suggest that the change in handshape was more salient to the 10-month-olds than the 6-month-olds although a significant Age by Test Event interaction did not emerge.

Infants did not look significantly longer at the *novel location* event ($M = 7.87$ s, $SD = 6.10$ s) relative to the familiar event, $F(1, 20) = 1.79$, $p > .20$, $\eta_p^2 = .08$. For the *novel movement* event, a significant main effect of Test Event, $F(1, 20) = 7.10$, $p < .02$, $\eta_p^2 = .26$, was qualified by a significant Test Event by Age interaction for infants' looking time to the novel event relative to the familiar event, $F(1, 20) = 7.36$, $p < .02$, $\eta_p^2 = .27$. As can be seen in Figure 3.2, the 6-month-old infants did not demonstrate as much of an increase in looking time to the *novel movement* event ($M = 7.12$ s, $SD = 5.39$ s) relative to familiar test event ($M = 6.80$ s, $SD = 2.80$ s) as the 10-month-old infants ($M = 10.76$ s, $SD = 5.95$ s; $M = 4.28$ s, $SD = 2.37$ s, respectively).

For the *novel expression* event, there was a significant interaction between Test Event, Age, and Sex, $F(1, 20) = 5.37$, $p < .05$, $\eta_p^2 = .21$. Specifically, for the comparison of looking times to the *novel expression* event, the 10-month-old females looked longer ($M = 7.74$ s, $SD = 3.59$ s) than the 10-month-old males ($M = 3.75$ s, $SD = 2.31$ s). However, the 6-month-old females looked less ($M = 5.88$ s, $SD = 2.64$ s) than the 6-month-old males ($M = 7.54$ s, $SD = 7.05$ s). For the familiar test event, female infants of both ages ($M = 4.76$ s, $SD = 2.90$ s for 10 months, $M = 7.64$ s, $SD = 3.02$ s for 6 months) looked longer than male infants of both ages ($M = 3.45$ s, $SD = .68$ s for 10 months, $M = 5.46$ s, $SD = 1.98$ s). The analysis did not yield any other significant effects or interactions.

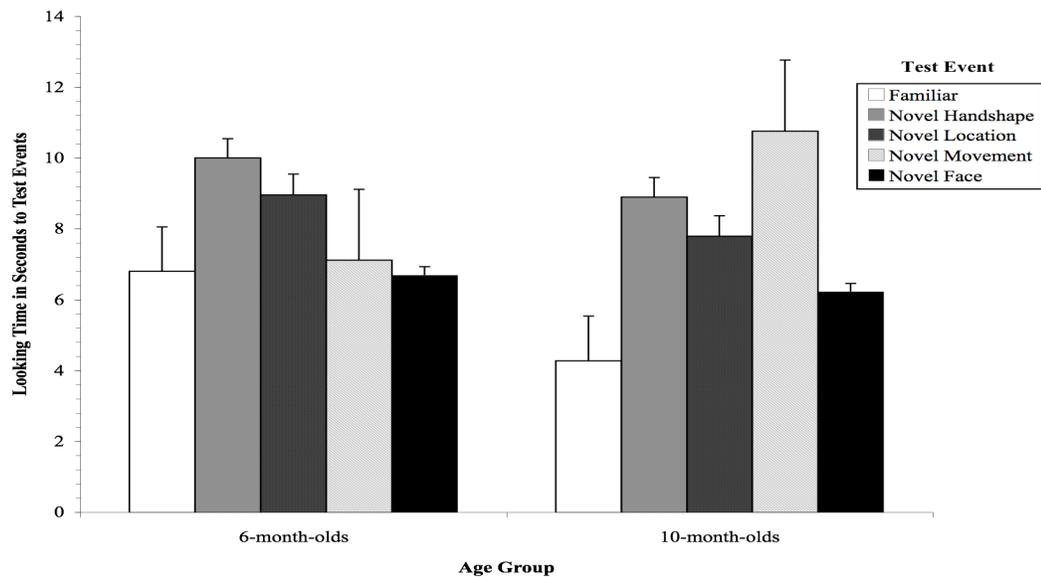


Figure 3.2 Mean Looking Times (in seconds) and Standard Errors to Test Events as a Function of Age

Discussion

When habituated to a one-handed sign articulated near the face (i.e., <FORGET>), ASL-naïve hearing infants discriminated a change in handshape. They looked significantly longer at the test event that presented the novel handshape with only the index finger extended rather than the open palm hand with all fingers extended. Infants also discriminated between the familiar movement of the hand moving across the forehead and the novel movement of the hand moving vertically above the forehead, replicating the findings of Carroll and Gibson (1986) and Schley (1991). However, the looking behavior of the 10-month-olds revealed that this change was particularly salient for this age group.

Infants provided no evidence of detecting the change in where the sign was articulated (i.e., the location). Specifically, infants' did not look significantly longer to the sign produced across the mouth versus across the forehead. Finally, infants

provided no evidence of discriminating the change in facial expression from the raised eyebrows to furrowed eyebrows.

The latter two findings are in contrast to the findings of Wilbourn and Casasola (2007), when infants were exposed to two-handed symmetrical signs articulated in neutral space. Recall that Wilbourn and Casasola (2007) found that infants were able to detect changes in location and facial expression, but not handshape and movement. However, infants in the current study did discriminate the changes in handshape and movement, but not location or facial expression. The finding that these infants were sensitive to the changes in movement is in line with the findings of previous research that used one-handed ASL signs (Carroll & Gibson, 1986; Schley, 1991), although those signs were articulated in neutral space. Therefore, it appears that (1) the number of hands used to articulate signs in addition to (2) where in the signing space (i.e., near the face versus in neutral space) signs are articulated plays a major role in infants' ability to detect changes in particular ASL parameters.

Caution must be used when interpreting the findings of the current study because modified and created signs were used and articulated by a non-native signer, making it difficult to generalize the infants' behavior in the current study to how infants may initially perceive actual ASL signs in a more naturalistic setting. Although each of the modified signs, with the exception of the created novel movement sign, was rated as recognizable by the independent sample of native signers, the modifications made in order to assess infants' discrimination abilities of *particular* changes in the parameters nonetheless affect the generalizability of the findings. Thus, the utilization of a within-subjects design allowed for more experimental control and internal validity, however decreased the ecological validity of the study. It is plausible that since infants were able to discriminate between some of the ASL parameters with these modified signs, they would equally likely be able to

discriminate between the parameters with naturalistic ASL signs as well. To test this possibility, we used a between-subjects design with stimuli created with a native signer articulating unmodified ASL signs for Experiment 2.

The lack of evidence that infants' were able to detect changes in facial expression may be attributable to where near the face the signs were articulated in the current study. Recall that when ASL-naïve infants are presented with two-handed signs articulated in neutral space, they detected changes in grammatical facial expressions (Wilbourn & Casasola, 2007). However in the current study, infants failed to provide evidence of detecting changes in the signer's facial expressions. This is particularly puzzling since previous research on face perception has demonstrated that infants, as young as 23 hours, have demonstrated the ability to discriminate facial expressions (Walker-Andrews, 1997). One possibility is that since the base sign, <FORGET> was articulated with the signer's hand sweeping across her forehead, this presentation obscured her raised brows. This obstruction may have ultimately not allowed the infants to notice the change when the eyebrows were furrowed in the novel expression test trial. In addition, the unexpected, and possibly spurious differences between six- and ten-month males and females in their overall looking at the novel expression event suggests that the expressions on the signer's face may have been more distracting than informative. Therefore, in Experiment 2, we opted not to include grammatical facial expressions as a measure of interest.

Furthermore, the finding that 10-month-olds found the movement change significantly more salient than did the 6-month-olds cannot be attributed to experience with ASL since neither group had been previously exposed to a visual-gestural language or sign-accompanied speech (e.g., Baby Sign). However, research on infants' perception of motion, unrelated to ASL, may provide some insight into this finding. Although previous research has shown that infants are particularly sensitive

to motion events, Rakison and Poulin-Dubois (2002) found that there were developmental changes in infants' ability to process dynamic motion events with older infants demonstrating more perceptual sensitivities compared to younger infants.

Specifically with 6-month-olds, Leslie (1982) found that when they viewed a hand removing an object from the right side of the screen, infants failed to detect the change when the hand removed the object from the left, indicating that they were not yet as sensitive to changes in the direction of movement. In the current experiment the sign pairs that contrasted movement comprised the base sign <FORGET>, which depicted the hand moving across the signer's forehead from right to left, contrasted with a created novel sign that depicted the hand moving up off of the forehead. This subtle change in movement may have been more salient for the 10-month-olds than the 6-month-olds as a function of visual experience with motion events, a consideration that warrants additional research. Since the remainder of the findings did not reveal any other relevant developmental changes, it is difficult to pinpoint what may be specifically responsible for these developmental changes. As a result, we made the decision in Experiment 2 to focus on the abilities of ASL-naïve hearing 6-month-olds.

Also in Experiment 2, we felt it was important to examine infant's sensitivity to the *degree* of change between the ASL parameters. Since actual ASL signs often vary in more than one parameter, we sought to directly assess infants' discrimination abilities in terms of (1) the number of parameter changes and (2) which parameter or combinations of parameters change. Exploring infants' sensitivities to ASL parameters using this level of detail allowed for us to pinpoint the specific factors that play a role in infants' ability to detect changes among ASL signs. For example, the actual parameters themselves may not be driving infants' perception but rather the

amount of change (e.g., 2 parameters or more) may determine infants' detection regardless of which parameter changes.

Experiment 2

In this experiment, infants were tested in one of three conditions: *Handshape Change*, *Location Change*, or *Movement Change*. In each condition, infants were habituated to a female native signer articulating a one-handed ASL sign near her face. After habituation, infants were tested with three novel one-handed signs that also were articulated near the face: (1) one sign depicted a change in only one parameter, while maintaining the two other parameters, (2) another sign depicted changes in two parameters, and (3) a final sign depicted a change in all three parameters. These incremental changes in the number and combination of parameter changes were done in an attempt to pinpoint the degree to which certain types of parameter changes were more or less salient to ASL-naïve infants.

Methods

Participants. Participants were recruited and compensated in the same manner as in Experiment 1. Infants that participated in Experiment 1 did not participate in Experiment 2. All infants were at least 37 weeks gestational age, of normal birth weight, and had no report of visual or auditory problems. None of the infants had been previously exposed to sign-accompanied speech or any visual-gestural language.

The final sample consisted of 37 infants (20 females) of six months of age ($M = 25.8$ weeks, $SD = 1.5$ weeks). For Experiment 2, we collected demographic data from the parent(s) which revealed that the participants were primarily from highly educated Caucasian families (65%) with approximately 25% of the parents holding graduate degrees, 41% with college degrees, and 11% of parents having at least some college experience. Sixteen additional six-month-olds were tested but were excluded from the final analyses for the following reasons: ten infants did not reach the

habituation criteria (described below), two infants did not finish the testing session, three demonstrated extreme looking times (+2 SD), after the data were Log_{10} -transformed, across two or more test trials including the familiar test trial, indicating that they had not sufficiently habituated and one infant had an experimenter error during the testing session.

Stimuli. The stimuli were videotaped dynamic events of a native female signer producing a one-handed ASL sign on her face. Similar to Experiment 1, the signer was filmed from the waist up so that her face and hands could be filmed at close range. All of the events depicted the signer slowly lifting her right hand up from her lap towards her face.

For the *Handshape Change* condition (hereafter *Hand-Chg*, so-called because in each novel test event there is at a minimum, a change handshape), the habituation event depicted the signer presenting the ASL sign, <HOME> (i.e., flat-O handshape moves from the mouth to the temple; Sternberg, 1998). Three test events were created for this condition. One test event depicted the signer presenting the ASL sign, <YESTERDAY> (i.e., Y-hand handshape moves from the mouth to the temple), which maintained the location and movement of the habituation sign <HOME> but varied the handshape. Another test event depicted the signer presenting the ASL sign, <TOMORROW> (i.e., the A- handshape is placed on the chin and is twisted forward out in front of the face), which maintained location of the habituation sign, but varied the handshape and movement. A third test event depicted the signer presenting the ASL sign, <SUMMER> (i.e., the index finger slides from left to right across the forehead and bends to represent wiping sweat away from the forehead), which varied the location, handshape, and movement of the habituation sign. See Figure 3.3 for photographs of the stimuli for this condition.

Habituation Event for *Handshape Change* Condition

ASL sign - **HOME**



Test Events for *Handshape Change* Condition

ASL sign - **YESTERDAY** - change in Handshape



ASL sign - **TOMORROW** - change in Handshape & Movement



ASL sign - **SUMMER** - change in Handshape, Movement, & Location



Figure 3.3 Photographs of the Dynamic Events Presented for the *Handshape Change* Condition for the Habituation and Test Trials

For the *Location Change* condition (hereafter *Loc-Chg*, so-called because in each novel test event there is, at a minimum, a change location), the habituation event depicted the signer presenting the ASL sign, <DRY> (i.e., the index finger slides from

left to right across the chin; Sternberg, 1998). Again, three test events were created for this condition. One test event depicted the signer presenting the ASL sign, <SUMMER>, which maintained the handshape and movement of the habituation sign, <DRY> but varied the location. Another test event depicted the signer presenting the ASL sign <FORGET> (i.e., the hand with fingers extended slides from left to right across the forehead), which maintained movement of the habituation sign, but varied the handshape and location. A third test event depicted the signer presenting the ASL sign, <FLOWER> (i.e., the flat-O handshape moves from the right side of the nose to the left side of the nose), which varied the location, handshape, and movement of the habituation sign. See Figure 3.4 for photographs of the stimuli for this condition.

For the *Movement Change* condition (hereafter *Move-Chg*, so-called because in each novel test event there is at a minimum a change in the parameter of movement), the habituation event depicted the signer presenting the ASL sign, <REALLY> (i.e., the index finger is upright at mouth and moves straight forward from the mouth). Three test events were created for this condition. One test event depicted the signer presenting the ASL sign, <HEARING> (i.e., the index finger is lateral and moves in circular motions in front of the mouth), which maintained the handshape and location of the habituation sign, <REALLY> but varied the movement. Another test event depicted the signer presenting the ASL sign, <THINK> (i.e., the index finger touches the right side of forehead), which maintained handshape of the habituation sign, but varied the movement and location. The last event depicted the signer presenting the ASL sign, <BROWN> (i.e., the B-handshape slides down the side of the right side of the face), which varied the location, handshape, and movement of the habituation sign. See Figure 3.5 for photographs of the stimuli for this condition.

Habituation Event for *Location Change* Condition

ASL sign - **DRY**



Test Events for *Location Change* Condition

ASL sign – **SUMMER** – change in Location



ASL sign – **FORGET** – change in Location & Handshape



ASL sign – **FLOWER** – change in Location, Handshape, & Movement



Figure 3.4 Photographs of the Dynamic Events Presented for the *Location Change* Condition for Habituation and Test Trials

Habituation Event for *Movement Change* Condition

ASL sign - **REALLY**



Test Events for *Movement Change* Condition

ASL sign – **HEARING** – change in Movement & Handshape



ASL sign – **THINK** – change in Handshape & Movement



ASL sign – **BROWN** – change in Handshape, Movement, & Location



Figure 3.5 Photographs of the Dynamic Events Presented for the *Movement Change* Condition for Habituation and Test Trials

All of the ASL signs were demonstrated once, lasting approximately 2 seconds before the signer returned her hand to her lap. This demonstration of the sign was

looped 15 times without pauses to create a trial with a 30s duration. Hence, the signs were presented 15 times per trial. As in Experiment 1, a pretest trial was used and depicted a pink stuffed pig being moved by a hand. This event was 10 s in duration and was looped 3 times to create a 30 s pretest trial. All of the stimuli were created and edited in an identical manner as in Experiment 1.

Apparatus & Procedure. The apparatus used in Experiment 2 was identical to that used in Experiment 1.

The procedure used in this experiment was identical to Experiment 1, with a few exceptions. First, after parental consent was obtained, infants were randomly assigned to one of the three experimental conditions: *Hand-Chg* ($n = 13$), *Loc-Chg* ($n = 13$), or *Move-Chg* ($n = 11$). Second, infants were habituated to one ASL sign (e.g., <HOME> for the *Hand-Chg* condition), and then tested with four trials. As in Experiment 1, one test trial presented the same event seen during habituation (e.g., <HOME>). The three additional trials presented test events that depicted a change in one, two, or all three parameter (s) from the habituation event. The order of presentation of the four test trials was counterbalanced across participants. A second observer recorded the looking time of nine randomly chosen infants off-line. The average correlation between on-line and off-line looking times was .993 (range = .980 - .999).

Results

As in Experiment 1, all of the looking time scores were converted to Log_{10} transformations (Neter et al., 1996). Again, infants' looking times in seconds are presented for interpretation purposes. The first analysis was conducted to ensure that infants had in fact demonstrated a significant decrease in looking time from the habituation phase to the test phase. The average of the looking times across the first three trials during habituation was compared to the familiar test event in a 2 (Sex:

males vs. female) by 3 (Condition: *Hand-Chg* vs. *Loc-Chg* vs. *Move-Chg*) by 2 (Trials: average of 1st three habituation trials vs. familiar test trial) mixed-model analysis of variance (ANOVA). The analysis revealed a significant main effect of Trials, $F(1, 31) = 94.52, p < .001, \eta_p^2 = .75$, indicating that the infants had significantly decreased their looking times from habituation to test and did not meet the habituation criteria by chance. A significant main effect of Condition also emerged, $F(1, 31) = 5.23, p < .05, \eta_p^2 = .25$. The infants in the *Loc-Chg* condition looked significantly longer across all trials compared to the *Hand-Chg* condition and the *Move-Chg* condition, all p 's $< .05$. No other significant main effects or interactions emerged, all p 's $> .05$.

Number of Changed Parameters. To determine whether the degree of change (i.e., 1 parameter or more) affected infants' ability to discriminate changes in the one-handed signs, a 2 (Sex) by 3 (Condition) by 4 (Test Trials: familiar, 1-parameter change, 2-parameters change, all parameters change) mixed-model ANOVA was conducted using simple contrasts comparing infants' looking times to each of the change trials relative to the familiar test trial. Figure 3.6 depicts infant's mean looking time and standard errors for each test trial. Overall, the findings revealed a significant main effect for Test Trials for each of the comparisons. Infants looked significantly longer at the 1-parameter change test event relative to the familiar test event, $F(1, 31) = 10.84, p < .01, \eta_p^2 = .26$. Infants also looked significantly longer at the 2-parameter change test trial, $F(1, 31) = 8.16, p < .01, \eta_p^2 = .21$ and the all change test trial, $F(1, 31) = 7.77, p < .01, \eta_p^2 = .20$, relative to the familiar test trial.

