A STUDY OF THE PHONETIC DETAIL USED IN LEXICAL TASKS DURING INFANCY

by

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ABSTRACT

In speech perception tasks young infants show remarkable sensitivity to fine phonetic detail. Despite this impressive ability demonstrated at early ages, studies of word learning in young toddlers indicate that they have difficulty learning similar-sounding words. This evidence suggests that infants may not be using this speech-perception ability as they begin to learn words. The studies in this thesis were designed to test how infants’ speech-perception skills are used in the early stages of word learning.

Using a simple habituation procedure, we have shown in earlier work that 14-month-old infants, but not younger infants, are able to learn the association between novel nonsense words and objects (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). The current series of experiments used this simple habituation procedure to test whether infants use minimally contrastive phonetic detail in the very early stages of word learning.

In this thesis, I show that 14-month-old infants, who are on the cusp of word learning, while still able to discriminate phonetically-similar words in a speech perception task, do not incorporate minimally contrastive phonetic detail when first forming word-object associations. Infants of 8 months of age do, however, appear to use fine phonetic detail in a similar task. Taken together, these results suggest a decline in the phonetic detail used by infants as they move from processing speech to learning words. I hypothesize that this decline may occur as infants move from treating the task as one of speech perception to treating the task as one of word learning.
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Introduction

One of the most amazing facets of infant development is the acquisition of language. The infant moves from understanding not a word spoken around him at birth, to speaking his first words within a year (see Jusczyk, 1997 for a review of this process). While much research has focused on speech perception in the early months of life and the nature of the child's first spoken words, there remain many gaps in our understanding of language acquisition in the first years of life. One of these gaps concerns the nature of the early lexical representation. Detailed study of how infants begin to use contrastive phonological information\(^1\) to mark differences in word meaning in the initial stages of word learning is missing from the literature. Young infants discriminate contrastive phonetic detail in speech perception tasks, but the degree of phonetic specification employed as the infant moves to begin word learning is not yet known. A careful reading of the existing research yields conflicting predictions about what speech perception skills the child is able to use during this transition period.

A popular notion in the child phonology literature is that in the early stages of word learning, lexical representations are only globally specified (e.g., Charles-Luce & Luce, 1990, 1995; Ferguson & Farwell, 1979; Menyuk & Menn, 1979; Studdert-Kennedy, 1986; Walley, 1993). Previous research with children almost 2 years of age supports this hypothesis. Barton (1978) found that children must be very familiar with phonetically

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\(^1\) The phonology of a language refers to that component of a grammar which is concerned with the rule-governed combinations of speech sounds. It is concerned with the relationship between the linguistic elements and their production. Contrastive phonological information is the information that indicates which differences in speech sound productions indicate a difference, or contrast, in meaning for that particular language.
similar words before they are able to access the fine phonetic detail necessary to discriminate between them in a functional manner. This theoretical stance posits that only with the acquisition of an increasing number of phonological contrasts in the lexicon is there pressure to provide greater detail in the phonological representation.

Reports such as those mentioned above, which suggest that infants have difficulty with similar sounding words, stand in contrast to the literature on phonetic perception in infancy, which shows that young infants can detect, discriminate, and categorize phonetic detail, including detail which is not readily discriminated by adults. By the end of the first year of life, infants' phonetic perceptual sensitivities reflect considerable influence from their native language. This influence is evident both in a preference for highly frequent phonetic patterns and in a narrowing of initial discrimination abilities to match the contextual distribution of phonetic information in the input. It would seem that these changes in ability would move the child into a position wherein acquisition of the phonetic detail of words in the native language would be facilitated. But, as mentioned above, evidence from child phonology research leads us to suspect otherwise.

The apparent lack of continuity between the sensitivities demonstrated by infants in perceptual tasks and those used by infants in linguistic tasks raises some interesting questions. Recent findings, which suggest that the amount of phonetic detail infants detect and use in word recognition tasks actually decreases between 7 1/2 and 11 months of age, also do not fit with the notion of increased perceptual honing of phonetic sensitivity in preparation for word learning. This pattern could be explained if we hypothesize that the forms being recognized prior to 11
months of age should not be considered "words", as there is no semantic information involved, but rather should instead be considered to be recognized phonetic sequences.

In order to explore this hypothesis, I conducted a series of studies designed to test if the phonetic detail infants extract and use in speech perception tasks is different than the phonetic detail they extract and use in word learning tasks. I used tasks that require the formation of word-object association in order to be passed, a speech perception task that does not support the formation of any association between a label and semantic information to be passed, and one task that could be passed either as a speech-perception or as a word-learning task. I controlled for age in order to allow clear conclusions to be drawn. Before discussing the experiments I will first review the literature that led me to design the research program described in this thesis.

Phonetic perception in infancy

The exquisite sensitivity to phonetic detail shown by young infants is one of the most exciting facts in child language acquisition, suggesting early abilities that will greatly aid the infant as he begins to learn a language. Infants' sensitivity to contrastive phonetic detail was first revealed in a number of studies in which infants were tested on their ability to discriminate syllables differing in only a single phonetic feature (for a review see Jusczyk, 1997). For example, infants of 2-6 months can discriminate minimal phonetic differences in the initial consonant of a
CV (Consonant-Vowel)\(^2\) syllable (e.g., Eimas, 1975; Morse, 1972), in the medial consonant in a VCV syllable (Jusczyk, Copan, & Thompson, 1978; Jusczyk & Thompson, 1978; Karzon, 1985), in the final consonant in a VC or CVC syllable (Jusczyk, 1977), and in vowels (Swoboda, Morse, & Leavitt, 1976; Trehub, 1973).

Infants demonstrate categorical-like speech perception as they discriminate a change in voice onset time (VOT)\(^3\) which adults perceive as a change from /ba/ to /pa/, but fail to distinguish equal sized changes in VOT between two different /ba/ or between two different /pa/ syllables (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). Also, infants can recognize phonetic equivalence while ignoring irrelevant phonetic variation. For example, Kuhl (1979) showed that infants aged 4-16 weeks, when presented with a background set of instances of one vowel category, were better able to detect a change in the vowel color (e.g., from /a/ to /i/) than a change in the pitch contour of the vowel. Furthermore, when presented with a series of CV syllables that are either consistent in the initial consonant (e.g., /bi/, /ba/, /bu/) or the following vowel (/bi/, /di/, etc.), both neonates and infants of 2 months of age can detect a change in the consistent element under ideal testing conditions (Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy, & Mehler, 1988; Jusczyk, Bertoncini, Bijeljac-Babic, Kennedy, & Mehler, 1990).