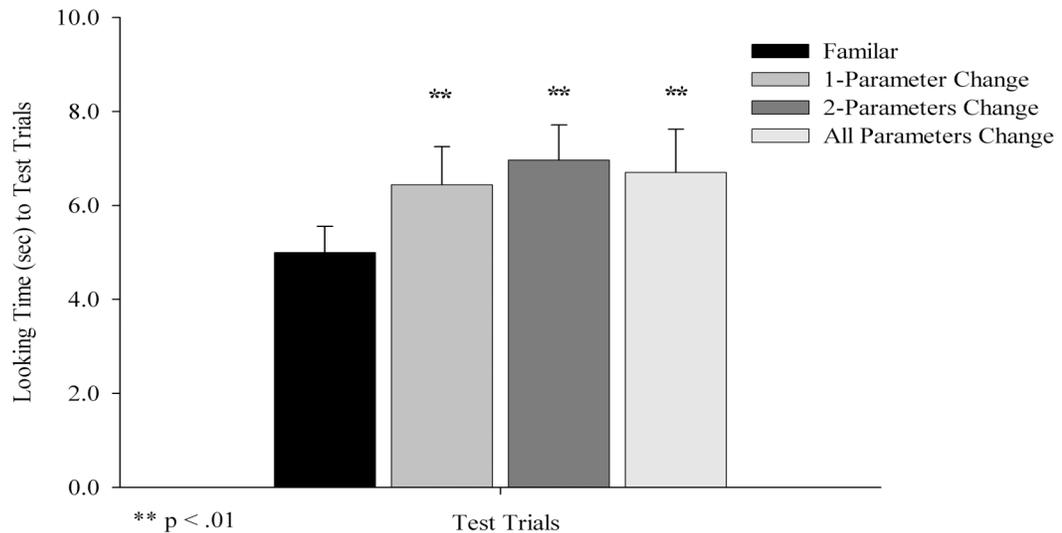


Figure 3.6 Mean Looking Times (in seconds) and Standard Errors to Each Test Trial

The analysis also revealed a significant main effect of Condition, $F(2, 31) = 3.88, p < .05, \eta_p^2 = .20$. Post hoc analyses revealed that infants in the *Loc-Chg* condition ($M = 8.25, SD = 4.50$) looked significantly longer across all trials compared to both the *Hand-Chg* condition ($M = 5.77, SD = 3.27$) and the *Move-Chg* condition ($M = 5.47, SD = 2.41$). Also, a significant Condition by Test Trials interaction, $F(2, 31) = 3.57, p < .05, \eta_p^2 = .19$ and a significant Sex by Condition by Test Trials interaction emerged, $F(2, 31) = 3.86, p < .05, \eta_p^2 = .20$ for the comparison of the familiar test trial to 1-parameter change test trial. Figure 3.7 depicts infants' looking times to each test trial as a function of condition.

Assessment of Individual Parameter Changes. To explore these interactions and to specifically address our hypotheses, planned comparisons were conducted within each condition comparing infants' looking times to each 1-parameter change test trial to the familiar test trial. For the *Hand-Chg* condition, a 2 (Sex) by 2 (Test Trials: familiar vs. handshake only change) mixed-model ANOVA revealed that

infants looked significantly longer at the test trial that depicted a change in handshape relative to the familiar test trial, $F(1, 11) = 8.24, p < .05, \eta_p^2 = .43$, indicating that they had discriminated the change in handshape when it was the only parameter to vary. For the *Loc-Chg* condition, the 2 (Sex) by 2 (Test Trials: familiar vs. location only change) mixed-model ANOVA revealed that infants did not look significantly longer at the change in location test trial relative to the familiar test trial, $F(1, 12) = .033, p > .10$. Thus, infants in this condition did not provide evidence of detecting the change in location.

For the *Move-Chg* condition, the 2 (Sex) by 2 (Test Trials: familiar, movement only change) mixed-model ANOVA revealed that infants looked significantly longer at the test trial that depicted a change in movement relative to the familiar test trial, $F(1, 9) = 11.73, p < .01, \eta_p^2 = .57$. Unexpectedly, this finding was qualified by significant Sex by Test Trials interaction, $F(1, 9) = 8.10, p < .05, \eta_p^2 = .47$. Paired t-test revealed that the male infants looked significantly longer at the change in movement test trial ($M = 9.52, SD = 2.75$) relative to the familiar test trial ($M = 3.92, SD = 2.05$), $t(5) = -4.25, p < .01$, whereas the female infants looked equally long at the change in movement test trial ($M = 3.57, SD = 1.94$) relative to the familiar test trial ($M = 3.05, SD = .95$), $t(5) = -.38, p > .10$.

Additional analyses were conducted in order to determine whether particular combinations of parameter changes could provide further insight into the nature of the previous findings. Recall that infants detected the change in handshape when it was the only parameter to vary. However, infants did not provide evidence of detecting changes in handshape when it varied with location or movement, all p 's $> .10$.

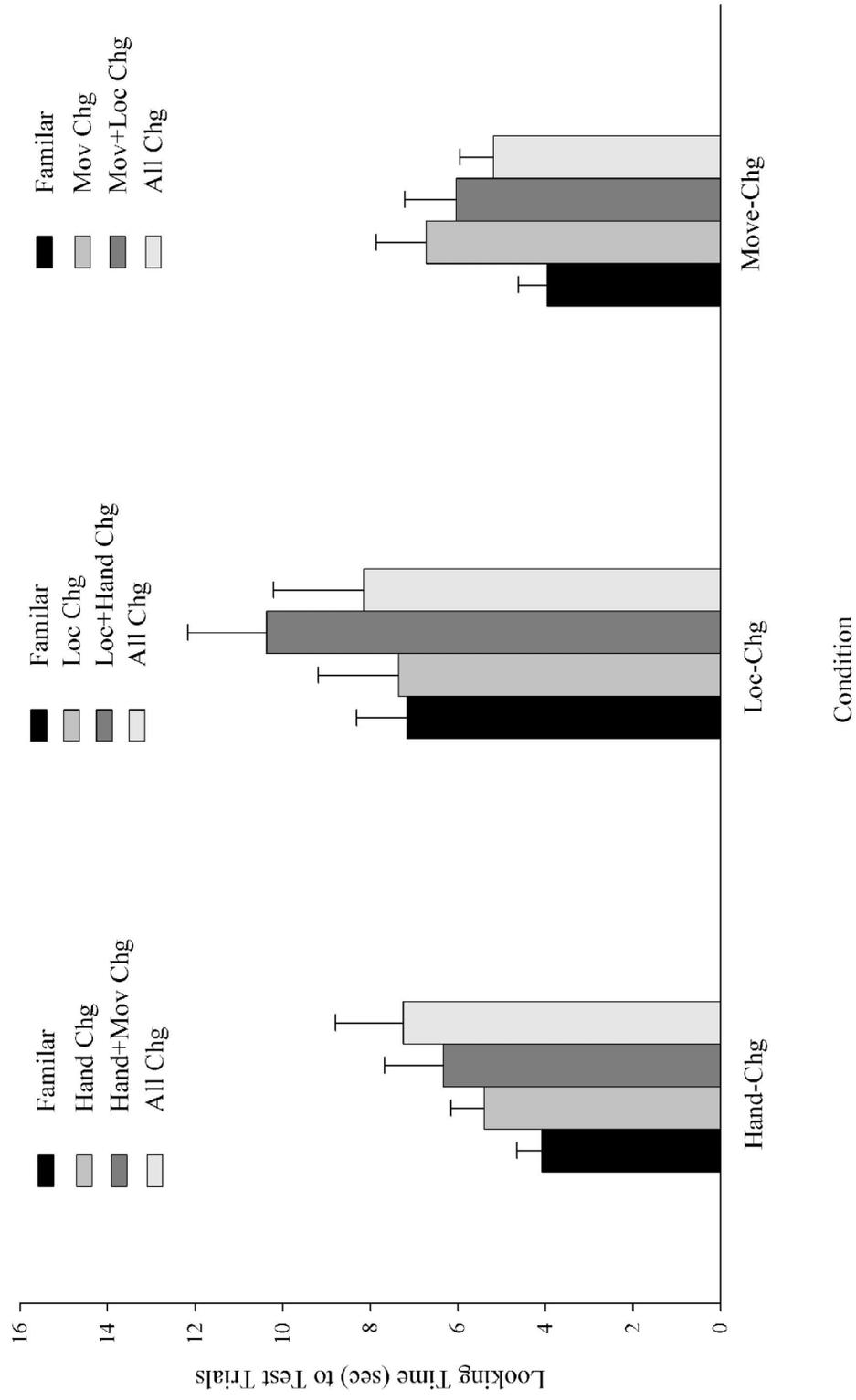


Figure 3.7 Mean Looking Time (in seconds) and Standard Errors) to Each Test Trial Compared to the Familiar Test Trial as a Function of Condition

Also infants did not provide evidence of detecting the change in location when it was the only parameter. Interestingly, infants did not provide evidence of detecting changes in location when it varied with handshape, $F(1, 12) = 2.88, p > .10$, but did provide evidence of detecting the change when both location and movement varied, $F(1, 12) = 5.12, p < .05, \eta_p^2 = .34$.

Discussion

The purpose of the current experiment was to examine prelingual ASL-naïve infants' ability to discriminate between the relevant parameters of one-handed sign ASL signs articulated near the face. In order to examine infants' abilities with ecological valid stimuli, we utilized a between-subjects design in lieu of the within-subjects design used in Experiment 1. Specifically, in this study we used unmodified ASL signs articulated by a native signer. We found that ASL-naïve infants, when presented with one-handed ASL signs articulated near the face, were able to discriminate changes in handshape, a result that is consistent with the findings from Experiment 1. Also, consistent with the findings from Experiment 1, infants in the current experiment did not provide evidence of detecting changes in location. Interestingly, only male infants provided evidence of detecting changes in movement. Thus, the parameter of handshape appears to be the most salient for ASL-naïve six-month-olds when it is the only parameter to vary.

One benefit of the design used in the current experiment is that it allowed us to assess the relative strength of infants' perceptual abilities to particular parameter changes depending on whether that parameter varied alone or varied with another parameter. In general, infants detected changes in handshape when it was the only parameter to vary. However, when handshape varied with location, infants no longer detected the change. Infant's ability to detect changes in handshape may have been disrupted when it varied with location, a parameter that they failed to detect changes in

when it varied alone. This raises the question of whether changes in handshape are particularly salient or rather infants' ability to detect changes is affected when handshape varies with a parameter that is more difficult to detect changes in (e.g., location). The latter appears to be the case since infants also failed to detect changes in handshape when it varied with movement. Thus, in one-handed ASL signs articulated near the face, changes in handshape may be more difficult to detect if location or movement also vary.

Interestingly, infants were able to detect changes in location when it varied with movement. This detection may be specifically attributable to the change in movement. However, given that only males detected changes in movement when it varied alone, caution must be used in this interpretation. It is relatively unclear as to why only male infants provided evidence of detecting changes in movement. Further research is required to determine whether the sex difference found in the current study is a spurious result or rather that male infants are particularly sensitive to movement contrasts or motion in their field of vision. A study conducted by Wilmer and Nakayama (2006) with adults may shed some light onto this particular findings. The vision researchers found that adult males were significantly more precise than adult females in their visual pursuit of an object during an oculomotor pursuit task (Wilmer & Nakayama, 2006). This finding offers some insight into the possibility that the sex differences found with this type of visual pursuit ability in adulthood may be apparent earlier in development and may also extend to various types of visual perceptual abilities, such as the perception of movement. However, this speculation requires further investigation.

General Discussion

Taken together, the findings from both experiments demonstrate that when ASL-naïve hearing infants are presented with one-handed ASL signs articulated near

the face, they (1) are able to discriminate changes in the parameter of handshape and (2) do not provide evidence of discriminating changes in location when they are the only parameters to vary. These findings are consistent with both modified and unmodified ASL signs and appear to be robust across different experimental designs (i.e., within-subjects vs. between-subjects). As a consequence, the findings from the first experiment cannot be attributed specifically to the artificial or unnaturalistic manner in which the signs may have been presented when the nonnative signer articulated the modified signs, but rather the findings accurately represent infants' ability to discriminate changes in the parameters of handshape and location.

Interestingly, the findings regarding infants' ability to detect changes in movement are somewhat inconsistent across studies. For instance, in Experiment 1 infants did provide evidence of detecting changes in movement; however these changes were particularly salient for 10-month-olds. Alternatively, in Experiment 2, only 6-month-old males reliably provided evidence of detecting changes in movement, when it was the only parameter to vary. Across both experiments infants' ability to reliably discriminate changes in the parameter of movement are at best, consistently inconsistent. Thus, future research is needed to further examine the nature of this ability in ASL-naïve infants.

The replication of the findings across both experiments provides further insight into the complexity of infants' early perceptual abilities in relation to the acquisition of ASL. Recall that Wilbourn and Casasola (2007) found that ASL-naïve infants, when presented with two-handed signs articulated in neutral space, discriminated changes in location and a grammaticized facial expression but failed to provide evidence of discriminating changes in handshape and movement. These results are in contrast to the results in the current set of experiments. Infants in the current set of experiment discriminated changes in handshape and movement, but failed to provide evidence of

discriminating changes in location and facial expression (Experiment 1). This apparent conflict between the current project and Wilbourn and Casasola (2007) provides strong support for our hypothesis that infants' sensitivities to ASL parameters are dependent upon where in the signing space the signs are articulated and the number of hands used to articulate the signs.

So why would infants demonstrate different perceptual sensitivities to ASL parameters when viewing signs articulated on the face compared to signs articulated in neutral space? Emmorey and Corina (1990) claim that some ASL parameters may be more easily identified as a function of where they are articulated in the signing space. Specifically, they posit that the parameter of handshape may be easier for perceivers to identify compared to location when signs are articulated near the face, as opposed to in neutral space, because the "phonetic" cues or handshape configurations are evident while the signer is moving his or her hand(s) up to the face (e.g., from his or her lap). Emmorey and Corina (1990) found that deaf adult signers were significantly faster at identifying ASL handshapes when signs were articulated near the face as opposed to in neutral space and concluded that this increased distance gives the perceiver more time to view the configuration of the hands as they reach the face. The findings in the current set of experiments further support this claim in that, across both experiments, the signer articulated the signs raising her hand up slowly from her lap allowing more time for the infants to attend to the signer's hand configuration.

Even more compelling is the finding that infants were able to discriminate changes between various types of ASL handshapes when one-handed signs were articulated near the face. Specifically, in Experiment 1, infants discriminated between the loose B-handshape (i.e., finger extended and touching side by side with the thumb alongside of the palm) used in the sign <FORGET> and a D-hand (i.e., index finger only extended) used in the sign <BLACK>. Infants in Experiment 2 discriminated

between the O-hand (i.e., thumb touching fingertips) used in the sign <HOME> and the Y-hand (i.e., three middle fingers touching palm with thumb and pinky extended) used in the sign <YESTERDAY>. However, infants' extended attention to the handshape of the sign may have been at the cost of attending to the location of the sign.

Emmorey and Corina (1990) posit that the parameter of location may be harder to identify when signs are produced near the face than neutral space, because the transition from the signer's lap up to the face is longer than the transition to in front of the torso or neutral space. Thus, signs reach their loci of articulation sooner when they are articulated in neutral space than when they are articulated near the face. This explanation provides insight into the findings of the current project as well as the findings of Wilbourn and Casasola (2007). Wilbourn and Casasola (2007) found that infants detected changes in location with signs articulated in neutral space, but failed to provide evidence of detecting changes in handshape. Hence, ASL-naïve infants' ability to detect changes in ASL parameters is contingent on where in the signing space the signs are articulated. In additional issue to consider is that infants' difficulty in

In addition, Emmorey and Corina's claim also helps to reconcile the differences in results from previous research with older children's perception, early production errors, and the current set of experiments. Recall that Hamilton (1986) found that deaf children exhibited more difficulty discriminating changes in handshape than in location. However, it is important to note that Hamilton did not explicitly make a distinction between signs articulated in neutral space compared to signs articulated near the face. For example, the stimulus set used in Hamilton's study to test children's detection of changes in handshape, included ASL signs that were articulated near the face and in neutral space. Specifically, this stimulus set included

two-handed signs, symmetrical and asymmetrical, and one-handed signs articulated in neutral space as well as one-handed signs articulated near the face (Hamilton, 1986). Considering that the majority of this stimulus set comprised signs that were articulated in neutral space (10 out of 11), it is not surprising that the children had more difficulty detecting changes in handshape than location as this is consistent with the findings of Emmorey and Corina (1990) as well as the results of the Wilbourn and Casasola (2007) study.

What could account for the discrepancy in the findings between infants' lack of discrimination of changes in the location of ASL signs and their seemingly successful production of ASL signs in the correct location? It is important to take into consideration that the research detailing children's sign production errors is based primarily on parental reports (Bonvillian & Siedlecki, 1996, 1998, 2000; Siedlecki & Bonvillian, 1993, 1997). Bonvillian and Siedlecki (2000) suggest that one important drawback to using this type of methodology, particularly in regard to the ASL parameter of location, is that parents may have only been able to accurately identify their child's signs if they were articulated in the correct location. Thus, the sign had to be articulated by the child in the correct location or *very close* to the correct location for parents to recognize and record the sign, which possibly skewed their results.

Bearing this in mind, further inspection of the findings from research documenting children's early ASL production errors, specifically related to location (Bonvillian & Siedlecki, 1998), demonstrates that children's accuracy varies as a function of the *particular* location of the sign articulation. More specifically, Bonvillian and Siedlecki (1998) found that children produced signs in neutral space with about 91% accuracy whereas signs produced near or on the head were produced with only about 75% accuracy across age groups. Overall, children were least accurate in their production of signs that were articulated near the middle of the face.

Interestingly, at the youngest ages (i.e., 6- to 13-months) only about 50% of the mid-face region signs were produced correctly. However as the children got older, between 14 to 15 months of age, their accuracy did increase to about 71%. Though at this age, when errors were committed, the children often substituted the forehead, chin, and cheek for signs that were articulated in the mid-face area (Bonvillian & Siedlecki, 1998). Hence, children's ability to produce ASL signs in the correct location actually varies depending on where signs are articulated in the signing space (neutral space vs. near the face), consistent with the findings on infants' perception of location changes in the current set of experiments and the Wilbourn and Casasola (2007) study.

The findings regarding infants' abilities to detect changes in movement contrast were consistently inconsistent across both experiments. Recall that infants in Experiment 1 did provide evidence of detecting changes in movement; however this finding was significantly more robust for the 10-month-olds. In Experiment 2, only male 6-month-olds provided evidence of detecting changes in movement. When assessing these findings in relation to previous research, which has demonstrated that ASL-naïve infants can detect changes in ASL movement contrasts (Carroll & Gibson, 1986; Schley, 1990), it is important to note that infants' sensitivity to ASL movement contrasts may vary as function of where in the signing space signs are articulated, in addition to the age of infants (e.g., 10- vs. 6-months-old). Recall that both the Carroll & Gibson (1986) and Schley (1990) examined these abilities infants between 3.5 to 4 months of age, which is younger than the infants tested in the current set of experiments.

Importantly, both the Carroll & Gibson (1986) and Schley (1990) studies used one-handed signs articulated in neutral space whereas in the current set of experiments, we used one-handed signs articulated on the face. For example, infants in the Carroll and Gibson (1986) study did not provide evidence of detecting changes in

movement contrasts between signs that were articulated parallel to the infants' line of sight (i.e., <SCOLD> vs. <WHERE>). More specifically, Carroll and Gibson found that signs with repeating movements, like the sign <SCOLD> were least salient for infants relative to signs with non-repeating movements, like <OTHER>. Infants' preference for non-repeating movement, as demonstrated in the Carroll and Gibson study, may offer some insight into the findings from the current set of experiments. In particular, the ASL signs used in Experiment 2 of the current study, which specifically tested infants' discrimination of movement contrasts, were articulated with both non-repeating and repeating movements. The base sign was <REALLY>, which is articulated with the index finger at the lower mouth/chin area with a forward non-repeating movement (Sternberg, 1998). However, the contrasting sign, <HEARING> is articulated with the index finger at the lower mouth/chin area with a repeating circular movement. This type of repeating movement may have been particularly challenging for infants to discriminate.