The results from several cross-language studies have shown that this sensitivity to fine phonetic differences is apparent in early infancy even for non-ambient languages. A study by Streeter (1976) demonstrated

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\(^2\) Throughout this thesis "C" will be used to indicate "consonant" and "V" will be used to indicate "vowel".

\(^3\) VOT is defined as the time interval between the articulatory release of the stop consonant and the onset of vocal fold vibrations.
that 4-month-old Kikuyu-learning infants can discriminate /ba/ from /pa/ even though that phonetic distinction is not used in Kikuyu. Similar findings have been reported by a number of other authors for a number of other non-native contrasts (Aslin, Pisoni, Hennessy, & Perey, 1981; Best, McRoberts, & Sithole, 1988; Lasky, Syrdal-Lasky, & Klein, 1975; Trehub 1976; Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Lalonde, 1988; Werker & Tees, 1984).

In acquiring a phonological system, infants must modify their initial language-general sensitivities to match the phonetic variation that is relevant in their language-learning environment. Considerable research with adults has shown that, unlike young infants, adults often have difficulty discriminating phonetic differences that are not used to contrast meaning in their native language (for reviews see Strange & Jenkins, 1978; Werker, 1995). It thus appears that at some point in development infants stop discriminating non-native phonetic variation and begin to attend selectively to only that phonetic detail which is used to contrast meaning in their ambient language.

The time course of this decline in infants’ discrimination of non-contrastive phonetic variation has been investigated. Using the Conditioned Head Turn Procedure (see Werker, Shi, Pegg, Polka, Desjardins, & Patterson, 1998 for a full description of this method), Werker and Tees (1984) found that although English-learning infants aged 6 to 8 months can discriminate two non-native place contrasts with ease, English-learning infants aged 10 to 12 months, like English-speaking adults, have difficulty. This evidence of a change within the first year of life from language-general to language-specific phonetic perception has been replicated using additional contrasts (e.g., Best, 1989, 1993; Polka &
Werker, 1995; Werker & Lalonde, 1988), and has also been found using a habituation-dishabituation discrimination procedure (Best & McRoberts, 1995). In the case of vowel contrasts, there is evidence of language-specific changes even before 6 months of age (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994). Thus, there is robust and replicable evidence that by the end of the first year of life, infants continue to distinguish contrasts from the ambient language, but are unable to distinguish contrasts that are not part of the native language.⁴

The impact of native-language phonology on phonetic perception is also apparent in the report that infants show selective sensitivity to only that phonetic variability which is used to distinguish meaning in their native language (Pegg & Werker, 1997). Although there is variability present in the input to infants, not all of this variability is used to contrast meaning. Pegg and Werker investigated English infants' and adults' ability to discriminate the syllable /da/ from the syllable created by removing the [s] from a /sta/ syllable. /Sta/ without the [s] ([t=ə]) is perceived to be an instance of /da/ by English-speaking adults. English adults labeled the [da] set and the [t=ə] set of stimuli as equally good instances of the English phoneme /da/, but were nevertheless able to discriminate the two sets of stimuli. Notably, approximately half of the English-learning infants aged 6-8 months of age were also able to discriminate the two sets of stimuli, but nearly all the English infants of 10-12 months of age failed this discrimination task.

⁴ The age-related change does not occur for all non-native consonant contrasts. It has been shown that discrimination remains high for contrasts that do not map on to the native language phonology, and hence exert no pressure on the speech perception system to reorganize (Best, McRoberts, & Sithole, 1988).
Pegg and Werker (1997) suggest that by 10-12 months of age infants are sensitive not only to the phonetic characteristics of their native language, but also to the syllabic context in which that phonetic variation occurs. The infants may have learned that in English an unaspirated \([t^\text{a}]\) (which one gets by removing the \([s]\) from a production of /sta/) does not occur in the same context as \([t^n\text{a}]\). Thus, when presented with the \([t^\text{a}]\) phonetic variant in syllable initial position, infants treated it as an instance of the closest context-appropriate form, which is /da/. Further investigation is required to determine whether or not this recognition of syllabic-specific phonetic variation reflects knowledge of language-specific phonemes. However, as will be reviewed in the next section, there are recent data that suggest that the convergence of several perceptual and cognitive capabilities could allow the emergence of something like a phoneme at this time.

A number of other studies have shown that by 10 months of age infants have acquired an enormous amount of detail about the language-specific contexts in which phonetic information occurs. By this age, infants show a preference for listening to lists of words that conform to the phonotactic regularities of their native language over words that violate these regularities (Friederici & Wessels, 1993; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993).\(^5\) By 9-10 months infants whose ambient language is English also recognize and prefer word lists that are made up of high probability over low probability legal English phonotactic sequences (Jusczyk, Luce, & Charles-Luce, 1994). The ability to pull out this kind of phonotactic detail may be assisted by prosodic bootstrapping.

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\(^5\) Phonotactic rules specify the ways in which phonemes can be combined and ordered in the syllables of a particular language.
Infants of 9 months demonstrate a preference for the dominant English stress pattern, strong-weak (SW), over the non-dominant weak-strong (WS) pattern (Jusczyk, Cutler, & Redanz, 1993). Knowledge of phonotactic regularities plus language-specific stress patterns may be just what is required for infants to make use of the kind of contextual detail infants displayed in the study by Pegg and Werker (1997). These studies reveal that across the first year of life infants progress from an initial sensitivity to considerable phonetic detail (at least in syllabic context) to a selective focus on the kind and location of phonetic variability that occurs in the native language.

Recognition of familiar phonetic forms

To begin to understand how speech perception abilities relate to mapping sound to meaning, it is important to examine the development of infants' sensitivity to word-sized units. Jusczyk and Aslin (1995) have conducted research to examine the age at which infants begin to recognize words in a fluent speech context. In this endeavor, they developed a procedure in which infants are first familiarized to a small number of CVC words in isolation, and are then tested to see if they recognize the words when the words are embedded in a sentence context. Using this procedure, they can also test infants in the reverse direction, familiarizing infants with words embedded in sentence context and then testing with lists of words. Recognition of familiar words is assumed if during the test phase infants listen longer to familiar words (either in lists or passages) than to unfamiliar foils. In a series of experiments, Jusczyk and Aslin (1995) found that infants as young as 7 1/2 months are able to recognize
monosyllabic words that they have heard before, even when the words are embedded in sentence context, either in the familiarization or test phases. This ability was not evident in 6-month-old infants.