Another aspect to consider when assessing infants' ability to discriminate between the parameters of ASL is the degree of change between the relevant ASL parameters. The degree of change seems to play a major role in infants' ability to identify various types of ASL signs. For instance, the design of Experiment 2 in the current project allowed for a detailed examination of infants' sensitivities to particular parameters as a function of whether they vary alone or in combination with one or more other parameters. Infants in this experiment demonstrated the ability to detect a change in handshape when it was the only parameter to vary but did not provide evidence of detecting changes when handshape varied with either movement or location. Apparently, infants' failure to reliably detect changes in location (and movement in the case of the female infants) adversely affected their ability to detect changes in handshape. Thus, infants' sensitivity to changes in handshape was not

robust enough to override their apparent inability to detect changes in location. However, when a change in movement co-occurred with a change in location, infants were sensitive to this change. Hence, infants' ability to detect changes in movement and location may be dependent upon a more holistic type of perceptual processing as opposed to the processing of individual parameters.

Although the findings are relatively consistent across both experiments, it is important to consider the role of experience in perceivers' sensitivities to the parameters of ASL. Due to the fact that all infants in the current set of experiments were naïve to ASL, we cannot suggest that the infants viewed the stimuli or signs as linguistic. Caution must be used when interpreting these data in relation to data from native signers. It is important for future research to determine whether simply developing a more sophisticated visual perceptual system with age is sufficient to fine tune children's ability to detect changes in ASL parameters, or rather having continued experience with ASL is required for such fine-tuning. Analogous to infants' perception of speech contrasts, it is reasonable to expect that experience fine-tunes perceivers' sensitivities (Eimas, 1975).

Furthermore, fine-tuning perceptual sensitivities to particular parameters of ASL may require more experience with a visual-gestural language. For instance, Hamilton (1984, 1986) found that older deaf children made significantly fewer errors discriminating signs than their younger deaf counterparts. Hamilton (1986) contends that children's abilities to discriminate between ASL signs appear to steadily increase with age and experience. Likewise, Poizner (1983) reported that with regard to adults' perception of movement, experience appears to play a significant role. In particular, Poizner found particular types of movement contrasts (e.g., direction, degree of arcness) were salient to all types of perceivers (i.e., with and without experience with ASL). However, other types of movements, specifically those that reflected lexical

and inflectional information (e.g., ASL signs, <LOOK AT>, <GIVE>), were not salient to ASL-naïve hearing adults. Consequently, Poizner concluded that with experience there is a “modification of natural perceptual categories” (1983, p. 215).

However, the extant research with adults with and without experience with ASL offers somewhat conflicting perspective on the role of experience in perceptual sensitivities to ASL parameters. For instance, Stungis (1981) found that hearing and deaf adults with and without ASL experience, performed equally well on tasks identifying and discriminating between various types of ASL handshape configurations. Subsequently, Stungis concluded that linguistic experience with ASL was not necessary for accurate handshape perception. Likewise, the findings with early and late exposed signing deaf adults support this conclusion (Emmorey & Corina, 1990). Although later exposed signers were slower to identify ASL signs, their overall pattern of responses and accuracy did not differ from their earlier exposed counterparts.

Considering that the infants in the current set of experiments did not have any experience with ASL, it is implausible that the infants viewed the stimuli as linguistic in nature. Rather, based on the results of the current set of experiments as well as previous research with ASL-naïve infants’ and adults’ perception of ASL signs (Carroll & Gibson, 1986; Emmorey & Corina, 1990; Schley, 1990; Stungis, 1981; Wilbourn & Casasola, 2007), we propose that infants recruited a more general perceptual mechanism when processing the visual signs as opposed to a perceptual mechanism that is specific to language. Undoubtedly, this general perceptual mechanism becomes more sensitive with increased exposure to motion events and particularly, input from a visual-gestural language like ASL, however experience is not required. Thus, this general perceptual mechanism gives infants the upper hand in the acquisition of language, whether that language is signed or spoken.

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CHAPTER 4

DEVELOPMENTAL CHANGES IN INFANTS' ABILITY TO FORM ASSOCIATIVE LINKS BETWEEN SIGNS AND WORDS WITH OBJECTS

Abstract

Two experiments were conducted examining whether input presented in two modalities affects infants' ability to form linkages between objects and words, gestures, or both. In Experiment 1, infants were habituated to either a gesture paired with an object or a word paired with an object. In alternate trials, infants viewed a second gesture or word presented with a second object. In Experiment 2, infants viewed words and gestures simultaneously with objects. Fourteen-month-olds formed the linkages when given words and objects, but not gestures and objects or both words and gestures with objects. Twelve-month-olds formed the linkages when given both words and gestures with objects, but not when given either a word or a gesture with an object. Thus, 12-month-olds appear to rely on more general types of cues (e.g., multiple sources), whereas 14-month-olds appear to rely on more specific cues (e.g., words) to form associative linkages.

DEVELOPMENTAL CHANGES IN INFANTS' ABILITY TO FORM ASSOCIATIVE LINKS BETWEEN GESTURES AND WORDS WITH OBJECTS

Throughout the typical course of development, infants acquire language with relative ease. Although there is some agreement as to *when* children acquire and master particular aspects of language, *how* these aspects are acquired is still widely debated. Many have argued that documenting the timeline for which linguistic milestones are reached provides very little insight into the processes by which these milestones are attained (Samuelson & Smith, 1999, 2000). Thus, we are left to question what abilities, in any, provide the scaffolding upon which children learn language. Even though a growing literature has amassed addressing potential precursory characteristics, there is still much debate and no widespread agreement regarding the nature of these abilities (Bonvillian, Orlansky, & Folven, 1990).

Several contrasting perspectives have dominated the discussion surrounding the nature of prerequisite abilities for language development, and in particular early word learning. One perspective proposes that when children are faced with the task of learning a new word, they recruit language-specific biases or constraints (Clark, 1973; Markman, 1989) to assist them in determining the correct word-referent mapping. In contrast, Akhtar, Campbell, and Tomasello (1996) argue that when faced with a new word, children rely on their adept sensitivities to social cues, such as the referential intent of the speaker, eye gaze, and joint-attention, to guide them to the correct word-referent conclusion.

Although both perspectives have a great deal of compelling empirical support, one criticism of both theories is that they make assumptions regarding children's preexisting knowledge (linguistic or social) and do not actually address the *processes* by which children acquire this knowledge (Samuelson & Smith, 1998). Samuelson and

Smith (1998) contend that the processes by which children learn to map words to meaning are governed by more general and “mundane” learning mechanisms like association and attention and attribution of a priori knowledge is unnecessary. To account for not only the processes by which early word learning occurs but also the mechanisms guiding the *development* of these abilities, many have argued that the process of word learning may initially begin with more general or immature cognitive and perceptual mechanisms and with experience, children may come to rely on more mature language and socially specific cues (Hollich, Hirsh-Pasek, & Golinkoff, 2000; Werker & Yeung, 2005)

Numerous studies have been conducted examining the development and characteristics of infants’ early word or symbol learning. In an attempt to elucidate the nature of underlying mechanisms, some of this work has examined the degree to which infants’ abilities extend to various types of input (e.g., words, gestures, nonlinguistic sounds; Namy & Waxman, 1998; Woodward & Hoyne, 1999). For instance, Woodward and colleagues (Woodward & Hoyne, 1999; Woodward, Markman, & Fitzsimmons, 1994) tested infants’ ability to link novel words or nonlinguistic sound to objects in an experimental setting that emulated the conditions by which infants may be first exposed to a new word within their natural linguistic environment. Specifically, an experimenter repeatedly labeled an object (e.g., “Look at the...”) with either a novel word (e.g., “toma”) or a nonlinguistic sound (e.g., sound of a whip) and subsequently tested the infants’ comprehension of the novel word or sound. The infants were asked to point to or grab the previously labeled⁸ familiar object (e.g., “Can you find the “toma” or sound?), as well as a novel object. The findings revealed that infants, as young as 13 months, could readily map and

⁸ Although a nonlinguistic sound cannot be considered a “label” in the traditional sense, Woodward and Hoyne (2000) as well as Namy and Waxman (1998) use the term “labeled” to describe the target object.

generalize both a novel word and a nonlinguistic sound to familiar and novel objects. However, older 20-month-olds did not demonstrate similar flexibility with both types of input (i.e., words and sounds). Similarly, Namy and Waxman (1998) report that 18-month-olds can readily map and generalize a novel word or manual sign to an object and object category, yet 26-month-olds do not demonstrate a similar ability in mapping and generalizing a manual sign to an object without additional training.

These findings suggest that in the very early stages of vocabulary building and word learning, younger infants appear to be agnostic to form or modality in which information is presented and are able to recruit similar abilities with various types of input (e.g., words, non-linguistic sounds, pictograms, manual gestures; Gentner & Namy, 2004; Namy, 2001). However, as infants acquire more experience with their particular linguistic environment (e.g., spoken language), they appear to become more specialized in their abilities and less willing to accept various types of input as potential associates or “labels” for objects (Namy & Waxman, 1998; Woodward & Hoyne, 1999). As a consequence of this specialization, infants come to rely language-specific cues (i.e., auditory words) and require additional social cues (e.g., training) and experience to acquire other types of symbols, such as nonverbal gestures.

Several factors must be considered when interpreting the findings from both the Namy (2001; Namy & Waxman, 1998) and Woodward studies (Woodward & Hoyne, 1999; Woodward et al., 1994). One factor to consider is the nature of the experimental learning environment. The testing environments in both sets of studies were rich with social cues (e.g., eye gaze, joint-attention), which undoubtedly played a significant role and may have played a major role in the infants’ ability to learn the words, gestures, or nonlinguistic sounds (Akhtar, 2002). As a result, it is difficult to accurately pinpoint the general cognitive or perceptual mechanisms at play since social scaffolding was also a contributing factor. In addition, all of the above

mentioned studies presented input or labels that were embedded within a spoken English syntactic frame (e.g., “Look at the <GESTURE>”), which makes it difficult to rule out the possibility that a more language-specific mechanism (e.g., knowledge of grammar) guides younger infants’ abilities to learn various types of labels.

When each of these factors is taken into consideration, some have argued that the infants in these studies were provided with the most advantageous conditions to learn the various types of labels (e.g., gestures, sounds, words). These conditions, rich with various types of cues, make it seemingly more difficult to pinpoint the actual mechanisms guiding infants’ abilities. Werker and colleagues (Werker, Cohen, Stager, Casasola, & Lloyd, 1998) claim that to truly understand the processes by which infants learn words under optimal conditions, researchers must first investigate infants’ ability to learn words under tightly controlled conditions without social scaffolding.

Another factor to consider in the Namy studies (Namy, 2001; Namy & Waxman, 1998) is that the youngest group of infants was 17 months of age. This particular age range could arguably be considered a period in which infants are becoming expert symbol/word learners, as evidenced by the well-established exponential increase in their receptive and expressive vocabularies (Fenson et al., 2000). Thus, it is unclear as to how younger prelingual infants will respond to a nonverbal symbol, like a manual gesture without the benefit of rich social cues.

It is important to bear in mind that the word or label learning abilities tested in the Woodward and Namy experiments may have been more cognitively advanced in that the infants were required to map labels to familiar referents as well as generalize the same labels to novel referents. Many have asserted that a child’s ability to generalize a label to a category is the final, and arguably the most complicated task of symbolic word learning (Oviatt, 1980; Werker et al., 1998; Woodward et al., 1994). Further, Oviatt (1980) has long argued that there are several, less cognitively

demanding steps children must take before they come to acquire a symbolic understanding of the relationship between a word and a referent. For example, Oviatt (1980) asserts that infants' ability to associate a word with an object or understand that a word and an object "go together" (i.e., recognitory ability) is a necessary precursor to their ability to understand that a word "stands for" an object (i.e., referential or symbolic ability). Thus, Oviatt (1980) contends that before a child can participate in the more cognitively complex task of symbolic word learning (i.e., referential), they must first have mastered the less cognitively complex task of forming associative links between words and referents (i.e., recognitory).

An explicit distinction between these recognitory and referential abilities is essential in the study of early word learning because cognitive and perceptual mechanisms may contribute differently to each type of ability (Hirsch-Pasek & Golinkoff, 1996; Hollich et al., 2000; Oviatt, 1980; Werker et al., 1998). More specifically, the less cognitively complex task of forming linkages between words and referents may be driven by more domain-general associative learning mechanisms and be less influenced by experience with particular types of labels (Samuelson & Smith, 2000). However, the more cognitively complex task of symbolic word learning may be driven by more language-specific mechanisms and be more influenced by experience with the infants' ambient linguistic environment (Hollich et al., 2000).

To explicitly investigate the associative learning mechanisms that may guide prelingual infants' ability to rapidly form linkages between words and objects, Werker et al. (1998) developed an associative learning habituation task that tested these abilities without the aide of social cues. Using a modified version of the classic "switch design" (Younger & Cohen, 1986), infants were habituated to two different word-object pairings and tested with (1) a *same* trial that maintained a word-object pairing presented during habituation, (2) a *switch* trial that violated a pairing. This

switch trial presents a novel combination of familiar parts or elements previously presented in the habituation stimuli. Therefore, if infants are attending to and processing not only the particular elements (i.e., words, objects), but also the relation between these elements (i.e., word-object pairings) then they should dishabituate (i.e., look longer) to the switch trial depicting a novel combination (Cohen, 1998). The results revealed that in less than optimal conditions, 14-month-olds reliably form word-object linkages, indicating that they are capable of a more advanced level of relational processing. However, 12 month-olds failed to provide similar evidence of attending to the relation between the words and objects, but did demonstrate that they were able to process and distinguish between the words and objects, separately (i.e., individual processing; Cohen, 1998; Werker et al., 1998). Thus, the ability to engage in the relational processing of arbitrary word-object associations in less than optimal conditions is not evident until about 14 months of age.

Why do 12-month-olds fail to demonstrate this ability? One possible explanation is that 12-month-olds have not yet mastered the cognitive cross-modal (aural to visual) mapping skill that is required to form linkages between auditory words and visual objects without social referencing or cues. However, Gogate and Bahrick (2001) have found that infants, as young as 7-month-olds, are able to link auditory vowel sounds to visual objects in a habituation paradigm without the aide of social scaffolding. The infants in their study were presented with the vowel sounds in temporal synchrony with the movement of the object. As a result, infants may have benefited from the non-arbitrary, amodal cue inherent in the stimuli (Werker, Fennell, Corcoran, & Stager, 2002). In contrast, Werker et al. (1998) presented the auditory label during the pause in the movement of the novel objects so infants would not attach the label to the movement of the object but rather to the object itself, thereby presenting a truly arbitrary pairing. Werker and colleagues (2002, 2006) make the case

that presenting the label in this manner is more representative of the actual abilities required for early word learning because the relations between words and objects *are* arbitrary. Thus, presenting the label in this way makes the “switch” design more specific to early word learning abilities (Werker et al., 2002).

It is plausible that 12-month-olds may have difficulty forming arbitrary cross-modal (aural to visual) mappings without amodal perceptual cues or social support. Nevertheless, these cues may not serve a similar purpose for 14-month-olds. Fourteen-month-olds exhibited a more mature level of relation processing indicating that they were sensitive to the co-occurrence of a word and an object regardless of the coordination between the two elements temporally. Werker et al. (1998) conclude that in an associative word-learning task, like the switch design, by 14 months infants may have already begun to focus primarily on language-specific cues as opposed to more general perceptual indicators.

One intriguing proposal is that the type of input, and specifically the modality of input, affects infants’ level of processing as well as their underlying ability to learn new words (or labels). This proposal is based on the growing literature examining the effects of the modality of input on infants’ ability to build a lexicon (Daniels, 2001; Goodwyn, Acredolo, & Brown, 2000; McNeil, Alibali, & Evans, 2000, Namy & Waxman, 1998). Specifically, previous research documenting the language development of hearing infants exposed to both a spoken and signed language has shown that these unique language learners typically produce their first sign several months before they produce their first word (Bonvillian & Folven, 1987; Meier & Newport, 1990; Orlansky & Bonvillian, 1985; Prinz & Prinz, 1979 but also see Pettio et al., 2001). Research with both typically- and atypically-developing (e.g., autistic, down syndrome, mentally-handicapped, language-delayed) populations supports the suggestion that receiving linguistic input visually in the form of manual gestures or

signs may actually facilitate language learning (Bryen & Joyce, 1986; Capone & McGregor, 2004; Daniels, 2001; Fulwiler & Fouts, 1976; Gaines, Leaper, Monahan, & Weickgenant, 1988), and in particular early lexicon building (Goodwyn et al., 2000). However, we know substantially less about infants' lexicon building skills at the level of forming arbitrary associative links between various types of input, like manual gestures, and objects.

Can visual gestures influence infants' ability to form arbitrary associations between labels and objects without the benefit of amodal perceptual cues or social support? Indeed, the task of forming arbitrary unimodal mappings (visual to visual), such as gesture-object linkages, may be easier than cross-modal mappings (aural to visual) due to the possibility that unimodal mappings may require less perceptual and cognitive coordination than cross-modal mappings because input is presented in one modality instead of two. To date no such studies have directly examined infants' ability to form associative linkages between gestures and objects without the benefit of social support.

The purpose of the current set of experiments was to examine the effects of modality of input on infants' ability to form arbitrary associative links between various types of input (i.e., words or gestures) and objects. The ability to form such links has been argued to be a necessary prerequisite to early word or symbol learning (Echols & Marti, 2004, Oviatt, 1980; Werker et al., 1998) and certainly, may be a necessary prerequisite for early sign learning. Examining infants' ability to form arbitrary associative links with input presented in multiple modalities may provide insight into the degree to which the mechanisms driving these early precursory abilities extend to manual gestures. In Experiment 1, we tested both 12- and 14-month-olds' ability to form arbitrary associative links between words and objects or gestures and objects without amodal perceptual or social cues. We sought to determine

whether gestures could facilitate 12-month-olds' associative learning abilities under tightly controlled testing conditions, an ability that they did not demonstrate in the Werker et al. (1998) study. Also, we examined whether 14-month-olds' ability to form arbitrary word-object associations extends to visual-gestural input as well.

In Experiment 2, we tested 12- and 14-month-olds' ability to form arbitrary associative links when given synchronous bimodal input in the form of visual gestures simultaneously presented with auditory words as labels for objects. The addition of this type of synchronous bimodal input served to potentially assist infants' associative word learning abilities by providing an additional source of information (i.e., two labels), across different modalities (auditory and visual), in a perceptually salient manner (i.e., temporal synchrony between the labels; Gogate & Bahrick, 2001), while maintaining the arbitrariness of the label(s)-object combination. Specifically, both labels were presented *asynchronously* with the movement of the object, yet *synchronously* with one another (Werker et al., 1998).

Experiment 1

In Experiment 1, we sought to determine whether infants' early associative word learning skills extend to nonverbal labels in the form of visual gestures. We tested 12- and 14-month-olds' ability to form arbitrary associative word-object or gesture-object linkages without the benefit of social scaffolding. Using the same "switch" paradigm as Werker et al. (1998), infants were habituated to two different gesture-object or word-object pairings and tested with a *same* trial that maintained a previously presented pairing as well as a *switch* trial that violated one of the pairings. If infants attended to the relations between the gestures and objects or words and objects, then they should look significantly longer at the switch test trial relative to the same test trial.

Similar to the findings of Werker et al. (1998), we expect that the 14-month-olds, but not the 12-month-olds, will provide evidence of forming the arbitrary word-object associations. In addition, if a similar cognitive mechanism drives this ability and is not influenced by the modality of input (words vs. gestures), then we expect a similar pattern of results for the arbitrary gesture-object associative links (i.e., 12-month-olds fail, 14-month-olds succeed). On the other hand, if a gestural advantage exists at the level of forming label-object links and unimodal mappings (visual to visual) is easier than cross-modal mappings (auditory to visual), then we would expect both the 12- and 14-month-olds to successfully form the gesture-object associations.

Methods

Participants. The participants were recruited via letter given to parents at the time of their child's birth. Parents were contacted when their infant was within the appropriate age range. The final sample consisted 38 infants (19 males) of 12 months ($M = 12.0$ months, $SD = .32$ months, range = 11.5 months –12.6 months) and 38 infants (18 males) of 14-month-olds ($M = 14.0$ months, $SD = .33$ months, range = 13.5 months –14.6 months). All infants were full-term, of normal birth weight, and had no reported visual or auditory problems. The participants were primarily from highly educated Caucasian families with approximately 20% of the parents holding graduate degrees, 29% with college degrees, and 18% of parents having at least some college experience.

Thirty-eight infants (19 in each age group) were in the *Gesture-Object* condition. For this particular condition, infants who had been previously exposed to a signed language or symbolic gestures were excluded from the analyses. Thirty-eight infants (19 in each age group) were in the *Word-Object* condition. For both conditions, the infants were excluded from the analyses if they possessed one of the toys used as stimuli. Twenty-two additional 12-month-olds were tested but their data were not

included in the analyses for the following reasons: Seven infants (5 infants in the *Gesture-Object* condition and 2 in the *Word-Object* condition) failed to meet habituation criteria (described below), ten infants (5 infants in *Gesture-Object* and 5 in *Word-Object*) did not finish the testing session, three infants in the *Word-Object* condition due to a computer error, two infants demonstrated extreme looking times (+ 2 SD) to the familiar test event (one in each condition) and one infant in the *Gesture-Object* condition had a sibling interrupt the testing session.

Thirty-one additional 14-month-olds were tested but their data were not included in the analyses for the following reasons: nine infants failed to meet habituation criteria (2 infants in the *Gesture-Object* condition and 7 in the *Word-Object* condition), sixteen infants did not complete the testing session due to fussiness (6 infants in the *Gesture-Object* condition and 10 in the *Word-Object* condition), two infants in the *Word-Object* condition had their parent interfere with or stop the testing session and four infants demonstrated extreme looking times (+ 2 SD) to the familiar test event (2 infants in each condition). Although the attrition rates for both age groups are high, the percentages are consistent with the attrition rates of other experimental studies that have used the switch design procedure (Casasola & Cohen, 2000; Casasola & Wilbourn, 2004; Werker et al., 1998, Werker et al., 2002). Infants were given a t-shirt in appreciation for their participation.

Stimuli. Three toys were used as novel objects. Figure 4.1 depicts photographs of these objects. A green bug puppet with black eyes served as the novel object for the pre- and posttest events. A blue octopus with multicolored legs (Lamaze Toy: “Octotunes”®), and a yellow and orange sun with a smiling face and black and white checkered arms and legs (Lamaze Toy: “Celeste”®) were used as the novel objects for the habituation and test events.

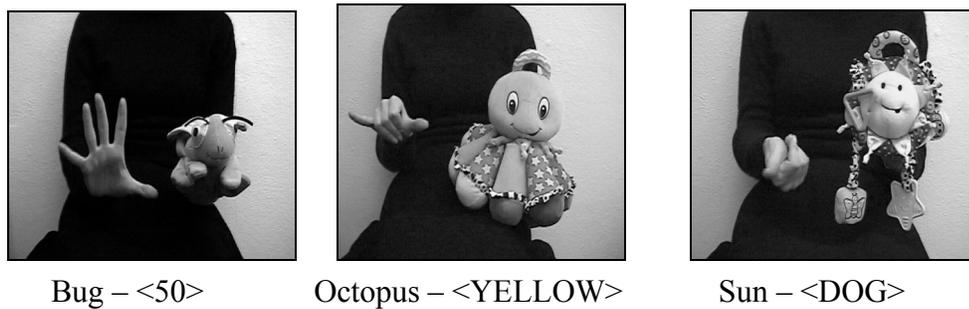


Figure 4.1. Photograph Examples of the Novel Objects and Novel Gestures

Three novel words were prerecorded, all of which presented varying intonations by a woman in infant-directed speech. The nonsense word “dax” was used for both the pre- and posttest events. The nonsense words “blicket” and “toma” were used for the habituation and test events. Two-syllable words were chosen so they would match, temporally, the presentation of the gestures. All of the novel words were phonemically possible in English and have been used in previous word learning studies (e.g., Booth & Waxman, 2003; Namy & Waxman, 1998; Woodward et al., 1994).

The novel gestures were derived from actual ASL signs (Sternberg, 1998). The ASL sign for <50> was used as the novel gesture for the pre- and post-test events. This sign begins with the palm facing out with the fingers extended, with the hand then slowly closing so that all of the fingertips touch one another (Sternberg, 1998). The ASL signs for <DOG> and <YELLOW> were used as the novel gestures for the habituation and test events. The ASL sign for <DOG> is produced using a finger snapping-like movement with the palm of the hand turned up. The ASL sign for <YELLOW> is produced with the palm facing out with the three middle fingers flat against the palm with the pinky finger and thumb extended (hereafter, y-hand). This y-hand twisted from left to right, alternating between a palm-out to a palm-in hand

orientation (Sternberg, 1998). Figure 4.1 depicts selected frames of these novel gestures. These gestures were presented twice in rapid succession. This was done so that the manual presentation of the novel gestures was similar to verbal presentation of the two-syllable novel words.

Videotaped dynamic events were created in which an object was paired with either a novel gesture or a novel word, depending on the condition. Each event depicted a woman wearing a black sweater filmed from the neck down sitting against a white wall. The woman's face was omitted to ensure that infants could not use social referencing, nonverbal or facial cues to form the association among the novel gesture or word and novel object. The videotaped events for the *Word-Object* condition depicted a pairing of a novel word and a novel object (e.g., "blicket"- Octopus). These events began with the woman holding one of the novel objects (e.g., the Octopus) with both hands and resting it on her lap. After a 1-second pause, the woman slowly moved the object away from her body and towards the camera. Once her arms were extended, the woman stopped the forward movement for approximately 1 second at which time the prerecorded audio of the novel word (e.g., "blicket") was played. After the presentation of the novel word, the woman slowly moved the object away from the camera, back towards her body. Once the object reached its original position in the woman's lap, she paused for approximately 1 second at which time the novel word was again presented. The back and forth movement of the object with the novel word presentation continued for a total of seven repetitions. These videotaped events were 25 seconds in duration.

The videotaped events for the *Gesture-Object* condition depicted a pairing of a novel gesture and a novel object (e.g., <DOG>-Octopus). These events began with the woman (i.e., "the signer") holding one of the novel objects (e.g., the Octopus) in her left hand and resting it on her lap. After a 1-second pause, the signer slowly moved

the object away from her body and towards the camera.

Once her arm was extended, the signer stopped the forward movement for approximately 1 second then presented the novel gesture with her right hand (e.g., <DOG>) to the left of the object (See Figure 4.1). After the presentation of the gesture, the signer slowly moved the object away from the camera, back towards her body. Once the object reached its original position, in the signer's lap, the signer again paused for approximately 1 second, then presented the same novel gesture (e.g., <DOG>) to the left of the object. The back and forth movement of the object with the gesture presentation continued for a total of seven repetitions. These videotaped events were 25 seconds in duration.

Although research by Gogate and Bahrck (2001) has demonstrated that 7-month-old infants learn to associate a vowel sound with an object when the movement of the object is synchronous with the presentation of the sound, we made the decision to present the novel gesture or word during the pause in movement as opposed to while the object was moving, similar to Werker et al. (1998). This was done to enhance the arbitrary nature of the pairing by decreasing the possibility that the infants would link the gesture or the word to the *movement* of the novel object instead of linking the word or gesture to the novel object itself (Werker et al., 2002). Movement was added before and after each presentation of the novel word or gesture because previous research has demonstrated that infants are more likely to attend to stimuli that are dynamic or moving as opposed to still images (Gogate & Bahrck, 2001; Werker et al., 1998).

All of the dynamic events and auditory stimuli were created using a Canon ZR10 digital video camera. The video events and auditory stimuli were transferred to and edited on a Macintosh G4 computer. The video events were edited using Final Cut Pro software then converted to Quicktime movies. The auditory stimuli (i.e., nonsense

words “dax”, “toma”, and “blicket”) were edited using Kaboom! Factory software and imported into the Quicktime movies.

Apparatus. Infants were tested in a 3 m x 3 m room. They sat with a parent approximately 127 cm away from a 20-inch color monitor. Approximately 22 cm below this monitor was a 9 cm opening for the lens of a Panasonic video camera that was connected to a 15-inch monitor and VCR in an adjoining control room. The camera, monitor, and VCR were used to record the infant’s looking time during the testing session. A Macintosh G4 computer and a specially designed software program, Habit 2000 (Cohen, Atkinson, & Chaput, 2000), were used to present each dynamic event and record the infant’s online looking times during the testing session.

Procedure. Once parental consent was obtained, parents were asked to complete the MacArthur Communicative Development Inventories (CDI) - Short Form Level I (Fenson et al., 2000), to obtain estimates of infants’ receptive vocabulary, and subsequently lead to the testing room with their infant. The infant sat on their parent’s lap in front of the computer monitor. The parent was asked not to speak to or direct his or her infant’s attention during the testing session. An experimenter sat in an adjoining control room and depressed a key on the computer to start the testing session, which began with an attention-getter (i.e., a green chiming circle that expanded and contracted). This attention-getter was used to focus the infant’s attention to the monitor before and after each trial. Once infants attended to the monitor, the experimenter began a trial by pressing a key on the keyboard then holding down a different key for as long as the infant attended during a trial. For a look to be counted during a trial, an infant was required to attend to the event for a minimum of 2 seconds. This 2-second minimum ensured that the infant viewed the novel object and at least one of the seven possible gesture-object or word-object

presentations. Each event played until the infant either looked away for a minimum of 1 second or until the event played for the full 25-second duration.

The infants were tested using the same infant-controlled habituation paradigm as Werker et al. (1998). During the testing session, an infant viewed one pretest trial, a maximum of 20 habituation trials, and three test trials. The first trial viewed by the infants was always the pretest trial. This trial presented the green bug puppet with the novel gesture, ASL sign <50>, in the *Gesture-Object* condition or the novel word, “dax” in the *Word-Object* condition. After the pretest trial, the habituation phase of the experiment began.

During the habituation trials, infants were presented either with alternating events that paired a novel gesture with a novel object (i.e., *Gesture-Object* condition) or alternating events that paired a novel word with a novel object (i.e., *Word-Object* condition). For example, in the *Gesture-Object* condition, one habituation event presented a particular novel object (e.g., Octopus) paired with a particular gesture (e.g., ASL sign, <DOG>). The alternate event depicted the other object (i.e., Sun) paired with the other gesture (i.e., ASL sign, <YELLOW>). In the *Word-Object* condition, the infants heard novel words paired with the objects instead of viewing novel gestures paired with the objects. All combinations of the gesture-object and word-object pairings were counterbalanced across participants. The habituation phase of the study ended when the infant met the habituation criterion (i.e., a 50% or more decrease in looking time calculated by the sum of the 4 longest consecutive trials divided by the sum of the 4 shortest consecutive trials) or a maximum of 20 trials were presented. After the habituation phase, the test phase began.

During the test phase, infants viewed three test trials. One test trial was a familiar event viewed during habituation, the *same* trial. This event maintained the previously presented label-object pairing seen during habituation (e.g., Octopus-

<DOG> in the *Gesture-Object* condition). A second test trial was an unfamiliar event for the infants, the *switch* trial. This event violated one of the previously presented label-object pairings (e.g., Octopus- <YELLOW> as opposed to Octopus- <DOG> in the *Gesture-Object* condition). Which aspect of the event that switched (i.e., the label or the object) as well as the order of presentation (same/switch v. switch/same) was counterbalanced across participants. The final test trial was always the posttest, which presented the same event seen during the pre-test trial. The purpose of this posttest trial was to determine whether fatigue might have played a role in infants' looking behavior during the test phase. To establish inter-rater reliability for the infants' looking times to each event, an independent observer recorded the looking times of 20 randomly chosen infants from the recorded testing sessions. The average correlation between the on-line and off-line looking times was .994 (range = .985 - .999).

Results

For purposes of statistical analyses, all looking time scores were converted to Log_{10} transformations to normalize the data (Neter, Kutner, Nachtsheim & Wasserman, 1996). For ease of interpretation, the looking time scores (in seconds) for all of the Log_{10} -transformed data are presented.

Habituation Criterion. The first analysis was conducted to ensure that infants had in fact demonstrated a significant decrease in looking time from the habituation phase to the test phase. The average of the four longest consecutive looking times during habituation was compared to the familiar test event (i.e., same test trial) in a 2 (Sex: males vs. female) by 2 (Age: 12 months vs. 14 months) by 2 (Condition: gesture-object vs. word-object) by 2 (Trials: average of the four longest consecutive habituation trials vs. same test trial) mixed-model analysis of variance (ANOVA). A significant main effect of Trials revealed that the infants looked significantly longer at the habituation events across four consecutive trials of habituation ($M = 15.96$ s, $SD =$

4.95 s) than at the same test trial ($M = 7.28$ s, $SD = 4.16$ s), $F(1, 68) = 237.75$, $p < .001$, $\eta_p^2 = .78$. Thus, infants did not reach the habituation criteria by chance. A significant main effect of Condition revealed that the infants in the *Word-Object* condition looked significantly longer across all trials ($M = 12.72$ s, $SD = 3.84$ s) compared to the infants in the *Gesture-Object* condition ($M = 10.51$ s, $SD = 3.41$ s), $F(1, 68) = 6.69$, $p < .05$, $\eta_p^2 = .09$. In addition, a significant Age by Condition interaction emerged, $F(1, 68) = 4.79$, $p < .05$, $\eta_p^2 = .07$, revealing that the 12-month-olds in the *Word-Object* condition looked significantly longer across all trials ($M = 13.03$ s, $SD = 4.59$ s) compared to the 12-month-olds in the *Gesture-Object* condition ($M = 9.80$ s, $SD = 2.93$ s). No other significant main effects or interactions emerged.

Label-Object Associations. A second analysis examined whether infants had formed associations between the novel gestures or words and the objects. The infants' looking times during the test phase was examined in a 2 (Sex) by 2 (Age) by 2 (Condition) by 2 (Test Trials: same vs. switch) mixed-model ANOVA. This analysis yielded a significant main effect of Condition, $F(1, 68) = 4.69$, $p < .05$, $\eta_p^2 = .07$, indicating that across all trials the infants in the *Word-Object* condition ($M = 9.18$ s, $SD = 4.52$ s) looked significantly longer than the infants in the *Gesture-Object* condition ($M = 7.12$ s, $SD = 3.46$ s). The analysis of interest revealed a significant main effect of Test Trials, $F(1, 68) = 4.75$, $p < .05$, $\eta_p^2 = .07$. However, this main effect was qualified by a significant Trials by Condition by Age interaction, $F(1, 68) = 5.68$, $p < .05$, $\eta_p^2 = .07$. In addition, a significant Condition by Age by Sex interaction, $F(1, 68) = 6.07$, $p < .05$, $\eta_p^2 = .08$ and a significant Trials by Condition by Age by Sex interaction, $F(1, 68) = 5.66$, $p < .05$, $\eta_p^2 = .08$ emerged. No other main effects or interactions revealed significant findings.

Post hoc tests were conducted within each condition to further examine the significant interactions. For each condition, a 2 (Sex) by 2 (Age) by 3 (Test Trials:

same, switch, posttest) mixed-model ANOVA was conducted. The posttest trial was included in these analyses to determine whether the infants may have failed to detect the change in the label-object pairing due to fatigue. Simple contrasts were conducted comparing infants' looking time to the switch test trials relative to the same test trial and their looking times to the posttest trial relative to the same test trial.

Gesture-Object Condition. Figure 4.2 depicts infants' mean looking times and standard error to the test trials for each age group. For the *Gesture-Object* condition, a significant main effect for the comparison between the switch and same trials did not emerge, $F = 1.89, p = .18$, indicating that the infants did not provide evidence of forming associations between the novel gestures and the objects. Although, the main effect for the comparison between the posttest trial and the same trials did not quite reach statistical significance, $F(1,34) = 3.63, p = .065, \eta_p^2 = .10$, the results suggest that the infants may not have been overly fatigued by the end of the testing session. Interestingly, a significant Sex by Age by Trials interaction emerged, $F(1,34) = 8.60, p < .01, \eta_p^2 = .21$, for the comparison between the switch and same trials. Further analyses revealed that the 14-month-old boys looked significantly longer at the same test trials ($M = 7.77$ s, $SD = 4.09$ s) than to the switch test trial ($M = 5.03$ s, $SD = 1.77$ s), $p < .05$. This pattern did not emerge for the 14-month-old girls nor 12-month-old boys or girls. Overall, infants in neither age group provided evidence that they had formed the associations between the novel gestures and the novel objects.

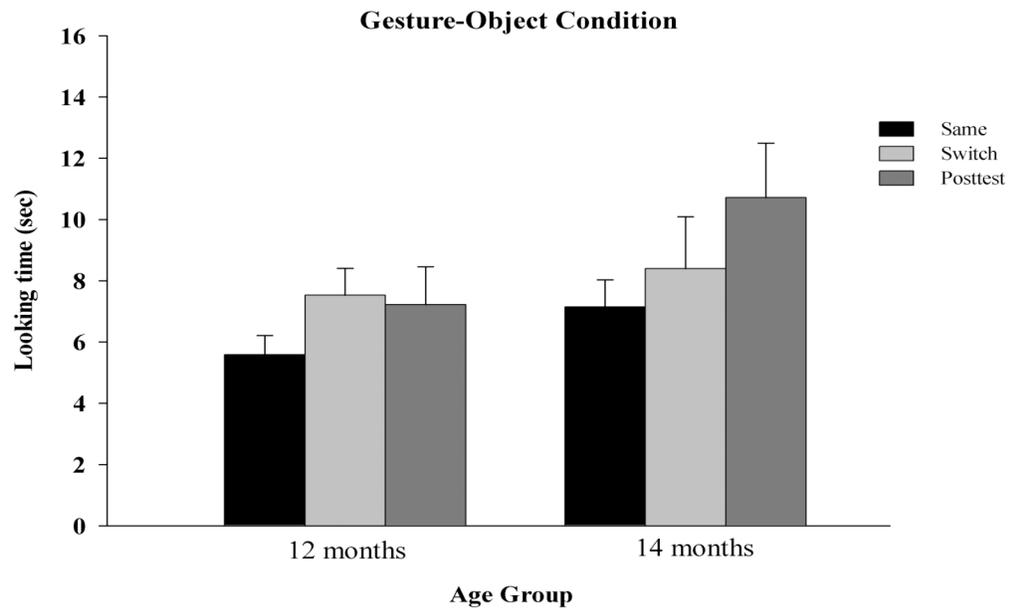


Figure 4.2 Mean Looking Time (in seconds) and Standard Error to Test Events as a Function of Age Group

Word-Object Condition. A significant Age by Trials interaction for the comparison between the switch and the same test trials emerged, $F(1, 34) = 4.83, p < .05, \eta_p^2 = .12$. Also, a significant main effect of Trials for the comparison between the posttest and same test trials emerged, $F(1, 34) = 8.17, p < .01, \eta_p^2 = .19$, an indication that the infants were not fatigued at the end of the testing session. No other main effects or interaction yielded significant results.