Jusczyk and Aslin (1995) were then interested in determining the level of detail used by 7 1/2-month-old infants in recognizing familiar words. They tested infants in the same procedure but used training and test words that differed in only the place of articulation of the initial consonant. Infants treated the modified words as unfamiliar, suggesting that their representation of the training words included detailed phonetic information that specified the initial consonant. A recent finding reported by Tincoff and Jusczyk (1996) using the same procedure suggests that at 7 1/2 months of age infants are also sensitive to changes in the final consonant.

Jusczyk and Aslin's (1995) finding of detailed phonetic representations in 7 1/2-month-old infants appears to contrast with research reported by Hallé and de Boysson-Bardies (1996), who found that 11-month-old French-learning infants did not appear to use detailed phonetic representations of familiar words. In an initial study, Hallé and de Boysson-Bardies (1994) tested infants’ preference for high versus low frequency words and found a robust preference for high frequency words by 11 months of age. In a second series of studies, Hallé and de Boysson-Bardies (1996) examined the phonetic detail infants used in recognizing these words by modifying the phonetic characteristics of the high frequency words. They found that if the modification involved a change in only the voicing or only in the manner of articulation of the initial consonant, 11-month-old infants treat the modified words as equivalent to their familiar word counterparts. Only when the initial consonant was
removed from familiar words did infants show some evidence of detecting the change. Hallé and de Boysson-Bardies interpret these findings as suggesting that at 11 months of age the representation of familiar words is underspecified. That is, it may be that information about syllable frame and vocalic nucleus is represented [e.g., (C)V(C)], however detailed phonetic information specifying the identity of the initial consonant is absent.

How can we reconcile Jusczyk and Aslin's conclusion that detailed representations are being used in word recognition at 7 1/2 months and Hallé and de Boysson-Bardies's conclusion that at 11 months of age infants are not utilizing such detailed representations? First, there are potentially important differences between the tasks. Although infants in both studies were tested in very similar conditions, Jusczyk and Aslin included a familiarization phase during which infants were familiarized to a set of two CVC words. In contrast, Hallé and de Boysson-Bardies did not first familiarize infants to the stimuli. Instead, Hallé and de Boysson-Bardies used exposure in the natural input as the factor influencing familiarity. For Hallé and de Boysson-Bardies, familiar words are those that occur frequently in the input and are common in the first words of children. Thus the very different exposure conditions could account for these discrepant findings – the subjects in Jusczyk and Aslin's study may have been more familiar with the words and thus are more likely to notice a change.

Hallé and de Boysson-Bardies propose other possibilities that might account for the greater access to phonetic detail shown by Jusczyk and Aslin (1995). Their primary hypothesis is that infants of 11 months, in contrast to infants of 7 1/2 months, are recognizing words that are
associated with some meaning rather than meaningless familiar speech. This listening strategy may predispose the infants to adopt a more holistic, less analytic processing strategy, in which equivalence categorization rather than fine discrimination is of primary importance.

Recent work by Myers and colleagues (Myers, Jusczyk, Kemler-Nelson, Charles-Luce, Woodward, & Hirsh-Pasek, 1996) helps tease apart the possible explanations for the evidence for phonetic detail at 7 1/2 but not at 11 months of age. In a series of studies investigating infants' ability to extract words from the speech stream, Myers and colleagues (1996) found that prior to 11 months of age, English-learning infants primarily use the cue of SW stress to pull out words. Not until 11 months of age are infants able to combine phonotactic and allophonic detail with stress cues to detect word boundaries at the onset of WS words. On the basis of these findings, Myers and colleagues suggest that before 11 months of age, infants in word recognition tasks are probably detecting a unit closer to the prosodic foot, rather than an actual word. It is only after this age that infants actually abstract "words".

Associating the lexical form with semantic information

The critical issue of when infants begin abstracting "words" returns us to the issue of the relationship between speech perception and word processing. It would seem that at the point in development when infants are able to extract actual words from the speech stream, combined with the phonetic discrimination skills demonstrated at a younger age, they are poised to begin to distinguish one word from another. In other words,

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6 Noncontrastive variation of a phoneme.
they may now be ready to construct a system of phonological contrasts. As argued above, considerable phonetic detail is required to accurately segment the lexical items from the speech stream. But, as suggested by theoretical work in both adult and child phonology, the representation required to distinguish one word from another could be quite minimal - particularly at the early stages of lexical acquisition (Walley, 1987). Thus when infants are extracting and using words, rather than simply extracting prosodic feet or some other pre-lexical acoustic unit, the representation required might be considerably less detailed.

It is possible that as infants begin to “comprehend” words, that is, when they begin to include semantic content as part of their lexical processing, a type of processing that is different than that seen at earlier stages emerges. This notion is consistent with the results from studies (reviewed below) designed to test phonemic perception in young children. These studies suggest, similar to the results reported by Hallé and de Boysson-Bardies (1996), that when first learning words, infants are not using the detailed phonetic information that is readily detected in speech perception tasks.

There is considerable evidence that once children are listening to speech to distinguish lexical items, the representation used in comprehension appears to be considerably less detailed than that used in speech perception. In order to determine this, researchers have studied infants' ability to learn phonetically-similar words. The rationale behind this is that if infants are not using complete representations, these words will be confusable for the infants. While some research of this type has been done, the nature of the lexical representation used during early word learning has not been fully studied.
Work by Shvachkin (1948/1973) and later by others (Barton, 1978; Garnica, 1973) has examined the ability of young children to learn phonetically-similar words. Many of the studies that have been done were motivated not by the question of whether learning similar-sounding words is difficult for young children, but rather by Jakobson's (1941/1968) hypothesis of a universal order of acquisition of phonemic contrasts (e.g., Garnica, 1973; Shvachkin, 1948/1973). Nevertheless, we can examine this literature for information related to the questions addressed in this thesis.

Shvachkin (1948/1973) tested Russian-learning children 1 to 2 years of age using minimal pairs. Shvachkin first taught young children three nonsense words as labels for novel objects: two phonetically-dissimilar words, and one word containing a minimal opposition to one of the words. After he determined that they had learned the associations, he placed all three objects with nonsense labels in front of the children and tested for discrimination. He tested discrimination of: (1) CV₁C vs. CV₂C, (2) C₁VC₃ vs. C₂VC₃, and (3) C₁VC₂ vs. VC₂. On the basis of his work, Shvachkin concluded young children are able to discriminate all the consonantal phonemes he tested in word-initial position before age 2;0.

Garnica (1973) followed up on the work of Shvachkin. In the pilot study Garnica taught English-learning children aged 1;5 to 3;5 puppet names which comprised a minimal pair (“Mr. C₁VC” vs. “Mr. C₂VC”). The child was presented with both objects and was asked to perform a task with one of the pair. In a second study Garnica tested infants aged 1;5 to 1;10, using the above technique. On the basis of these two preliminary studies and the observation of great individual variability in the order of acquisition of phonemic contrasts in both of her studies and the differences between her
results and those of Shvachkin, Garnica concluded that there is no universal order of acquisition.

The contribution of Shvachkin and Garnica's work has been minimized by a lack of information about their procedures such as the number of trials required, etc. What is known about the procedure, however, is that it was a complicated and time-consuming procedure with high endurance and cognitive demands placed upon the young children. There also exists the possibility of experimenter bias, as the experimenter was not blind to the condition being tested. Barton (1978) criticizes both the Shvachkin and Garnica studies for small sample sizes, inappropriate statistical treatment of the data, the possibility that the experimenter was not blind to the stimuli being tested, the lack of a reliability assessment, and inadequately familiarizing the children with the stimuli before testing.

Eilers and Oiler (1976) also examined discrimination of phonetically-similar word pairs. They used pairs of stimuli in which one member of the pair was a familiar word and the other was a similar-sounding unfamiliar word. They reported that infants aged 1;10 to 2;2 were able to perform a discrimination task if the words differed in at least 2 phonetic features, but other discriminations were more difficult or impossible for the children. Eilers and Oiler do not report whether discrimination performance was related to how familiar children were with the “familiar” word.

Barton (1978) designed a series of studies in which he attempted to rectify the problems inherent in the previous studies. Children aged 2;3 to 2;11 were tested on minimal-pair discrimination of real words by being asked to match the word they heard to the appropriate picture referent. He tested 20 minimal pairs and found that infants were able to make most
discriminations. He attributed any failures to discriminate within a pair to the infants having not properly learned the words.

In a second study Barton (1978) examined the ability of infants aged 1;8 to 2;0 to retrieve the requested member of a minimal pair. He found children were able to correctly retrieve items when the words were very familiar to the children, even using contrasts that were reported by Garnica and Shvachkin to be difficult for children. He attempted to test children younger than 1;8, but found the task was too difficult for the children at this age.

Werker and colleagues (see Stager & Werker, 1998; Werker & Pegg, 1992) attempted to control the confounding of word familiarity and phonetic similarity that is present in previous studies. Results from these studies suggest that by 19 months, but not before, children can use minimally contrastive phonetic detail to distinguish one word from another. However, procedural problems and inconsistencies in the pattern of results necessitate further investigation.

A semantic hierarchy

The discrepancy between the findings reported by Hallé and Boysson-Bardies (1996) and those reported by Jusczyk and Aslin (1995) highlights a deep problem in the literature, namely identifying when an infant knows a "word". Ingram (1989) adapts McCarthy's (1954) discussion to outline the possible criteria that can describe "first words". The important dimensions include whether the word is comprehended or produced, and whether the word is pronounced correctly. Also important, and of direct interest to this thesis, is the issue of whether any meaning is
attached to the word. McCarthy proposes an item could be considered to be in the lexicon either when it still has variable meanings or when it has a meaning consistent with that of the adult. The most minimal definition of having any meaning associated with the word is that the meaning may be variable or unrelated to that of the adult meaning. What we see in the early lexical acquisition literature described above, however, is some instances in which there may be no meaning attached to the label. Of critical interest to the questions posed in this thesis is how the lexical representation is affected when the infant begins to associate some meaning with the label.

To help clarify the stages in acquiring new words, we (Stager & Werker, 1998) have constructed a theory of the developmental progressions involved in word learning, focusing on the dimension of associated meaning. In learning a new word, we hypothesize that infants progress from single syllable discrimination, to single syllable categorization and then to the recognition of familiar word forms. None of these early stages contain any association of meaning with the label. We might consider the representations used by infants in the Jusczyk and Aslin study (1995) to fall into this category. Infants then move to recognitory comprehension, then to referential comprehension and finally to productive language use. With recognitory comprehension comes some association of meaning with the label. The task of adding meaning to the representation requires additional work on the part of the infant. Infants need to solve the mapping problem between the words they have extracted from the speech stream and objects in the world. In experimental procedures that look at this stage of word learning some visual stimulus is associated with the auditory stimulus. In this initial
stage of incorporating meaning, the relationship is best considered a "goes with" understanding between word and object (Hirsh-Pasek & Golinkoff, 1996; Oviatt, 1980, 1982). This is the type tested by Shvachkin and others in their word comprehension task. In order to match the word and the object, children must understand that they go together, but they do not need to understand that the word can stand alone to symbolize the object. The next level is referential comprehension. It is only at this stage that the child may be considered to have reached the full "stands for" understanding (Hirsh-Pasek & Golinkoff, 1996; Oviatt, 1980, 1982), in which the ultimate use of language as a symbolic system can be observed. The task differences between stages are quite substantial, and we predict that while the use of fine phonetic detail might be seen in one stage it might not be used at the next.

Statement of the problem

The nature of the phonetic detail used during early comprehension has not been fully established. The tacit assumption has existed that the phonetic sensitivities that are evident in infant perception are reflected in the information used in early word learning. However, the body of evidence discussed above suggests that even though infants have remarkable speech perception capabilities that have been finely tuned to the properties of the native language, we might anticipate that young children in the early stages of word learning will have trouble learning phonetically similar words. The studies reviewed above suggest that, under many different testing conditions, children in the initial stages of word learning appear to confuse phonetically similar words. The studies
relevant to the task of phonemic perception conducted with older children seem to indicate that children are underspecifying, or not determining, the information they receive from the input in some way. Indeed these studies seem to indicate that infants are not using all the abilities that they demonstrated at a younger age.