Figure 4.3 depicts infants' mean looking times and standard error to the test trials for each age group. An examination of infants' looking times to the switch test trial relative to the same test trial for each age group revealed that the 14-month-olds detected the change in the word-object pairing and thus, provided evidence of forming the novel word-object associations, $F(1, 17) = 7.64, p < .05, \eta_p^2 = .31$.

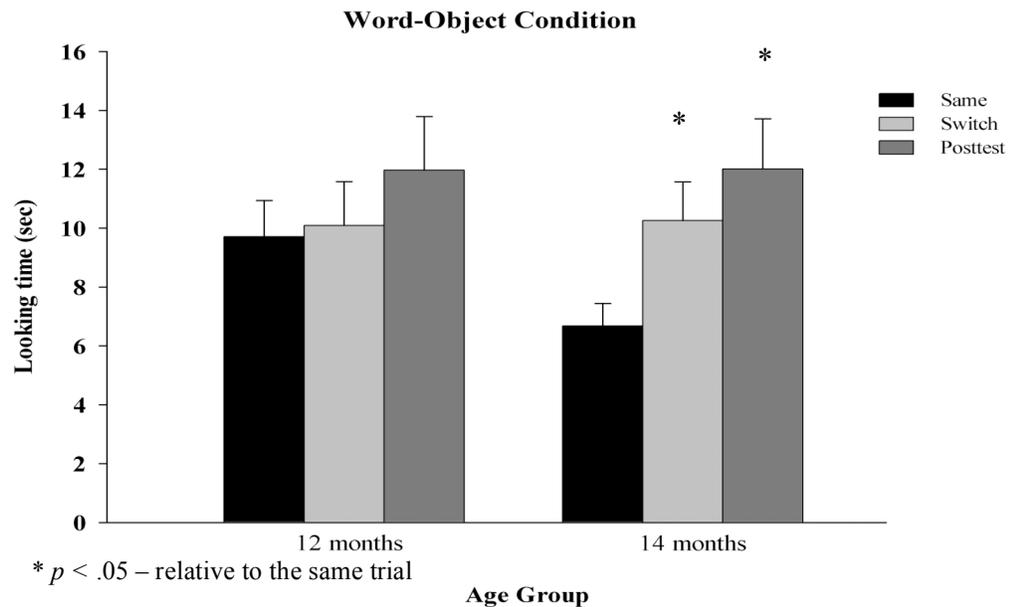


Figure 4.3 Mean Looking Time (seconds) and Standard Error To Test Events as a Function of Age Group

In contrast, the 12-month-olds did not provide similar evidence $F = .12, p = .74$. The analysis of 12-month-olds' looking times to the posttest trial relative to the same test trial did not yield a significant results, $F = .70, p = .42$, indicating that fatigue cannot be completely ruled out. Although it is important to consider that their looking times to the posttest trial were relatively high ($M = 11.97$ s, $SD = 7.93$ s). A 2 (Sex) by 2 (average of the four shortest habituation trials vs. posttest trial) mixed-model ANOVA revealed that the 12-month-olds did look significantly longer during the posttest trial than during the last phase of habituation ($M = 6.78$ s, $SD = 2.46$ s), $F(1, 17) = 10.02, p < .01, \eta_p^2 = .37$, indicating that infants may not have been inattentive during the test trials but rather were equally attentive to each test trial. No other main effects or interactions yielded significant results.

Additional Analyses. Overall, when given novel word-object pairings, 14-month-olds, but not 12-month-olds, provided evidence of being able to form the arbitrary word-object linkages. However, neither the 14-month-olds nor the 12-month-olds provided evidence of forming the arbitrary gesture-object linkages. As a result of these findings, we conducted two additional analyses to determine whether infants' (1) accumulated looking time during habituation (i.e., speed of processing) or (2) reported vocabulary size could account for these findings abilities.

Speed of Processing. In the first analysis, we examined both the 12 and 14-month-olds' speed of processing (i.e., time to reach habituation criterion) across both conditions. Previous research with young infants (Cohen, 1995; Columbo et al., 1995; Younger & Cohen, 1986) has reported that infants who demonstrate longer processing times during habituation typically exhibit a more individual level of processing (i.e., attending only to the parts) whereas infants who demonstrate shorter processing speeds during habituation typically exhibit a more relational level of processing (i.e., attending to the relations between the parts).

To determine whether infants' speed of processing could provide insight into the findings, infants' average looking time (in seconds) during habituation was subjected to a one-factor (Condition) between subjects ANOVA for each age group. For the 14-month-olds, this analysis revealed that the infants' rate of processing in the *Gesture-Object* condition did not significantly differ from the infants' rate of processing in the *Word-Object*, $F(1, 35) = 1.73, p = .20$. It took infants equally long to habituate in both the *Gesture-Object* and *Word-Object* conditions, yet only the 14-month-olds in the *Word-Object* condition demonstrated that they had processed the *relations* between the words and objects. For the 12-month-olds, this analysis revealed that the 12-month-olds in the *Word-Object* condition took significantly longer to habituate than the 12-month-olds in the *Gesture-Object* condition, $F(1, 36) = 5.58, p$

< .05. However, infants in neither condition provided evidence of forming associations between either words or gestures with objects. Thus, the speed by which infants processed the input (i.e., accumulated looking time during habituation) was not indicative of their subsequent level of processing (i.e., individual vs. relational).

Receptive Vocabulary. In the second analysis, we explored whether the number of words in the infants' receptive vocabularies, as reported on the MacArthur CDI, may account for the above findings. The infants' average number of words in the their receptive vocabularies was subjected to a 2 (Age) by 2(Condition) by (Sex) between-subjects ANOVA. The analysis revealed a significant main effect of Age, $F(1, 49) = 9.71, p < .05, \eta_p^2 = .11$, with 14-month-olds reported as having significantly more words in their receptive vocabularies ($M = 27.4$ words, $SD = 18.1$ words, range 3-70 words) than the 12-month-olds ($M = 18.0$ words, $SD = 10.8$ words, range 1- 51 words). No additional main effects or interactions yielded significant results. As expected, a follow-up regression analysis revealed that the degree to which an infant detected the change in the labels-object combinations (i.e., difference scores = looking time to the switch test trials – looking time to the same test trial) could not be predicted from the number of words reported to be in his or her vocabulary, $\beta = .09, t(55) = .67, p > .10$. Further, the number of words in the infants' vocabularies accounted for little if any of the variance in the difference scores, $R^2 = .01, F(1, 55) = .44, p > .10$.

Discussion

The findings from Experiment 1 demonstrate that 14-month-olds, but not 12-month-olds, form associations between words and objects when habituated to two different word-object pairings (e.g., “blicket”- Octopus and “toma”- Sun) and tested with a trial that maintained a previously presented combination (i.e., same trial) and a trial that violated a combination (i.e., switch trial). However, when habituated to two

different gesture-object pairings neither age group demonstrated the ability to form associations between gestures and objects.

The results from the current experiment replicate and extend the findings of Werker et al. (1998). In particular, the developmental change, from 12- to 14-months of age, in infants' ability to form word-object associations in a habituation paradigm without social cues directly replicates the findings of Werker et al. (1998). The findings that 12-month-olds similarly fail to provide evidence of being able to form gesture-object associations (i.e., unimodal mappings), extends Werker's findings in that 12-month-olds' failure to form arbitrary word-object linkages cannot be attributed solely to the cross-modal nature of the auditory-visual stimuli. Therefore, 12-month-olds' difficulty in forming associative links requiring either unimodal (i.e., gesture-object) or cross-modal (i.e., word-object) mappings appears to be specific to the nature of the task rather than specific to the modality of input. Mainly, the complete arbitrariness of the label-object pairings (i.e., lack of temporal synchrony between the labels and the movement of the objects) may have made the task particularly more difficult for the 12-month-olds (Gogate & Bahrick, 2001; Werker et al., 2002). The absence of temporal synchrony may have made it more difficult for the infants to attend to and focus on the *relation* between the stimuli and as a result, the 12-month-olds simply attended to the individual elements (Cohen, 1998; Younger & Cohen, 1986; Werker et al., 1998).

Interestingly, the modality of input did seem to affect the 14-month-olds' associative learning abilities. The 14-month-olds successfully formed associative word-object associations, but were not able to extend this ability to gesture-object pairs. This finding is particularly interesting in light of the finding that infants given words with objects took just as long to process these stimuli as infants given gestures with objects. This underscores the importance of auditory words over visual gestures

at 14 months. It took 14-month-olds just as long to process the information, yet were only able to relationally process the word-object pairings. This supports Werker et al's (1998) claim that by 14 months, infants are particularly in tune with and focused on auditory words functioning as associates with objects.

As a consequence of this focus on words, when presented with a visual gesture paired with an object, 14-month-olds may not have viewed this particular source of input as informative. Given that they took the same amount of time to process this visual input as the more familiar type of auditory input, it is plausible that although the infants were attentive to this nonverbal presentation, they were nonetheless distracted by the ambiguity of the nonverbal gesture. Possibly 14-month-olds, who are inexperienced with a visual-gestural language, require more converging evidence or more salient perceptual cues for them to consider a gesture as a potential associate with an object without the benefit of cues from their environment.

Experiment 2

The purpose of Experiment 2 was to investigate the degree to which additional perceptual information could assist infants' ability to form associations between both words and gestures with objects. Our goal was to provide infants with more salient perceptual cues (e.g., temporal synchrony), while at the same time maintain the arbitrary nature of the associative label-learning task. It is well established that infants are particularly sensitive and attentive to input that is temporally synchronous and multimodal (e.g., auditory+visual; Bahrick, 1984, 2001; Bahrick & Lickliter, 2000, 2004; Bahrick, Lickliter, & Flom, 2004; Gogate & Bahrick, 2001). Furthermore, this sensitivity has been implicated in the early word learning abilities of prelingual infants (Gogate & Bahrick, 2001; Gogate, Walker-Andrews, & Bahrick, 2001). As a result, we made the decision to present infants with both visual gestures and auditory words simultaneously (i.e., gesture-accompanied speech) as labels for objects. However in

contrast to this previous work, we chose to present these synchronized labels during the *pause* in the movement of the object, similar to Experiment 1 and Werker et al. (1998). We hypothesized that temporal synchrony between the labels, as opposed to synchrony with the movement of the object, may be sufficient in highlighting the *relation* between both labels and the object.

In more naturalistic language learning environments, gesture-accompanied speech has been shown to facilitate young children's early word learning abilities (Acredolo, Goodwyn, & Adams, 2002; Daniels, 2001; Goodwyn et al., 2000). For example, Goodwyn and colleagues (2000) report that prelingual infants, who were exposed to words and gestures presented simultaneously, demonstrated a linguistic precocity compared to their peers with respect to building a vocabulary. Likewise, additional research has shown that during the one-word stage of language production, infants can successfully integrate (nonlinguistic) gesture and speech, and this integration facilitates their language comprehension (Capone & McGregor, 2004; see McNeil, Alibali, & Evans, 2000 for similar evidence with preschool-aged children). These findings support the hypothesis that multiple labels (gestures and words) presented in simultaneously across multiple modalities (auditory and visual) may facilitate infants' ability to process and attend to the relation between labels and objects.

Using the same switch design as in Experiment 1, infants were habituated to one novel gesture presented simultaneously with a novel word and a novel object. In alternate trials, infants viewed a second novel gesture presented with a second novel word and novel object. During test trials, the infants viewed one trial that maintained a previously presented combination (i.e., same test trial) and another trial that violated one element (i.e., word, gesture, or object) in a previously presented combination. (i.e., switch test trial). If infants attend to the relations between the words, gestures, and

objects, then they should look significantly longer at the switch test trial relative to the same test trial.

The additional perceptual cues may facilitate both the 12- and 14-month-olds' associative learning abilities across modalities due to the salience of the temporal synchrony between the labels by heightening their attention to the relation. Also, increasing the number of elements that co-occur simultaneously (from 2 to 3) may enhance infant's ability to process the input more relationally as opposed to individually (Younger & Cohen, 1986). With 14-month-olds, it is possible that the addition of temporal synchrony between the gestural and verbal labels may emphasize the significance of the gesture and assist infants in overriding their specialized reliance on auditory words specifically as potential associates with objects. On the other hand, the additional source of information (i.e., gestures + words) might make the task more cognitively challenging by increasing the processing load in that infants will have to attend to the 3-way association between the gestures, words, and objects as opposed to the simple 2-way association between either word and object or gesture and object.

Method

Participants. The participants were recruited and contacted in the same manner as in Experiment 1. The final sample consisted 25 infants (13 males) of 12 months ($M = 12.1$ months, $SD = .34$ months, range = 11.5 months – 12.7 months) and 24 infants (12 males) of 14 months ($M = 14.0$ months, $SD = .41$ months, range = 13.5 months – 14.7 months). As in Experiment 1, all infants were full-term, of normal birth weight, and had no reported visual or auditory problems. Also similar to Experiment 1, the majority of the participants were reported to be Caucasian and about one-third of the parents had completed graduate or bachelors degrees.

Twenty-five additional 12-month-olds were tested but their data were not included in the analyses for the following reasons: 7 infants failed to meet habituation

criteria (same as Experiment 1), 7 infants did not finish the testing session due to fussiness, 2 infants' data were not included due to a computer or experimenter error, 2 infants demonstrated extreme looking times (+ 2 SD) to the familiar test event, 1 infant had a sibling present in the testing room, 1 infant possessed one of the toys used in the events, and 5 infants had previous exposure to a signed language or gesture-accompanied speech.

Fifteen additional 14-month-olds were tested but their data were not included in the analyses for the following reasons: 2 infants failed to meet habituation criteria, 3 infants did not finish the testing session due to fussiness, 3 infants demonstrated extreme looking times (+ 2 SD) to the familiar test event, 3 infant possessed one of the toys used in the events, and 4 infants had previous exposure to a signed language or gesture-accompanied speech.

Stimuli. The novel objects, novel words and novel gestures used in Experiment 2 were identical to those used in Experiment 1. The dynamic events created for Experiment 2 presented a novel object paired with both a novel gesture and a novel word simultaneously. See Figure 4.4 for photograph examples of these stimuli. These events were identical to the events used in the Gesture-Object condition of Experiment 1, except that the prerecorded audio of the two-syllable novel word (e.g., “toma”) was dubbed into and synchronized with the double presentation of the novel gesture. As in Experiment 1, the gesture-word-object presentation continued for a total of seven repetitions and each of the dynamic events was 25 seconds in duration.

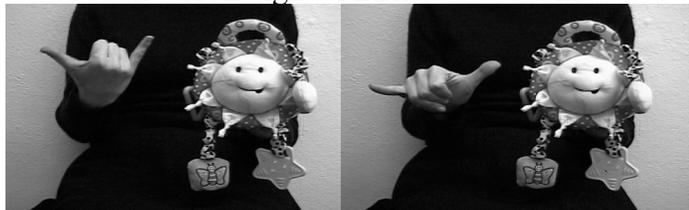
Apparatus and Procedure. The apparatus and procedure were identical to Experiment 1. The combinations of gestures, words, and objects were counterbalanced across participants. Again, to establish inter-rater reliability, an independent observer recorded the looking times of 15 randomly chosen infants. The average correlation between the on-line and off-line looking times was .995 (range = .983 - .999).

Habituation Trials

Octopus + ASL sign <DOG> + “blicket”

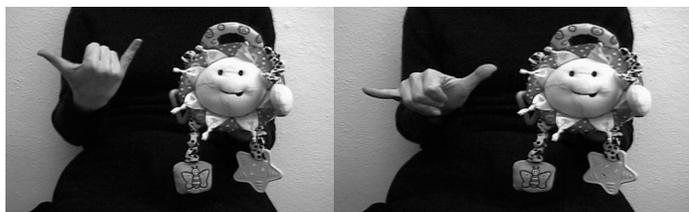


Sun + ASL sign <YELLOW> + “toma”



Test Trials

SAME TRIAL: Sun + ASL sign <YELLOW> + “toma”



SWITCH TRIAL: Octopus + ASL sign <YELLOW> + “blicket”

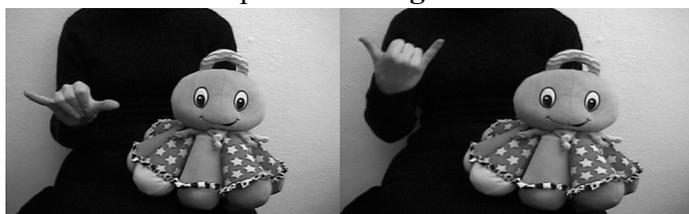


Figure 4.4 Photograph Examples of Habituation and Test Trials for Experiment 2

Results

As in Experiment 1, all looking times in seconds were converted to Log_{10} transformations for statistical analyses (Neter et al., 1996), however the non-transformed data are presented.

Habituation Criterion. To determine whether the infants had significantly decreased their looking time from habituation to test, a 2 (Sex) by 2 (Age: 12 months vs. 14 months) by 2 (Trials: average of the four longest consecutive habituation trials vs. same test trial) mixed-model ANOVA was conducted. The analysis yielded a significant main effect of Trials, $F(1, 45) = 313.14, p < .001, \eta_p^2 = .87$. Infants looked significantly longer during the habituation events ($M = 19.93$ s, $SD = 4.58$ s) than during the same test trial ($M = 6.21$ s, $SD = 3.33$ s). Therefore, infants did not reach the habituation criteria as an artifact. No other main effects or interactions were significant.

Labels-Object Associations. The second analysis was conducted to examine whether the infants had formed 3-way associations between the novel gesture, novel word, and the corresponding object. Figure 5 depicts the infant's average looking time to each test trial for each age group. The infants' looking times during the test phase were examined in a 2 (Sex) by 2 (Age) by 2 (Test Trials: same vs. switch) mixed-model ANOVA. The analysis yielded a significant main effect of Test Trials, $F(1,45) = 10.58, p < .01, \eta_p^2 = .19$, indicating that the infants looked significantly longer at the switch test trial ($M = 9.45$ s, $SD = 6.47$ s) than at the same test trials ($M = 6.21$ s, $SD = 3.33$ s). However, this main effect was qualified by a significant Test Trials by Age interaction, $F(1,45) = 4.24, p < .05, \eta_p^2 = .09$, with the 12-month-olds looking significantly longer to the switch test trial relative to the same test trial than the 14-month-olds. No other significant main effects or interactions emerged.

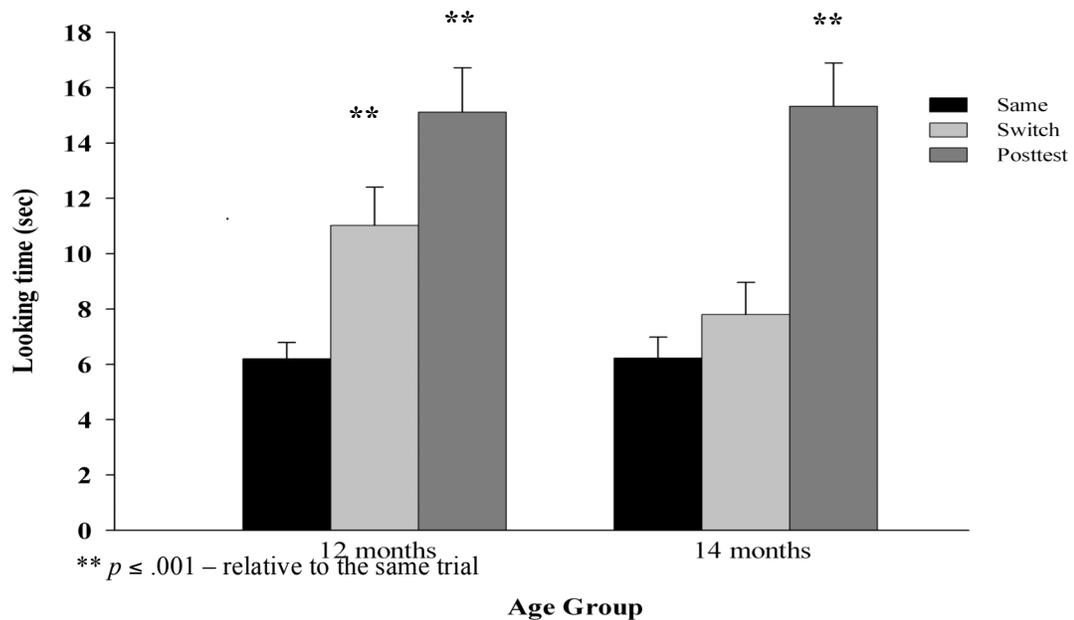


Figure 4.5 Mean Looking Time (in seconds) and Standard Error to Test Events as a Function of Age Group

Post hoc tests were conducted within each age group to further examine the significant Test Trials by Age interaction. For each age group, a 2 (Sex) by 3 (Test Trials: same, switch, posttest) mixed-model ANOVA was conducted. Simple contrasts comparing the 12-month-olds' looking times to the switch relative to the same test trial revealed that they had formed associative links between the novel gestures, novel words, and novel objects, $F(1, 23) = 15.27, p = .001, \eta_p^2 = .40$, indicating that they had attended to the relations between the gestures, words, and objects. In addition, the contrasts comparing the 12-month-olds' looking times to the posttest relative to the same test trial revealed that they were not fatigued at the end of the testing session, $F(1, 23) = 22.63, p < .001, \eta_p^2 = .50$.

Alternatively, the same analysis comparing the 14-month-olds' looking times to the switch relative to the same test trial did not yield significant results, $F = .82, p = .38$. Thus, 14-month-olds did not provide evidence of forming the 3-way associative

links between the gestures, words, and objects. Moreover, the analysis comparing their looking times to the posttest relative to the same test trial revealed that they were not fatigued by the end of the testing session, $F(1, 22) = 52.90, p < .001, \eta_p^2 = .71$. In sharp contrast to previous findings, 12-month-olds, but not 14-month-olds, provided evidence of forming 3-way associative links between gestures and words simultaneously paired with objects.

Additional Analyses. One possible explanation for the current findings is that one element was more or less salient to the infants when it was “switched”. Recall that in the switch trial, only one of the elements (gesture, word, or object) was “switched” while the other two elements maintained their previously presented pairing. To rule out the possibility that only one particular element being switched was detected by infants, a 2 (Sex) by 2 (Age) by 2 (Test Trials: same vs. switch) by 3 (Element: gesture switched vs. word switched vs. object switched) mixed-model ANOVA was conducted with Sex, Age, and Element as between subjects factors and Test Trials as a within subjects factor. This analysis did *not* reveal a significant main effect for Element $F(2, 36) = 1.03, p = .37$. Most importantly, a significant Age by Test Trials by Element interaction did not emerge, $F(2, 36) = 1.09, p = .35$, indicating that the 12-month-olds formed associations between all three of the elements and noticed when one of the elements, regardless of whether it was the gesture, word, or object, was changed from the combinations previously presented during habituation.

Individual Looking Times. An examination of individual infant’s looking times during the test trials was conducted to determine if the pattern of results could be attributed to a small portion of the sample in each age group with robust looking times. A difference score was calculated by subtracting an infant’s looking time to the same test trial from his or her looking time to the switch test trial. Infants that demonstrated a positive difference score of 1.5 seconds or more were considered to

have detected at least some degree change in the labels-object combinations. Nineteen of the 25 (76%) 12-month-olds detected a change using this criterion, whereas only 11 of the 23 (48%) 14-month-olds provided similar evidence of detecting the change using this criterion ($p = .07$, Fisher's exact test, two-tailed test). Although this result approaches but does not reach statistical significance, it is indicative of a trend.

Receptive Vocabulary. Similar to Experiment 1, we examined whether the number of words in the infants' receptive vocabularies, as reported on the MacArthur CDI (Fenson et al., 2000), may shed insight into the above findings. The 12-month-olds were reported, on average, to have 24 words ($M = 23.8$, $SD = 14.0$ words, range 5-47 words) in their receptive vocabularies. The 14-month-olds were reported, on average, to have 28 words ($M = 28.0$ words, $SD = 10.5$, range 11- 49 words) in their receptive vocabularies. The infants' average number of words in the their receptive vocabularies was subjected to a 2 (Age) by 2 (Sex) between-subjects ANOVA and did not reveal a significant main effect of Age, $F(1, 38) = 1.02$, $p = .32$. No other main effects or interactions yielded significant results. Similar to Experiment 1, a subsequent regression analysis revealed that the degree to which the infants detected the change in the labels-objects pairings could not be predicted from the number of words they were reported to understand, $\beta = .115$, $t(36) = 1.66$, $p > .10$, and accounted for little if any of the variance in the difference scores, $R^2 = .07$, $F(1, 36) = 2.75$, $p > .10$.

To address the possibility that the developmental changes in infants' abilities across both experiments is attributable to differences in overall vocabulary size, we subjected the average number of words in the infant's receptive vocabulary to a 2 (Age) by 3 (Condition: Gesture-Object, Word-Object, Gesture-Word-Object) between subjects ANOVA. The analysis yielded a significant main effect of Age, $F(2, 89) = 6.70$, $p < .01$, $\eta_p^2 = .07$, indicating that across both experiments, 14-month-olds ($M =$

27.60, $SD = 15.51$) were reported to have significantly more words in their receptive vocabularies relative to 12-month-olds ($M = 20.48$, $SD = 12.46$). No other main effects or interaction yielded significant results. Thus, the difference in results across both experiments and between both age groups cannot be attributed to differences in their receptive vocabularies.

Speed of Processing Analyses Across Experiments. Additional analyses were conducted examining infants' rate of processing across both experiments in an attempt to pinpoint the mechanisms responsible for the developmental changes in infants' ability to form arbitrary label-object relations. A preliminary analysis indicated that infants' looking time throughout habituation did not differ as a function of sex, both $F_s < 1$, p 's $> .10$. As a result, subsequent analyses were conducted collapsing this variable.

In order to determine whether infants' speed of processing played a major role in their level of processing (i.e., individual vs. relational), we examined infants' average looking time to reach the habituation criteria across experiments. A 2 (Age) by 3 (Condition: Gesture-Object, Word-Object, Gesture-Word-Object) between-subjects ANOVA failed to yield a significant main effect of Age, $F = .254$, $p = .62$, or Age by Condition interaction, $F = .822$, $p = .44$. Figure 4.6 presents mean looking times during habituation as a function of age and condition.

Planned comparisons were conducted within each age group to further assess the infants' pattern of results as function of processing speed. For each age group, we conducted a one-way (Condition: gesture-object, word-object, gesture-word-object) between-subjects ANOVA on the average looking time to habituate. For 12-month-olds, the analysis yielded a significant main effect of Condition, $F(2, 63) = 11.11$, $p < .001$, $\eta_p^2 = .27$. Planned comparisons revealed that the 12-month-olds in the *Gesture-Word-Object* condition took significantly longer to habituate than the 12-month-olds

in the *Gesture-Object* condition, $t(42) = -5.06, p < .001$ and the infants in the *Word-Object* condition, $t(42) = -2.02, p < .05$.

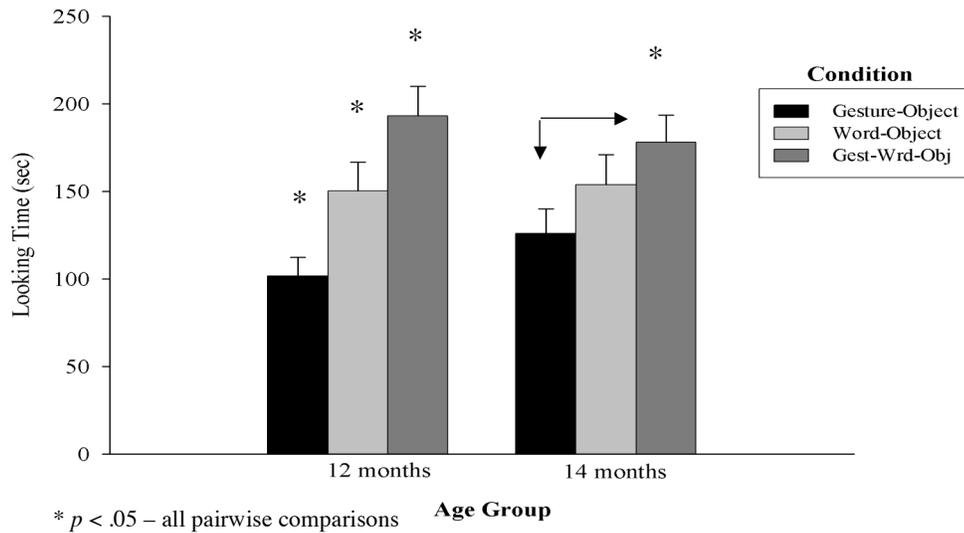


Figure 4.6. Mean Looking Time (in seconds) and Standard Error to Habituate as a Function of Age Group and Condition

Also, the infants in the *Word-Object* condition took significantly longer to habituate than the infants in the *Gesture-Object* condition, $t(36) = -2.36, p < .05$, two-tailed test.

For the 14-month-olds, this analysis also revealed a significant main effect of Condition, $F(1, 56) = 3.27, p < .05, \eta_p^2 = .10$. The planned comparisons demonstrated that the 14-month-olds in the *Gesture-Word-Object* condition took significantly longer to habituate than the infants in the *Gesture-Object* condition $t(39) = -2.53, p < .05$. However, the infants in the *Word-Object* condition, took equally long to habituate relative to the infants in both the *Gesture-Word-Object* and *Gesture-Object* conditions, $t < -1.5, ps > .15$.

To determine which particular aspect of the stimuli may have contributed to the speed by which infants habituated, we conducted additional analyses. We

specifically sought to determine whether the presence of an additional label (both words and gestures), or simply the presence of a word or a gesture affected infants' ability to process the label-object pairings.

One Label vs. Two Labels. The first analysis examined infants' processing time (i.e., looking time until habituation) when presented with one label (either gesture or word) compared to both labels in a 2 (Stimuli: One Label vs. Two Labels) by 2 (Age) between-subjects ANOVA. The findings revealed a main effect of Stimuli, $F(1, 118) = 17.50, p < .001, \eta_p^2 = .13$. Infants took significantly longer to habituate when presented with two labels ($M = 185.99$ s, $SD = 78.54$ s) than when presented with one, either a word or gesture ($M = 132.64$ s, $SD = 66.02$ s). No other main effects or interactions yielded significant results. Planned comparisons within each group revealed that both 12- and 14-month-olds took significantly longer to habituate when presented with two labels versus one, $t(61) = 3.85, p < .01, \eta_p^2 = .20$, and $t(59) = 2.13, p < .05, \eta_p^2 = .07$, respectively.

Presence of a Gesture. The second analysis compared the average looking during habituation between infants that were presented with a gesture, either alone or with a word (i.e., *Gesture-Object* condition + *Gesture-Word-Object* condition), relative to the looking times of infants who were presented with only a word paired with an object. This analysis highlighted the degree to which the mere presence of a gesture affected infants' processing time. A 2 (Stimuli: Presence of Gesture, Word Only) by 2 (Age) between-subject ANOVA did not yield a significant effect of Stimuli, $F = .01, p = .91$. Infants took equally long to habituate whether they viewed a gesture (i.e., gesture + gesture -word - $M = 153.73$ s, $SD = 77.51$ s) or not (i.e., word only - $M = 151.95$ s, $SD = 71.46$ s). No other main effects or interactions emerged as significant. Again, planned comparisons revealed that both the 12- and 14-month-olds demonstrated a similar pattern with both groups looking equally long during

habituation when presented with a gesture or a gesture combined with a word compared to when presented with just a word, both $F_s < 1$, $p_s > 1$.

Presence of a Word. The third analysis sought to determine whether the mere presence of a word affected infants' level of processing. To explore this, we conducted a 2 (Stimuli: Presence of Word, Gesture Only) by 2 (Age) between-subjects ANOVA on infants' average looking times during habituation. The analysis yielded a significant main effect for Stimuli, $F(1, 118) = 20.41, p < .001, \eta_p^2 = .15$. Infants took significantly longer to habituate when presented with a word (i.e., Word-Object + Gesture - Word-Object, $M = 170.99s, SD = 76.96s$) than when presented with only a gesture (i.e., Gesture-Object, $M = 113.83s, SD = 54.90s$). The planned comparisons within age revealed that both 12- and 14-month-olds took longer to habituate when a word was presented than when presented with only a gesture, $t(61) = 4.13, p < .01, \eta_p^2 = .22$ and $t(57) = 2.31, p = .05, \eta_p^2 = .09$, respectively. Taken together, the findings demonstrate that presenting a word, either in isolation or with a gesture, is particularly salient and required longer processing time than when a gesture was presented in isolation.

Discussion

The findings from Experiment 2 demonstrate that 12-month-olds, who were habituated to two different gesture-word-object combinations (e.g., “blicket” - <DOG> - Sun), detected when one of the elements (word, gesture, or object) was changed from the habituation to the test phase, providing evidence that they were able to attend to the relations between all three elements. Fourteen-month-olds did not provide similar evidence. When habituated to two different word-gesture-object combinations, 14-month-olds did not provide evidence of forming the associative links between the words, gestures, and objects.

These results are in sharp contrast to the findings of Experiment 1 as well as Werker et al. (1998) demonstrating that infants do not provide evidence of forming arbitrary links between words and objects when the auditory label is presented asynchronously with the movement of the object until 14 months of age. The 12-month-olds in the Experiment 2 provided reliable evidence that they *are* capable of attending to the relations (i.e., forming arbitrary label-object associations) in the absence of social cues and when presented with asynchronous movement of objects with two types of labels (i.e., gesture + word), an ability they failed to demonstrate in Experiment 1 when presented with only one type of label (i.e., gesture or word). This associative learning ability with arbitrary pairings between labels and objects has not been previously demonstrated with infants as young as 12 months.

The findings of Younger and Cohen (1986) provide similar evidence of relational processing with infants as young as 10 months. Specifically, 10-month-olds consistently demonstrated the ability to process the relation between three different attributes of hand drawn animals (e.g., body, tail, feet). However, it is important to note that the combinations of attributes (elements) used in the Younger and Cohen study (1) were completely visual and did not require the coordination of cross-modal input in the form of words, gestures, and objects as in the current study and (2) were not arbitrary. Nonetheless, the findings of Younger and Cohen (1986), in conjunction with the findings from the current experiment reveal that infants, younger than 14 months, can attend to the relation among multiple numbers of elements and that this ability is not specific to language. However, the findings from the current experiment are also the first to demonstrate that infants as young as 12 months *can* form arbitrary associative links with multiple types of labels (gestures and words) and objects in less than optimal conditions. What specifically can account for this newly revealed ability?

General Discussion

Effects of Processing Speed: 12-month-olds. The examination of infants' speed of processing during habituation shed some insight into the specific cues the infants' may have been sensitive to during the associative word-learning task. Based on the information processing model proposed by Cohen (1998), we would anticipate that longer processing times would be indicative of a *parts* or *individual* level of processing whereas shorter processing time would be indicative of a *whole* or *relational* level of processing. However, speed of processing does not seem to account for the levels of processing for the 12-month-olds in the current study. Recall that the 12-month-olds presented with both a gesture and word simultaneously took significantly longer to habituate than the 12-month-olds who were presented with either a word or a gesture. Considering that only the 12-month-olds presented with both a gesture and word simultaneously demonstrated what Cohen (1998) would define as a relational level of processing (i.e., forming associations between words, gestures, and objects), it appears that the additional time looking during habituation (i.e., more exposure to pairings) was actually beneficial and not indicative of a lower level of processing. Interestingly, the 12-month-olds that were presented with a word paired with an object also took longer to habituate than the 12-month-olds that were presented with a gesture, yet neither of these groups of infants demonstrated the ability to attend to the relation between the elements. Thus, infants' speed of processing during habituation provides less insight into their level of processing compared to the presence (or absence) of particular types of labels.

One possibility is that in the current study, longer looking times during habituation are more representative of increased attention due to the complexity of the stimuli (Robinson & Sloutsky, 2007) as opposed to less mature levels of processing (Colombo et al., 1995). For example, the unimodal presentation of gestures with

objects may have been perceived as less complex than the cross-modal presentation of words with objects, which in turn was perceived as less complex than the bimodal synchronous presentation of both words and gestures with objects. This proposal is supported by the finding that the 12-month-olds that were presented with only the gesture and the object (i.e., unimodal presentation) may have been less attentive throughout habituation, as evidenced by similar looking times across both the familiar and novel test trials. However, the 12-month-olds in both conditions that had the presentation of words, either alone (i.e., cross-modal) or combined with gestures (i.e., synchronous bimodal) reliably dishabituated to the completely novel stimulus.

Robinson and Sloutsky (2007) report similar findings with infants accumulating more looking time to stimuli with cross-modal pairings (i.e., auditory sound or word and visual object) compared to stimuli that were unimodal (i.e., two visual objects). These researchers found that more accumulated looking time (i.e., increased attention) to the particular stimuli did not predict the degree to which the infants exhibited a novelty preference. Based on these findings, it seems plausible that for the 12-month-olds in the present study, speed of processing during habituation is more reflective of increased attention to the complexity of the stimuli rather than the qualitative level of processing (i.e., relation vs. individual).

Impact of Labels: 12-month-olds. What role, if any, did the various types of labels have on 12-month-olds' speed and level of processing? Given that the 12-month-olds only provided evidence of forming associative links when given two labels simultaneously paired with objects, the additional label and perceptual cue (i.e., temporal synchrony) may have contributed to this ability. However, it is somewhat unclear as to the independent contribution of each of these additional sources of information.

The examination of processing time as a function of the presence (or absence) of a particular type label revealed that for 12-month-olds, more is more. The infants took longer to habituate and demonstrated the ability to form associative links when given two labels than when given only one (either word or gesture). Although the infants failed to provide evidence of forming arbitrary associations with either words or gestures paired with objects, they did not respond to the presence of gesture in the same way that they responded to the presence of word. For example, they took longer to habituate (i.e., required more processing time) when a word was presented whether it was combined with a gesture or presented alone than when a gesture was presented alone. This extended processing time was not evident when a gesture was presented (in isolation or with a word) relative to the processing time required when only a word was paired with an object. This highlights the increased significance for 12-month-olds of auditory words over visual gestures. However, the mere presence of a word was not sufficient in facilitating their ability to form arbitrary associative links in less than optimal conditions. For that, they benefited from more than just a word. Specifically, they seemed to benefit from an additional label and perceptual cue.