However, the paradigms previously used to test children on phonemic discrimination may not present a clear picture of children's abilities. A critical problem in many of the above reviewed studies is that word familiarity was not controlled. These procedures required the child to show discrimination of words that they may have already been exposed to, and their demonstrated performance may simply reflect a familiarity effect. Indeed, as shown by Barton (1978), if children as young as 20 months know a word very well, they are able to use contrastive phonetic detail to distinguish the two minimal pair items. Thus it is possible that many of the reported results reflect differences in word familiarity rather than differences in the nature of the representation (see Ganong & Zatorre, 1980, for evidence of the effect of word frequency on phonetic discrimination in adults). Furthermore, even if previous studies on phoneme perception did control for word familiarity, they would still leave an unfilled gap in our understanding of the phonetic detail detected, represented, and used as children move from speech perception to word use. The previous studies on phoneme perception primarily tell us what kind of detail is readily accessed (or not) in the lexical entry, but they do not tell us whether or not children at the early stages of word learning are still able to detect contrastive phonetic detail. Additionally, the procedures used to test children on phoneme discrimination typically require the child to be able to understand and follow complex instructions. Thus,
some of the limits in performance may be related to cognitive load or other processing factors rather than the detection and use of phonetic detail. Previous procedures, such as those developed by Shvachkin (1948/1973) and Barton (1978), are not suitable for use with infants in the early stages of word learning.

The paradigms used by Jusczyk and Aslin (1995) and Hallé and de Boysson-Bardies (1996) are also problematic. It is difficult to compare their results directly. It has been hypothesized that infants perform differently at 11 months than at 7 1/2 months because the older infants are trying to attach some meaning to the words at 11 months and not before then. In order to test this directly, it is necessary to use a procedure that requires the infants to incorporate meaning in order to succeed at the task. The two procedures differed in the familiarization method used: Jusczyk and Aslin directly familiarized their infants, while Hallé and de Boysson-Bardies assumed familiarity based on prior experience. While it can be assumed that the older infants in the Hallé and de Boysson-Bardies have attached some meaning to the test words, we can not be sure of how much meaning. It is unlikely that there was any meaning involved for the subjects in the Jusczyk and Aslin study. The best test of the influence of associated meaning on the nature of the phonetic detail used would come from a comparison of infants at the same age, tested with words for which there is some meaning attached, and with words for which there is no meaning attached. I thus chose to examine phonemic discrimination in children as they first learn words within tightly controlled conditions, in which key variables such as item familiarity and the presence or absence of associated meaning are controlled.
A Test of Associative Word Learning

The laboratories of Cohen and Werker have developed a procedure that is ideally suited to assess the critical gap that separates word learning and prelinguistic perception (Werker, Cohen, et al., 1998). This procedure controls for item familiarity and exposure time. As well, it allows for tests of representational detail in both word-learning and simple discrimination. The procedure involves familiarizing infants to one or two word-object pairings. Following the familiarization phase, infants are tested on their ability to detect a change in the word, the object, or both. This procedure ensures complete control over word and object familiarity. This kind of associative task is believed to be simpler than tasks requiring clear evidence of referential comprehension (the child need not show evidence of a "stands for" relation in an associative learning task), but it does require that the infant use the word form in a minimally semantic way. We characterize performance of this task as being at the level of recognitory comprehension, or requiring a "goes with" understanding (see Werker, Cohen, et al., 1998 for a discussion). The task represents an ideal procedure for teaching infants new words and then examining their ability to detect and use contrastive phonetic detail as they begin the task of word learning.

In the standard condition in this procedure, infants are seated on their parent's lap in a testing room, and are shown two randomly alternating word-object pairings on a video monitor. For example, on one trial they will be shown Object 1 accompanied by Label 1. On another trial they will be shown Object 2 accompanied by Label 2. All labels are nonsense words, delivered in infant-directed prosody, with prosody
matched as closely as possible for the different labels. The presentation of these two trial types alternates in a semi-random fashion until the infant becomes familiar with the pairings (as evident in a decline in looking time). At this point, two types of test trials are presented: one involves the same word-object combination ("same" trial) and the other involves a switch in pairing, where, for example, Object 1 is now paired with Label 2 ("switch" trial). The dependent variable is looking time. It is expected that if infants have formed an association between the word and the object, they will show an increase in looking time to the "switch" trial over the "same" trial.

To interpret studies in which the infants could not detect a switch in the pairing we needed to be sure that infants were actually able to discriminate the words and objects, and that the difficulty arose for them only when trying to learn the association. To do this we devised a simpler control form of this procedure. In this simpler condition, infants are familiarized to a single word-object pairing (Object 1 and Label 1). Following familiarization, they are presented with two trials: one trial comprises a word-object pair identical to that seen in the familiarization stage ("same") and the other pair involves a change ("switch") in either the word (e.g., to Label 2), or the object (e.g., to Object 2). The former tests discrimination of the words, and the latter tests discrimination of the objects.

Results from a series of studies with infants of 8, 10, 12, and 14 months have helped to determine the conditions under which the task does and does not work. Using the standard version of this procedure (2 word-object pairings), we have found that infants of 14 months are able to learn the association between words and objects when the words used are
phonetically dissimilar; e.g., "li" and "neem" (Werker, Cohen, et al., 1998). When presented with two objects and two labels 8, 10-, and 12-month-old infants are unable to perform successfully in the task. Thus, infants younger than 14 months appear unable to rapidly learn a link between a word and an object. When tested in the simplified procedure (one word-object pairing) infants as young as 8 months can perform in this task: they detect the change to either a new word or a new object (Werker, Cohen, et al., 1998).

Given that 14 months of age represents the threshold for success in the word-object association task, I chose to conduct the studies reported here with infants of 14 months of age. At this age, infants have clearly begun to learn word object pairings in such a way that there is a significant semantic content associated with the words in the infants' vocabulary. Infants have also begun to show a strong interest in learning new words. The attention facilitation effect has been strongly established, as infants as young as 10 months of age demonstrate that the presence of a label increases their attention to the object (Baldwin & Markman, 1989). While it is known that word learning has begun by this age, it has previously been difficult to test these infants given the concern that failures at this age may reflect the difficulty of the tasks required by the procedure rather than failure to learn the words.
Experiment 1

Experiment 1 was designed to address whether infants represent sufficient phonetic information to notice a switch in the word-object pairing. Previous research in our lab has shown that 14-month-old infants are able to learn word-object associations for words that are phonetically dissimilar (Werker, Cohen, et al., 1998) using a procedure identical to the one described here. In this experiment, infants were habituated to two word-object pairs in which the words were phonetically similar, and were then tested for a dishabituation in looking time when either the object or the label was switched with that belonging to the other pair. Two test trials were presented: a "switch" trial, that contained a switch in either the label or the object, and a "same" trial, in which there was no switch in the pairing. It is important to note that the object and the word presented during the test trial were both familiar, and it is only the pairing that was changed. The order of presentation of these test trials was counterbalanced across orders. A pre-test trial was included to attract the infant's attention to the procedure. A post-test trial was also included so we could verify that the child was still paying attention, even if we saw no recovery during the test phase.

Predictions

If infants are able to form phonetically detailed word-object associations when the words are phonetically similar, they should dishabituate to a change in the word-object pairing. If infants are not using sufficient phonetic detail to notice the switch in pairing, then infants should not dishabituate to a change in the pairing. Comparison of
the "switch" and "same" test trials will therefore indicate whether infants are dishabituating to a change in the pairing.

Method

Participants

The subjects were 64 infants (32 male, 32 female) of 14 months of age (mean age, 14 months 16 days; range 14 months 1 day to 14 months 29 days). An additional 22 infants were excluded from the study because they were fussy (n = 11), their parents interfered in some way (n = 2), they were not visible to the coder (n = 6), they had a toy for part of the procedure (n = 1), they did not look during one of the test trials (n = 1), or because of equipment failure (n = 1). All infants were 38-42 weeks gestation and had a birth weight of between 2800 and 4200 grams. All infants came from homes in which English was spoken at least 80% of the time.

Subjects of the appropriate age were selected from the infant database in Dr. J. F. Werker's laboratory. These infants were recruited mainly through visiting new mothers at BC Women's Hospital, but also through voluntary response to public service announcements. At the time of recruitment, parents consented to be contacted about the possibility of participation. Participating infants were given an "Infant Scientist" t-shirt and diploma.

Stimuli

Audio stimuli.

The audio stimuli were infant-directed tokens, presented with different infant-directed speech (IDS) intonation. I chose to use IDS as it has been shown to be effective in gaining and maintaining infant
attention (Fernald, 1985; Werker & McLeod, 1989) and has been shown to facilitate word learning in infants (Fernald, McRoberts, & Herrera, 1991). The use of IDS is also thought to simplify discrimination for the infant (Karzon, 1985). The habituation stimuli were two nonsense CV labels: "bih" and "dih". These stimuli differ in the place of articulation of the initial consonant. An additional nonsense label, "pok", was presented during the pre- and post-test trials. The stimulus "pok" was chosen as it is maximally different from the habituation tokens. See Appendix A for further discussion of stimulus selection.

An English-speaking female recorded the tokens in a soundproof booth. To approximate IDS, the speaker was asked to imagine she was speaking to an infant. She produced seven exemplars of each syllable in an infant-directed, rise-fall intonational phrase. Each of the seven exemplars was approximately 0.7 s in duration, with a 1.5 s silent interval between exemplars, resulting in audio files that are 13.9 s in duration.

**Visual stimuli**

Two objects ("poky" and "roundy") made from brightly coloured modeling clay were used for the habituation and test trials and another object, a commercially manufactured water-wheel ("spinner"), was used for the pre- and post-test trials (Figure 1). At the distance tested, the objects take up a 13.50° vertical and 13° horizontal visual angle. The visual stimuli were videotaped against a black background and transferred to a Laser Disc format. The stimuli were taped moving back and forth across the screen at a slow and constant velocity ("roundy" = 14.34 cm/s; "poky"

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7 These stimuli can be phonetically transcribed as: /bl/ and /dl/.
8 This stimulus can be phonetically transcribed as: /pok/.
9 There is work by Fernald and Simon showing that IDS is different when an infant is present than when a speaker is imagining an infant to be present. However, the latter is more like IDS than typical ADS (Fernald & Simon, 1984).
The pre- and post-test stimulus rotated constantly at a moderate rate. The stimuli are the same as those used by Lloyd, Werker, and Swanson (1994). See Appendix A for further discussion of stimulus selection.

**Equipment**

The infant was seated on their parent's lap facing a Mitsubishi HC3905, 45 cm video monitor with 640 dot by 480 line vertical resolution. A BOSE 101 speaker was located below the monitor. A black cloth background that stretched the width and height of the room surrounded the monitor. The two side walls were bare of decoration. A gray striped tapestry was hung on the rear wall behind the infant. A single warm-tone fluorescent bulb dimly lit the room. The video monitor was located about 70 cm from the infants' eyes. Directly above the monitor was a Panasonic PV-5770K video camera. A 6 cm hole was cut in the black cloth to accommodate the camera lens.

To ensure the parent could not detect the audio or video stimuli being presented to the infant, two precautions were taken. The parent wore Koss Pro/4AA headsets over which female vocal music was played from a Panasonic RX-C5700 portable stereo. The parent also wore a visor (felt cloth hanging from a baseball cap) to prevent detection of the visual stimulus. This design ensured the parent was able to see the child and that the child was able to establish eye contact with the parent, if they desired.

A closed circuit system allowed the experimenter, located in an adjacent room, to record the child's behaviour on-line. The experimenter watched the child on a NECPM 1271-A monitor in the observation room and recorded the duration of the child's looking to the video stimulus by
pressing a designated key on the computer. At the beginning of each trial a flashing red light was presented. When the infant looked at the flashing light, the experimenter initiated the next trial by pressing a button on the computer. Presentation of the stimuli was controlled by custom software on a MacIIfx computer interfaced with a Sony 1550 Laser Disc Player. The video segment for each image from the laser disc player was synchronized with a digitized audio file by the computer and the signals were transmitted to the monitor and speaker (see Figure 2).

The computer stored the length of the infant’s visual fixation for each trial, as recorded by the experimenter, and produced a summary record of trial-by-trial fixation time.

Procedure

The parent or parents brought the infant into the lab, at a time scheduled by the research coordinator, such that the time did not conflict with the infant’s nap time. The procedure was explained to the parent or parents, who then signed a consent form. The infant and one parent were taken to the testing room and positioned for the experiment. The experimenter returned to the observation room to begin the procedure.