Role of Temporal Synchrony: 12-month-olds. It is possible that having two labels presented across two sensory modalities increased the processing load for infants and subsequently heightened attention. This heightened attention, in combination with a salient perceptual cue (i.e., temporal synchrony between the labels), may have prevented infants from becoming overloaded and allowed them to properly focus their attention to the *relation* between the labels and the objects. Arguably, the addition of temporal synchrony between the labels, in and of itself, may have been sufficient to assist the 12-month-olds' ability to form associative links between the words, gestures, and objects. This possibility is supported by previous research demonstrating that infants younger than 12 months form cross-modal sound-

object associative links when a sound is presented in temporal synchrony with the movement of the object (Gogate & Bahrick, 2001). Specifically, the temporal synchrony between the labels may have highlighted to the infants that both the word and gesture “go with” the object. However, this perceptual cue was not available for the 12-month-olds in the single label conditions, which may have contributed to the differences in the findings. Thus, the 12-month-olds’ ability to form arbitrary associations between labels and object in the current study may have been enhanced by the temporal synchrony between the words and the gestures (i.e., synchronous bimodal input). Future research is needed to pinpoint the degree to which temporal synchrony alone was sufficient to assist infants in forming the associative links. However, these findings do demonstrate that temporal synchrony specifically *with the movement of the object* is not necessary as argued in previous research (Gogate et al., 2000)

These findings suggest that 12-month-olds are able to use salient perceptual cues, such as temporal synchrony, to process incoming information whether the information is specific to language or not. Numerous studies have found that infants, younger than 12-month-olds, are capable of forming associative linkages with various types of amodal or temporally synchronous nonlinguistic input (e.g., facial features, causal relations, rhythm and tempo, correlated attributes; Bahrick, 1984; Bahrick & Lickliter, 2004; Cashon & Cohen, 2004; Cohen & Oakes, 1993; Younger & Cohen, 1986). However, since the presentation of the label-object pairings in the current study was truly arbitrary and more indicative of associative word learning abilities, the finding that 12-month-olds were able to recruit their general perceptual sensitivities to temporal synchrony to assist them in forming the arbitrary relations provides some support for the contention that early word learning abilities may be driven by more general learning mechanisms (Cohen, 1998; Hollich et al., 2000; Werker & Yueng,

2005). However, future research is needed to further explore this possibility.

Specialization for Words: 14-month-olds. The findings from the 14-month-olds further support the proposal that early word learning skills may be based initially in general cognitive or perceptual domains and through experience become more language specific or specialized. Specifically, the 14-month-olds' pattern of looking during habituation provides some evidence that by 14 months, infants have already become particularly attentive to and focused on auditory words as sources of information. For instance, the 14-month-olds were equally attentive during habituation (i.e., took equally long to habituate) when presented with either a word or gesture paired with an object, yet only engaged in relational processing with word-object pairings. It is possible that the ambiguity of the gesture heightened their attention during habituation, however this heightened attention was not enough to override 14-month-olds' acquired preference for words over gestures as potential associates with objects. As a consequence of this acquired preference or specialization, the infants may have found the associative learning task particularly ambiguous and challenging when presented with a gesture instead of a word paired with an object.

Role of Temporal Synchrony: 14-month-olds. This suggestion is further supported by the finding that the 14-month-olds also failed to provide evidence of forming associative linkages with both words and gestures simultaneously presented with objects. For instance, the salient perceptual cue of temporal synchrony did not appear to exert a similar effect on the 14-month-olds' ability to form arbitrary linkages between specific types of labels and objects as it did for the 12-month-olds. It is apparent that the infants were particularly attentive and responsive to this additional perceptual cue because they accumulated significantly more looking time during habituation when presented with two labels in temporal synchrony than when presented with only one label asynchronously. This increased amount of exposure did

not translate into a more advanced level of processing (i.e., relational) as it did for the 12-month-olds. We propose that because 14-month-olds have come to rely specifically on auditory labels as potential associates to objects, the presence of temporal synchrony between the word and the gesture may have actually distracted or hindered their ability to attend to the relations between the gestures, words, and objects.

Complementary evidence that the addition of temporal synchrony and the visual gesture may have made the associative learning task particularly more challenging for the 14-month-olds comes from the examination of the individual patterns of looking as a function of which specific element “switched”, the word, gesture, or object. Considering that 14-month-olds demonstrate the ability to form associative links when presented with only words paired with objects, if the 14-month-olds who were habituated to both words and gestures paired with objects were able to attend solely to the word-object pairings and ignore the presence of the gesture, then the infants who had either the word or the object “switch” during the test trials should have demonstrated the ability to successfully form the associative links. Whereas this strategy would have been successful for these particular subsets of infants, it would not have been successful for infants that had the gesture “switch” during the test trials.

The findings of this detailed examination revealed that 14-month-olds’ associative word learning abilities in less than optimal conditions is tenuous. Specifically, of the 15 infants in the subgroups that had either the word or the object switch, only about half looked for 1.5 seconds or more. This proportion of the infants who did look slightly longer to the switch relative to the same test trial was the same for the group that had the gesture switch. Thus, the 14-month-olds were not able to ignore the presence of the gesture or the temporal synchrony and attend only to the word-object pairings. This suggests that the 14-month-olds were not able to override their specialization for words in lieu of the more basic perceptual cue of temporal

synchrony. The addition of temporal synchrony and a visual gesture appears to have made it difficult for the 14-month-olds to attend to the relation between any of the pairings. Hence, 14-month-olds' associative word-learning abilities in less than optimal conditions appear to be tenuous and restricted to auditory words.

Precursors to Word Learning: Developmental Change. The findings from the current set of experiments provide complementary support for the proposal that early word learning abilities begin with more general cognitive and perceptual mechanisms and through experience become more specialized and focused on language-specific mechanisms or cues (Hollich et al., 2000; Werker & Yeung, 2005). More precisely, previous research has shown that 12-month-olds fail to provide evidence of being able to attend to the relations between words and objects when the pairings between the two are arbitrary (i.e., asynchronous with the movement of the object; Werker et al., 1998). Werker and colleagues (1998, 2002) argue that investigating these abilities in less than optimal conditions and with stimuli that are more representative to the arbitrary nature of word-object pairings in infants' word learning environments provides essential insights into the cognitive and perceptual precursory skills required for subsequent word learning. However, the findings from the current project demonstrate that 12-month-olds *can* recruit their perceptual sensitivity to temporal synchrony in order to form arbitrary associative linkages between labels and objects. However, by 14-months, infants appear to have shifted their focus or attention from more general perceptual cues, like temporal synchrony, to more language-specific cues like auditory words.

Given that it took the 12-month-olds significantly longer to habituate when presented with a word (either alone or paired with a gesture) than when presented with only a gesture, it is not that 12-month-olds were completely agnostic to the types of labels presented. They clearly demonstrated an increased interest to auditory words

over visual gestures. Yet, this sensitivity and attentiveness to auditory words was not enough to assist them in attending to the relation between the words and their corresponding objects. To do that, they relied on temporal synchrony and an additional label. Thus, at 12 months, words maintain infants' attention, but not enough to override the seemingly more informative and salient perceptual cue. This suggests that although 12-month-olds are not as specialized or committed to words over other cues as 14-month-olds, the period between 12 and 14 months appears to be one of transition for early word associative learning abilities (Werker et al., 1998).

The transition from more flexibility in the types of cues infants rely on to more restricted reliance on language specific cues found in the current project is line with the findings of Namy and Waxman (1998) and Woodward and Hoyne (1999). Recall that Namy and Waxman (1998) found that 18-month-olds were equally receptive to both words and gestures as labels for objects but 26-month-olds only accepted words as appropriate labels. The authors contend that the 18-month-olds were more flexible and not as committed to words as labels for referents, but the 26-month-olds, who were more specialized in their word learning abilities, required additional training to acquire the visual gestures as labels for objects.

Likewise, Woodward and Hoyne (1999) found a similar developmental change in infants' reliance on auditory words as opposed to other nonlinguistic sounds as labels for objects. In their study, 13-month-olds demonstrated the ability to link both words and sounds to objects but 20-month-olds only provided evidence of linking words with object. The findings from both the Namy and Waxman (1998) and Woodward and Hoyne (1999) studies, in conjunction with the findings from the current project, provide some evidence that infants' abilities that provide the scaffolding for early label learning may be more flexible and less specialized and through experience, become more restricted and specialized to language-specific cues,

like auditory words in the case for infants learning a spoken language.

It is important to bear in mind that the infants in the Woodward and Hoyne (1999) and Namy and Waxman (1998) studies were provided with optimal word-learning conditions rich social and linguistic cues in an attempt to examine infants' word/symbol learning abilities. In addition, these studies tested more advanced abilities in that the infants were required to both map and generalize the labels in a more referential sense (Oviatt, 1980). In contrast, the infants in the current project were tested in less than optimal conditions without social support or linguistic cues (e.g., syntax) in order to test infants' early associative learning skills that are essential, but not specific to early word learning. Hence, the abilities tested in the current study are less cognitively advanced (i.e., recognitory abilities) than those tested in the previous studies. The differences in the nature of the word learning tasks between the current study and the studies of Namy and Waxman (1998) and Woodward and Hoyne (1999) may account for why the 14-month-olds in the current study demonstrated more of a specialization for auditory words, yet the 13- and 18-month-olds in the Woodward and Hoyne and Namy and Waxman studies demonstrated more flexibility with regard to the type of label they were able to map onto objects.

In sum, the findings from the current study are the first to demonstrate that infants as young as 12 months can form arbitrary label-object associations with words, gestures, and objects without the benefit of social support. In addition, this study replicates and extends the findings of Werker et al. (1998) to include infants' abilities to form arbitrary associative links with visual gestures in addition to auditory words. Moreover, the current study provides additional support for Werker et al.'s (1998) hypothesis that by 14 months, infants have become more specialized in their abilities and rely on more language-specific cues to assist them in early word learning.

These findings also support Hollich and colleagues (2000) contention that the

process of early word learning begins with children's ability to readily form associative links between words and referents and is gradually replaced by their growing dependency on social and linguistic cues in their environment regarding the meaning of words. Further, Hollich et al. (2000) insist that the prerequisite abilities for word learning change as children develop and acquire more experience with their linguistic and social environment, and thus theories of early word learning must consider that mechanisms driving early word learning skills at one stage of language learning may have a much less influential role at another stage. The current study also demonstrates that infants' early precursory abilities appear to be influenced by particular types of cues (e.g., temporal synchrony, multiple sources of input) and not solely a function of a "mundane" mechanism, like attention (Samuelson & Smith, 2000). Without question, attention played an important role in the findings of the current study, yet attention alone cannot account for the pattern of results.

If early word learning abilities were based simply on infants' ability to form simple one-to-one associations, we would have expected both the 12- and 14-month-olds to form associative links simply by attending to those elements that co-occurred. On the other hand, infants also did not require specific linguistic cues in the form of syntax (e.g., Look at the "toma") to aid them in their ability to form the arbitrary label-object links, demonstrating that they were able to recruit and use more domain-general mechanisms and cues. Importantly, infants also did not require a word-learning context rich with social cues to form the appropriate label-object linkages. The findings of the current study demonstrate that infants rely on and use different types of perceptual and linguistic cues depending upon where they are in the developmental trajectory of their early word learning abilities.

Even though the ability to detect and form relations between word and objects is a necessary precursor to word learning (Oviatt, 1980; Samuelson & Smith, 2000;

Werker et al., 1998), and arguably the ability to form relations between gestures and object is a necessary precursor to gesture learning, it is not certain whether infants in the current project viewed the pairing of the novel gesture and novel word as linguistic. However, considering that previous research has demonstrated that infants' sensitivity to bimodal input that is temporally synchronous is not specific to linguistic input (Bahrick, 2001; Bahrick & Lickliter, 2000, 2004), it is plausible that the 12-month-olds would have demonstrated a similar ability with other types of labels (e.g., pictograms, nonlinguistic sounds) presented in temporally synchrony. Future research is needed to address the degree to which infants' abilities extend to additional types of input. In particular, it is unclear as to whether younger (e.g., 6- or 10-month-olds) infants can also utilize and benefit from salient perceptual cues in associative word learning tasks. Likewise, it remains unclear as to whether older (e.g., 18- or 26-month-olds) infants' would be able to override their specialization for words over other types of labels in lieu of more basic perceptual cues, such as temporal synchrony. Future research exploring these questions is needed to further elucidate the nature and characteristics of the precursory abilities that provide the scaffolding for later language learning.

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CHAPTER 5

SUMMARY

The exploration of infants' early perceptual and cognitive abilities related to the acquisition of language as a function of input provides valuable insight into the nature and characteristics of the mechanisms driving early language acquisition. For word learning in particular, several precursory perceptual and cognitive abilities have been put forth as the necessary scaffolding upon which a child's lexicon is built (Echols & Marti, 2004, Werker & Yeung, 2006). Oviatt (1980) has proposed that one of these precursory perceptual and cognitive skills (i.e., label-referent associative links) requires less advanced levels of understanding and is ultimately the foundation upon which more advanced cognitive abilities (e.g., referential learning) that require higher levels of symbolic understanding are acquired. Oviatt (1980) posits that once children have mastered these lower level abilities, they then go on to master the skills required to referentially map and generalize labels to referents (referential understanding). Therefore, children's early referential word learning abilities are based on earlier developing perceptual and cognitive abilities.

Echols and Marti (2004) have eloquently proposed a model by which early word learning occurs. For example, Echols and Marti (2004) contend that children's path to early word or symbol learning begins with the precursory ability to (1) perceptually discriminate between relevant speech contrasts and is followed by (2) infants' ability to parse the speech stream. Once these units are parsed from the speech stream, they must then be (3) associated with the appropriate referent (Echols & Marti, 2004; Oviatt, 1980; Werker et al., 1998). Much of the empirical support for this particular hypothesis has been focused on spoken language and the acquisition of auditory words. However, we know substantially less about the nature of the

precursory abilities related to a visual-gestural language and the acquisition of visual gestures. More succinctly, we do not know *if* and *how* these proposed abilities extend to signed languages with visual input. The goal of the current dissertation was to provide insight into the ways in which these previously proposed perceptual and cognitive skills required to learn words might extend to input presented visually (e.g., manual gestures or ASL signs). Specifically, the current project examined two of the three proposed precursory abilities (i.e. discriminating relevant contrasts and forming associative linkages), proposed by Echols and Marti (2004), using ASL signs, manual gestures, auditory words, or both gestures and words presented simultaneously.

Current Set of Experiments

The present set of experiments explored the characteristics of the perceptual and cognitive abilities proposed to underlie early label learning as a function of auditory and visual input. Using the Echols and Marti (2004) model as a guide, the project sought to examine whether the perceptual and cognitive requirements for the early label learning (e.g., words or gestures) were similar whether the input is visual, auditory, or both. The current set of experiments tested infants' ability to discriminate between the relevant contrasts of ASL signs (Chapter 2 & 3) as well as the degree to which infants are able to form associative links between visual gestures, auditory words, or both with objects (Chapter 4).

Perceptual Sensitivities to ASL Sign Contrasts

The first two projects (i.e., Chapters 2 & 3) directly examined prelingual infants' ability to distinguish between the relevant contrasts of a visual-gestural language, such as ASL. Considering that there is a substantial amount of research documenting young infants' acute perceptual sensitivities to auditory speech contrasts (Werker & Tees, 1984; Werker & Fennell, 2004), it was important to gain similar insights into how analogous sensitivities to sign contrasts may provide the basis by

which visual-sign languages are acquired. The present studies provide an empirical starting point for the exploration of the developmental trajectories of infants' visual perceptual sensitivities to sign contrasts in ASL (i.e., location, movement, handshape).

Sensitivity to ASL Sign Contrasts: Two-Handed Symmetrical Signs

The goal of the first experiment (Chapter 2) was to examine the degree to which hearing infants' perceptual sensitivities provide the scaffolding required for the acquisition of a visual-gestural language, such as ASL. Hearing ASL-naïve 6- and 10-month-olds' ability to discriminate changes in three primary parameters (location, handshape, movement), as well as a grammatical marker (facial expression) in ASL with two-handed symmetrical signs articulated in neutral space, was tested. The findings revealed that the infants detected changes in location and facial expression. However, the infants' failed to provide evidence of detecting changes in handshape or movement.

Implications & Conclusions. These findings are consistent with previous research on the early production errors of young learners acquiring ASL, demonstrating that toddlers typically produce their first signs in the correct location but with incorrect handshapes and movement. As a result, these findings suggest that these early production errors may not be due solely to motoric constraints, as previously suggested (Conlin, Mirus, Mauk, & Meier, 2000), but also may be a function of children's ability to *perceive* certain parameters more accurately than others (Bonvillian & Siedlecki, 2000). Not only were hearing ASL-naïve infants able to use their perceptual abilities to detect changes in the ASL contrast of location, articulated manually (i.e., location), but they also demonstrated that they are able to recruit similar abilities to detect changes in contrasts articulated on the face. Grammatical contrasts articulated on the face are not used in English (Reilly, McIntire, & Bellugi, 1991), thus the ASL-naïve infants in the current study would not

have been familiar with this particular type of grammatical marker. Based on these findings, it can be concluded that with no prior experience with a visual-gestural language, prelingual infants possess the perceptual sensitivities required for the acquisition of a visual-gestural language, however experience with this type of input must play a pivotal role. With experience with a visual-gestural language, infants likely acquire the ability and become more effective in accurately discriminating between each of the relevant parameters of ASL.

It is important to bear in mind that since the infants in the current experiment were naïve to ASL, it is unlikely that they perceived these gestures as “linguistic”. Perhaps, a more general perceptual mechanism rather than a mechanism specific to language is responsible for guiding these early perceptual sensitivities. Since the infants did not demonstrate the ability to successfully discriminate between each of the relevant parameters equally well, it is also important to not only consider the role of experience in fine-tuning infants’ perceptual sensitivities to ASL sign contrasts, but also (1) the number of hands articulating the sign, and (2) where in the signing space the signs are articulated. In order to assess the role that these factors may have played, a second project was conducted.

Sensitivity to ASL Sign Contrasts: One-Handed Signs on the Face

Experiment 1. In the first experiment of this second project the same paradigm was used in the above-mentioned experiment to test hearing ASL-naïve 6- and 10-month-olds’ ability to discriminate between the parameters of ASL with one-handed ASL signs articulated near the face. Infants were habituated to a one-handed ASL sign (i.e., FORGET), and tested with different one-handed ASL signs that varied in only one parameter. The findings revealed that when presented with a one-handed ASL sign articulated on the face, both 6- and 10-month-olds were sensitive to changes in handshape and only the 10-month-olds were sensitive to changes in movement.

Interestingly, neither age group provided evidence of detecting changes in location or facial expression.

Experiment 2. The purpose of the second experiment was to address the previous methodological limitations found in the first experiment as well as further examine whether changes in particular parameters were more easily discriminable by ASL-naïve infants than others. The experimental design utilized in the current experiment allowed for a detailed examination of whether infants' ability to detect particular parameter changes varies as a function of which parameters change or remain constant using unmodified ASL signs articulated on the face.