The infant was assigned to participate in a pre-selected order, chosen from a randomly sequenced list of possible orders. Four subjects were assigned to each of the 16 possible orders. These orders counterbalanced the pairing of each label ("bih"/"dih") with each shape (poky/roundy). They were also designed to counterbalance order of test trial ("same" before "switch"/"switch" before "same"). In addition they were counterbalanced for the type of switch between the test trials (switch in object/switch in word).
The infants were tested using a modified habituation paradigm, identical in structure to that used by Werker and colleagues (Werker, Cohen, et al., 1998). Each trial began when the infant fixated a flashing red light and each trial lasted for 14 s. On the first trial, infants were presented with a pre-test stimulus, the label 'pok' paired with the water wheel ("spinner"). During the habituation phase the infant was shown two word-object pairs (e.g., Pair A: "bih" and "roundy", Pair B: "dih" and "poky"). Every block of four trials contained two instances of each word-object pairing presented alternately in a semi-random order (ABAB, ABBA, BAAB, BABA, etc.). Looking time was calculated on-line, and when the average looking time across a four-trial block decreased to a preset criterion (sixty-five percent of the first block of four trials), the habituation phase ended. The infants participated in a minimum of 12 habituation trials and a maximum of 28 habituation trials.

When the habituation criterion was met the test phase began. This phase comprised two trials. One trial was a "same" trial, in which one of the pairings presented in the habituation phase was presented again (e.g., Pair A). The other trial was a "switch" trial and contained a novel pairing, composed of one of the objects paired with the label it was not paired with during the habituation phase (e.g., label from pair A with object from pair B). The order of presentation of these trials was counterbalanced across subjects. The final phase in the experiment was the post-test trial, where the child was again presented with 'pok' and the water wheel. It was expected that looking time would recover to near baseline level during this final trial. Total testing time was approximately 5 min.

Results and Discussion

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Reliability Coding

To determine the reliability of the experimenter’s coding, a second trained coder scored the looking times of 25% of the usable subjects off-line. On-line scores were rounded to the nearest 0.1 s. Off-line scoring was also done to the nearest 0.1 s. A Pearson product-moment correlation of on- and off-line scores had to be equal to or greater than .95 for the data to be considered reliable. This level of agreement was reached for all subjects.

Analysis of the data

In addition to the individual criterion ensuring each child had habituated, group data was also analyzed for habituation. Continued interest in the procedure was also assessed using data from the post-test. A planned contrast was conducted using data from the first block (the first four habituation trials), the last block (the last four habituation trials), and the post-test. Last block, as opposed to last trial, was used in this analysis in order to ensure looking times to both pairs of stimuli were represented. Results of the contrast indicated last block was significantly different from first block and post-test trial ($F(1, 61) = 1186.485, p < .0001; M_{first block} = 11.924, SD = 1.550; M_{last block} = 5.831, SD = 1.507; M_{post-test} = 13.540, SD = 1.139$), suggesting that infants did habituate and also recovered to the post-test trial.

The primary question of interest in this experiment is whether infants noticed a switch in the word-object pairing. If children learned the word-object associations, we would expect significantly longer looking times to the "switch" trial than to the "same" trial. The result of the one group paired $t$-test was non-significant ($t(63) = .916, p = .363, d = .13$;
The finding of no significant difference between looking time to "switch" and to "same" trials indicates that 14-month-old infants have difficulty using fine phonetic detail in making word-object associations. It is not immediately clear, however, why infants might have had this difficulty. Successful performance in Experiment 1 requires a number of competencies on the part of the child. The child must pick up details about the word and the object, must form a detailed representation of the two word-object associations, must notice a switch in the pairing during the "switch" test trial, and must behaviourally register their notice of the switch by increased looking within the 14 s of the "switch" trial.10

Although 14-month-old infants performed successfully with dissimilar words (Werker, Cohen, et al., 1998), the similarity of the labels may be increasing the cognitive load of the task in some way for the infant. The phonetically similar stimuli may be increasing the cognitive load by increasing the pressure on the infant's memory and attentional resources. Thus, it may be that the task is too complicated for the child, and that in a simpler task the child may be able to demonstrate learning of the phonetically similar word-object associations. In order to examine this possibility, a second experiment was conducted where the child was presented with a simpler task. I decreased the memory and attentional demands by habituating the infants to a single word-object pairing, and

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10 I confirmed in an earlier experiment that infants are able to pick up details about the object. I habituated another group of 14-month-old infants to a single-word object pair, and then tested them with a switch in object. Infants had no trouble discriminating the objects and showed a difference in looking time between the "same" and the "switch" trials (Stager, 1995). See Appendix B for a fuller description of this study.
then testing them with a switch in label. If the observed difficulty infants had in Experiment 1 was related to memory and attentional demands, we would expect infants to more easily notice the switch in label in this study.

Experiment 2

Experiment 2 was designed to determine if infants respond to a switch to a phonetically similar word after being habituated to a single word-object pair, a less demanding task than that used in Experiment 1.

Predictions

I predicted that if infants are able to encode information about the label that is detailed enough to notice a switch in the label, they will exhibit increased looking time on the "switch" test trial as compared to the "same" test trial.

Method

Participants

A new sample of 16 infants (8 male, 8 female) of 14 months of age was tested (mean age, 14 months 12 days; range 14 months 3 days to 14 months 30 days). All subjects met selection criteria described previously. An additional 9 infants were tested but were not included in the analyses because they were not visible (n = 4), the experiment had to be stopped because they were fussing (n = 4), or they did not habituate (n = 1).

Stimuli and Equipment

Remained the same as for Experiment 1.

Procedure
The habituation process differed from that of Experiment 1 in three ways. Firstly, the habituation phase included only one word-object pairing, as opposed to the two pairings presented in Experiment 1. Secondly, the habituation criterion was changed from Experiment 1. The habituation criterion was measured over a block of two trials as opposed to a block of four trials. Pilot work suggested that requiring habituation over four trials made the procedure too long when only one word-object pairing was being used. Every habituation trial in this experiment was the same, which meant a block of two trials in this experiment can be seen as equivalent to a block of four trials (two of each pair) in Experiment 1. The habituation criterion used was that looking time during each of the last two habituation trials must be less than or equal to sixty-five percent of the average of the first two trials. Finally, in Experiment 1, all infants were familiarized for a minimum of 12 trials, whereas in Experiment 2 the minimum number of habituation trials was reduced to eight trials, again, in an effort to maintain infant participation.

Results and Discussion

Reliability Coding

Reliability coding was conducted as in Experiment 1. A correlation equal to or greater than .95 was reached for all subjects coded.