Six-month-olds were assigned to one of three conditions and habituated to one sign (e.g., HOME) and tested with 3 novel signs that varied in one or more parameters. The findings replicated the results from the first experiment. Six-month-olds demonstrated the ability to discriminate between changes in handshape. Unexpectedly, only the male infants reliably demonstrated the ability to detect changes movement. Neither the male nor female infants provided evidence of detecting changes in location. The findings also revealed that infants appeared to detect changes when handshape was the only parameter to vary, yet did not demonstrate similar sensitivity when handshape varied with location or movement.

Implications & Conclusions. These findings from each of the above mentioned studies provide important insights into the nature of infants' pre-existing perceptual sensitivities to the sign contrasts relevant to a visual-gestural language, such as ASL. These findings, in conjunction with the findings from the previous experiment (Chapter 2), provide additional support for the argument that infants' possess acute perceptual sensitivities and are able to recruit these sensitivities in discriminating changes in the formational parameters of a visual-gestural language, like ASL. In addition, the current set of studies also demonstrates that hearing ASL-

naïve infants are sensitive to grammatical facial expressions used in ASL but not used in spoken languages.

In sum, prelingual ASL-naïve infants' possess the requisite perceptual skills that serve as the building blocks for the acquisition of a signed language. However, infants' ability to exhibit these sensitivities vary as a function of (1) the number hands used to articulate the gestures, (2) where in the signing space the gestures are articulated, and (3) the degree of change in the parameters. These findings draw attention to the role of experience. At some point along the path of learning a signed language, repeated exposure to that type of linguistic input must fine tune infants' abilities to detect changes in parameters that may be more difficult to detect without experience depending on the characteristics of the sign (i.e., one-handed vs. two-handed). Thus, experience with a visual-gestural language, like ASL, can only serve to foster and enhance infants' already adept perceptual sensitivities. Nonetheless, a task for future research is to explore and document the developmental trajectory of these abilities and compare this trajectory with spoken languages.

Developmental Changes in Label-Object Associative Learning

Another important step along the path to early word learning, proposed by Echols and Marti (2004) is infants' ability to form associative links with labels and referents. This ability has been repeatedly examined with various types of auditory word-referent relations (e.g., causal relations, Casasola & Cohen, 2000; spatial relations, Casasola & Wilbourn, 2004; word-object relations, Werker et al., 1998). However, much less is known about infants' ability to associate other types of labels, such as visual gestures or gesture-accompanied speech, with referents, which may be a necessary prerequisite for early sign learning. Thus, the purpose of the final study (Chapter 4) was to assess the infants' ability to form associative links between words, gestures or both and objects. An additional goal of this study was to further investigate

the developmental change from 12- to 14-months reported in previous research (Werker et al., 1998) with auditory words and objects. And thus, two experiments were conducted.

Experiment 1. In the first experiment, 12- and 14-month-olds' ability to form arbitrary associative links between words and objects or gestures and objects was tested. Infants were habituated to two different word-object or gesture-object pairings and tested with a trial that maintained one of these pairings (i.e., same trial) and another trial that violated one of these pairings (i.e., switch trial). The findings revealed that the 14-month-olds, but not 12-month-olds, demonstrated the ability to form the associative linkages between words and objects. However, neither the 12- nor 14-month-olds provided evidence of forming similar linkages between the gestures and objects.

Implications & Conclusions. The results of this experiment are the first to replicate and extend those of Werker et al. (1998). For instance, the finding that 14-month-olds are able to attend to the relations between words and objects, but do not demonstrate the ability to extend this skill to visual gestures and objects provides support for Werker et al.'s claim that by 14 months, auditory words have attained a unique status as potential associates to referents. In addition, the findings from the current experiment support the proposal that infants' ability to engage in this level of associative word learning develops somewhere between the ages of 12 and 14 months.

Interestingly, the 12-month-olds failed to provide evidence of being able to engage in this type of associative word/sign learning with either auditory words or visual gestures. This indicates that 12-month-olds' failure to demonstrate this ability in previous studies (Werker et al., 1998) cannot be specifically attributed to a lack of cross-modal (auditory to visual) mapping skills. In the present study, 12-month-olds failed to provide evidence of forming unimodal gesture-object mappings (visual to

visual) as well. As a result, it is possible that 12-month-olds' require additional sources of information and support from their environment (e.g., perceptual cues or social cues) to form associations between various types of input and objects in less than optimal conditions; a hypothesis tested in a second experiment.

Experiment 2. Twelve- and 14-month-olds' ability to form arbitrary associative links when given multiple sources of information (i.e., gestures simultaneously presented with words with objects) was tested. The 12- and 14-month-olds were habituated to two different gesture-word-object combinations and tested with trials that maintained one of the previously presented combinations. Surprisingly, the findings revealed that 12-month-olds were able to form associative linkages with both words and gestures paired with objects. The 14-month-olds did not provide similar evidence.

Implications & Conclusions. These findings are the first to demonstrate that infants as young as 12 months, *can* form associative linkages without the benefit of social scaffolding, but must be provided with additional sources of information. Also, these findings provide further support for the proposal that 14-month-olds are particularly focused on and have become specialized to auditory words as associates to objects. Given that the 12-month-olds were able to successfully use the multiple sources of information (gestures and words) presented in temporal synchrony to assist them in forming the linkages and the 14-month-olds did not provide such evidence, these findings further support the possibility that the addition of a salient perceptual cue (i.e., temporal synchrony) and visual gesture (i.e., added information) may have confused or distracted the 14-month-olds, but assisted the 12-month-olds. In sum, the current set of experiments provides compelling evidence that it is not that infants' ability to form associative linkages with brief exposure to the input and in lieu of social cues develops somewhere between 12- and 14-months, but rather infants'

ability to use and rely on various types of cues (multiple sources of input, and temporal synchrony) appear to develop and change between 12- and 14-months.

In particular, the temporal synchrony between the word and gesture may have assisted infants in detecting the relations between both words and gestures by highlighting that both the word and the gesture “go with” the object (Bahrlick & Lickliter, 2000). This heightened attention may have ultimately allowed infants to process and encode the information more richly. Daniels (1996) suggests that the combination of signals (visual gesture + auditory word) may create multiple imprints on the learner’s memory. This explanation is further supported by research demonstrating that from a very young age infants are adept at perceiving and deciphering multimodal information (Bahrlick, 2001). Bahrlick and Lickliter (2000, 2002, 2004) have outlined a hypothesis which contends that in early infancy, information presented that is temporally synchronous across multiple modalities selectively recruits and directs attention as well as highlights perceptual differences more effectively than information presented unimodally. Thus, when unimodal information is presented, infants’ attention may be more broadly distributed across various properties specific to one particular modality (Bahrlick, Lickliter, & Flom, 2004). The findings from the current study provide some support for this hypothesis in that the infants who were exposed to unimodal information (i.e., *Gesture-Object* condition) in the absence of temporal synchrony did not detect the relations between the gestures and objects.

Even though the ability to detect relations between labels and objects is a necessary precursor to word learning, it is not certain whether infants in the current project viewed the novel gesture and novel word as linguistic or symbolic. However, the facilitative effect of the simultaneous presentation of the auditory and visual stimuli may be the same regardless of whether the infants’ viewed the words or

gestures as labels for the objects. Previous research has demonstrated that infants' sensitivity to bimodal input that is temporally synchronous is not specific to linguistic input (Bahrick & Lickliter, 2000, 2004). Numerous studies have shown that infants are able to form similar types of association links between nonlinguistic elements if these elements are presented bimodally and are temporally synchronous (Bahrick, 2001; Bahrick & Lickliter, 2000, 2004). However, a task for future research is to pinpoint the degree to which the 12-month-olds relied *specifically* on the temporal synchrony between the words and gestures, the multiple source of input, or the combination of the two.

Taken together, the findings from the current set of experiments support the hypotheses that when faced with the challenge of learning a new word, children actively coordinate and evaluate various types of cues in order to solve the word-to-world mystery (Bloom & Tinker, 2001). Moreover, infants' ability to process and use various types of input in an associative learning task depends on how far along they are on the path to acquiring language. As children develop and gain more experience with their surrounding linguistic environment, the degree to which they give weight to certain cues over others changes depending on the nature and combination of cues (Hollich, Hirsh-Pasek, & Golinkoff, 2000).

Prevalent Themes

Taken together, this entire project extends the extant literature on early cognitive and perceptual abilities that might lay the foundation for early word, sign, and language learning. In particular, the findings from each experiment underscore two particular themes: (1) infants' possess acute perceptual sensitivities that they can recruit for tasks related to early word or sign learning and (2) experience with a particular type of input (e.g., spoken language) appears to influence infants' perceptual sensitivities and abilities in a more focused and specialized way.

Perceptual Sensitivity. Infants in each of the current sets of experiments were able to recruit their general perceptual and cognitive abilities to assist them in discriminating between relevant sign contrasts and in forming associative links in less than optimal word or sign learning conditions. Considering that none of the children had previous experience with a visual-gestural language and were unlikely to view the input as “linguistic”, it is plausible that they were able to utilize a more general learning mechanism (e.g., perceptual sensitivity to motion, temporal contiguity, and temporal synchrony) as opposed to a learning mechanism specific to language. Arguably, both of these precursory abilities may not only assist infants’ early word or sign learning, but also may provide the necessary scaffolding upon which language (either signed or spoken) is built.

Experience. The findings from the current project also highlight the pivotal role experience *must* play in fine-tuning infants’ existing cognitive and perceptual skills. For example, the findings from Chapters 2 and 3 demonstrate that although infants’ acute perceptual sensitivities allow them to discriminate changes in the relevant contrasts of a visual-gestural language when they have not had previous exposure, these sensitivities are tenuous and appear to be influenced by various factors (e.g., number of hands signings, where gestures are articulated). Certainly, the more experience infants have with visual-gestural input, the more likely they are to sharpen these sensitivities and acquire the ability to discriminate changes in each relevant parameter (i.e., handshape, location, movement) equally well. Undoubtedly, accomplishing this is as fundamental in the acquisition of a signed language as it is fundamental in the acquisition of a spoken language with the discrimination of speech contrasts. As such, the findings from Chapters 2 and 3 suggest that when it comes to infants’ perceptual sensitivities and the acquisition of signed language, more exposure and experience may be beneficial. In other words, “more may be more”.

However when it comes to infants' ability to form associative linkages between words, gestures, and objects, experience seems to have an inverse effect on their abilities (Chapter 4). More specifically, it appears that the more experience infants have with a particular type of input (e.g., auditory words), the less likely they are to demonstrate the ability to form associative linkages with other types of input, such as manual gestures, as was the case with the 14-month-old infants' results presented in Chapter 4. One interpretation of the finding, that there is a developmental change in infants' ability to form associative links with various types of input between 12- and 14-month-olds, is that with experience comes a more specialized reliance upon more familiar types of cues, such as auditory words.

Alternatively, this specialization towards auditory words may have made the less familiar cues (i.e., manual gestures or gesture-accompanied speech) seemingly ambiguous and confusing to the 14-month-olds. Therefore, 12-month-olds' lack of specialization (i.e., ability to use the multiple sources of input and salient perceptual cues) in forming linkages between words, gestures, and objects may actually be a result of being at a stage developmentally where they are more flexible in using multiple sources of input, particularly when they are presented with a salient perceptual cue, such as temporal synchrony. The 14-month-olds' reliance on a particular type of cue (i.e., either a word or gesture) may have made the task substantially more challenging when presented with unfamiliar types of input, like gestures. Thus, experience with an auditory language appears to affect infants' ability to form associative linkages between labels and objects in a "less is more" type manner. Thus, when assessing the perceptual and cognitive abilities that underlie the acquisition of both signed and spoken languages, it is important to not only consider the nature of the task in relation to where infants are developmentally, but also to consider the complexity and characteristics of the input.

In sum, the current project provides another piece, albeit a small piece, to the language acquisition puzzle. With regard to early word learning, the findings from the current set of experiments suggest that the prerequisite perceptual and cognitive abilities put forth by Echols and Marti (2004) are not specific to language and can be applied to various types of input, such as manual gestures or ASL signs. Furthermore, the findings from the current study also support the suggestion that infants' experiences or interactions with their environment (e.g., particular types of input) influence these early perceptual and cognitive abilities in a way that fine-tunes and guides language development (Bates & Dick, 2002; Bates, O'Connell, & Shore, 1987; Piaget, 1955; Werker & Yeung, 2005) for *both* signed and spoken languages. Thus, the acquisition of language, whether signed or spoken, may just be the result of wonderfully coordinated interactions between infants' ever-changing perceptual and cognitive abilities and their ever-changing environment, similar to Piaget's (1955) suggestion long ago. Hopefully, it won't take us another 40 years to know for sure.

Future Directions

Examining the development of language across modalities provides valuable insight into the possible mechanisms guiding language development, whether that language is signed or spoken (Bonvillian, Orlansky, & Folven, 1990; Lillo-Martin, 1999; Volterra & Iverson, 1995). It has been well established that, at the perceptual level, signed and spoken languages are processed similarly in the classic language areas of the brain (Emmorey et al., 2003; Hickok, Love-Geffen, & Klima, 2002). However, the majority of the research demonstrating similar left-hemisphere specialization for both signed and spoken languages has been conducted with adults, both hearing and deaf (Hickok, Bellugi, & Klima, 1998).

As a consequence, we are substantially less knowledgeable about how this type of left-hemispheric specialization develops in infancy for signed languages (see Mills,

Coffey-Corina, & Neville, 1993, 1997; Mills, Plunkett, Prat, & Schafer, 2005 for a research on left-hemispheric specialization for spoken languages). The literature has shown that similar cortical regions (e.g., Broca's area in the left inferior frontal cortex) traditionally thought of as classic language areas are recruited for different types of cognitive processes and in particular, processes which may be fundamental in early sign learning (Hickok et al., 2002; Levanen, Uutela, Salenius, & Hari, 2001). For example, Broca's area, which has traditionally been thought to function specifically for language production, has been implicated in manual action observation and semantic selection (Willems & Hogaart, 2007).

Perception of Signs. So, when does a gesture become a sign, neurologically? How much experience is required for a sign to be interpreted linguistically and be processed in the classic language areas? To date, it remains unclear as to *when* and *how* this left-hemispheric specialization occurs in monolingual deaf children learning a signed language or bilingual/bimodal hearing children learning both a signed and spoken language. With infants exposed to and acquiring a spoken language, such as English, the well-established behavioral data has repeatedly shown that the decline in infants' sensitivities to non-native speech contrasts between the ages of 7- to 11-months (Werker & Tees, 1984) is similarly demonstrated neurologically using ERP measures (Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005). Do infants acquiring a signed language demonstrate a similar neural commitment to the sign contrasts of their native language from the ages of 7- to 11-months? An important task for future research is to establish a similar body of research using both behavioral and electrophysiological measures for the perception of native and non-native sign contrasts.

Another fruitful area of inquiry would be to examine whether there are any perceptual and cognitive advantages or disadvantages, behaviorally and

neurologically, of early exposure to this type of input and do these advantages or disadvantages extend to other domains, such as spatial memory and numerical knowledge. In other words, will hearing children exposed to a visual-gestural language early in language learning exhibit different trajectories of development in other domains?

We do have some insights into the possibilities with studies conducted with deaf and hearing adults. Several studies have examined the effects of sign language exposure, gesture-accompanied speech, and gesture on non-linguistic cognitive functioning and memory in adults (Arnold & Mills, 2001; Cattani & Clibbens, 2005; Cattani, Clibbens, & Perfect, 2007; Capirci, Cattani, Rossini, & Volterra, 1998; Courtin, 1997; Courtin, 2000; Emmorey & Kosslyn, 1996; Emmorey, Kosslyn, & Bellugi, 1993; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Guttentag & Schaefer, 1987; Ronnberg, Soderfeldt, & Risberg, 1998). The motivation for most of this research is based primarily on anecdotal reports of deaf signers' more advanced visual-spatial abilities and memory, relative to hearing non-signers'.

Many have argued that repeated exposure to a visual-gestural language, such as ASL enhances visual processing and memory for particular types of items for both hearing and deaf signers (Arnold & Mills, 2001; Cattani et al., 2007; Emmorey & Kosslyn, 1996; Emmorey et al., 1993). For instance, Arnold and Mills (2001) and Cattani and colleagues (2007) found that exposure to a signed language significantly affected participants' performance in a memory task with pairs of faces, shoes, abstract shapes, and common objects. Both hearing and deaf signing adults performed better than their hearing non-signing peers in correctly locating and describing the faces, shoes, and abstract shapes. However, the groups yielded similar results for the common objects. The lack of a difference in the participants' memory for common object condition supports the notion that easily nameable objects are encoded

linguistically and are not affected by different types of environmental input (Cattani et al., 2007). But what does this pattern look like in *prelingual* infants who may or may not already have “names” for the nameable objects?

Cattani and team (2007) propose that the visual skills necessary for the acquisition of a signed language are transferred to other non-linguistic abilities. More specifically, the researchers claim that in both sign language comprehension and production, perceivers/signers must memorize seemingly abstract movement of the hands. And thus, in their study, the signers’ memory for abstract shapes required the activation of their ability to process and “construct abstract representations of visual objects” (Cattani et al., 2007. p.120). Hence, skills acquired through language learning are effectively recruited for non-linguistic tasks. These findings leave open the question of whether the ability to recruit these skills is directly related to the amount of experience with a signed language: another task for future research.

Associative Word Learning Skills. In the current research, we found that hearing infants exposed to a spoken language appear to become specialized towards auditory words as associates with objects at about 14 months. One particular question of interest surrounds the other types of cues (e.g., sounds, pictograms, hand movements, emotional facial expressions) that infants may use to form associative links between words, sounds, or gestures with referents (e.g., objects). For example, if 14-month-olds were given a tone instead of an auditory word paired with a sign and an object, would they demonstrate the ability to form the 3-way associative linkage, similar to the way the 12-month-olds did with given a word, gesture, and an object? If so, this would indicate that 14-month-olds were able to use the multiple sources of input and a salient perceptual cue to form the linkages, providing additional support for the hypothesis that auditory words have a unique status by 14-month-olds.

Another interesting question surrounds the specific role that the multiple

sources of input (words and gestures) and the temporal synchrony between the word/gesture presentations played in facilitating 12-month-olds' ability to form the 3-way associations. One way to do this would be to disentangle the two by presenting both a word and a gesture paired with an object but present these combinations asynchronously. If 12-month-olds demonstrate a similar ability to form the 3-way associations without the salient perceptual cue of temporal synchrony, then this would provide additional evidence in support of the "more is more" hypothesis in associative learning tasks at 12 months. However, if the 12-month-olds do not demonstrate a similar ability then this would provide additional support for the saliency and importance of a perceptual cue, such as temporal synchrony.

A third area of inquiry is to examine the degree to which the precursory ability of forming label-object associative links extends to various types of word or sign learning tasks. More specifically, the incorporation of gesture-accompanied speech in experimental paradigms with social cues would provide insight into the role of social referencing and input on infants' ability to form associative linkages. Further, it would be fruitful to explore the degree to which various types of cues (e.g., social, perceptual, multiple types of labels) affects infants' ability to engage in the more advanced level of symbolic understanding. In other words, how and when can infants and toddlers understand that a gesture, sign, word, pictogram, or nonlinguistic sound can *stand for* various types of referents such as objects, actions, or spatial relations? Although the current project helps to shed some light onto the ways in which infants' early cognitive and perceptual skills extend across modalities and potentially lay the foundation by which both signed and spoken languages are acquired, there is still much work to do.

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