Analysis of the Data

In addition to the individual criterion ensuring each child had habituated, group data was also analyzed for habituation. Continued interest in the procedure was also assessed using data from the post-test. A planned contrast was conducted using data from the first two habituation
trials (first block), the last two habituation trials (last block), and the post-test. The planned complex contrast revealed a significant difference between the first block and the post-test as compared to the last block ($F(1, 13) = 397.079, p < .0001; M_{first\ block} = 12.004, SD = 2.181; M_{last\ block} = 4.835, SD = .861; M_{post-test} = 13.691, SD = .504$), suggesting that infants had habituated and recovered.

The primary question of interest in this experiment is whether infants notice a switch in the word-object pairing. If children are learning the word-object associations, we would expect significantly longer looking times to the "switch" trial than to the "same" trial. The result of the one group paired $t$-test was non-significant ($t(15) = .242, p = .812, d = .08; M_{same} = 7.120, SD = 2.979; M_{switch} = 6.888, SD = 2.965$) (See Figure 4). This suggests infants were not responding to a switch in the word-object pairing.

**Discussion**

The results of Experiment 2 suggest that infants did not distinguish the two phonetically similar words, even in this simplified version of the word-object association task. This finding on its own suggests that even in a task that involves only the most minimal word learning requirements, and even when familiarization time is carefully controlled, infants fail to access and represent the phonetic details distinguishing the two words. This suggests that infants' failure to notice the switch in pairing in Experiment 1 is not solely the product of large memory demands. Instead, it suggests there may be something special about the auditory stimuli. This result is quite surprising given the predicted discrimination abilities of infants this age. It is possible that the auditory stimuli are too difficult to discriminate in this task. To test this, I tested 8 month olds, an age
group which we know is able to perform in this task with phonetically
dissimilar words (Werker, Cohen, et al., 1998), and is known to possess
excellent speech discrimination abilities (e.g., for a review see Jusczyk,
1997). As well, this age is close to the age at which Jusczyk and Aslin (1995)
showed infants can discriminate phonetically similar word forms in a
word recognition task that has no semantic requirements.

Experiment 3

To ensure that infants were able to perform in this task I tested 8-
month-old infants, infants who are still thought to be able to make fine
phonetic discriminations easily.

Predictions

I predicted that if infants are able to encode information about the
words that is detailed enough to notice a switch in the label they will show
increased looking time on the "switch" test trial as compared to the
"same" test trial. I predicted that the 8-month-old infants may perform
better than the 14-month-old infants did on this task.

Method

Participants

Results include the data from 16 (8 male, 8 female) 8-month-old
infants (mean age, 8 months 18 days; range, 8 months 4 days to 9 months 2
days). All subjects met selection criteria described previously. An
additional seven infants were tested but were not included in the analyses
because they were not visible on the monitor during testing (n = 1), the
experiment had to be stopped because they were fussing (n = 4), parental interference (n = 1), or they spit up during a critical trial (n = 1).

Stimuli and Equipment

Remained the same as for Experiment 1.

Procedure

Same as Experiment 2. (Infants were habituated to a single word-object pair.)

Results and Discussion

Reliability Coding

Reliability coding was conducted as in previous experiments. A correlation equal to or greater than .95 was reached for all subjects coded.

Analysis of the Data

As in Experiments 1 and 2, I conducted a planned contrast to determine if as a group the infants had habituated and exhibited recovery during the post-test trial. The contrast revealed a significant difference between last block as compared to first block and the post-test trial (F (1,13) = 529.794, p < .0001; M \text{first block} = 12.499, SD = 1.293; M \text{last block} = 6.146, SD = 1.274; M \text{post-test} = 13.462, SD = .877).

As in Studies 1 and 2, if the infants noticed a change in the pairing, I would expect longer looking to the "switch" trial. A t-test revealed infants did appear to notice the switch in word, and looked significantly longer during the "switch" trial than during the "same" trial (t(15) = 2.225, p = .041, d = .66; M \text{same} = 6.350 s, SD = 3.021; M \text{switch} = 8.198 s, SD = 2.592) (see Figure 5).

Discussion
Taken together, the results of Experiments 2 and 3 suggest that the task used in Experiments 2 and 3 is performed differently by infants of 8 and 14 months of age. Since 8-month-olds performed easily in this task, it seems unlikely that the factor limiting the performance of the 14 month-old infants was overall cognitive load.

Several alternative explanations may be proposed to account for this data pattern. The interpretation of these findings that I find most plausible is that infants of 8 and 14 months treat this task differently. In particular, for the infants of 14 months, the single word-object association task does involve word learning. One component of the process of learning a new word is making the association between the word and the object or associating some meaning with the label. It may be that during the task of first forming the association, the difference between "bih" and "dih" is not noticed. In contrast, infants of 8 months may treat this experimental task as a simple sound discrimination task. As a sound discrimination task, the difference between "bih" and "dih" is easily detected. This is a hypothesis that I will explore further in the Discussion portion of this thesis.

There remain two alternative explanations that must be addressed before we consider the above possibility further. My results may also reflect a change in infants' phonetic-perception abilities, so that by 14 months of age they simply can no longer make the phonetic discriminations that they demonstrated at younger ages regardless of whether they are tested in word learning or simple speech discrimination tasks. This possibility is addressed in Experiment 5. Another possible explanation, which is the focus of the next experiment, is that infants of 14 months were unable to perform successfully in the single word-object
association task because of some aspect(s) of the visual stimuli in the simplified procedure. This procedure has not been tested before with these objects. To rule out this as a possible explanation, I repeated Experiment 2 using phonetically dissimilar words.

Experiment 4

In order to ensure that infants of 14 months are able to perform successfully in the single word-object association task with the visual stimuli used in Experiments 1-3, I conducted a control experiment using the same phonetically dissimilar words that have previously been used in the two word-object association task (Werker, Cohen, et al., 1998) and using the visual objects I chose for this series of experiments. The procedure used in Experiment 4 was identical to that used in Experiment 2, except that I used the phonetically dissimilar stimuli "lif" and "neem" as the object labels.

Predictions

I predicted that this should be an easier task for them than when the labels are phonetically similar. If infants are able to detect a switch in the label, they would be expected to show increased looking time during the "switch" trial.

Method

Participants

Sixteen 14-month-old infants (8 male, 8 female) with a mean age of 14 months 6 days (range, 13 months 25 days to 14 months 29 days)
completed this experiment. All subjects met selection criteria described previously. An additional 10 infants participated in the study, but were not included in the analysis because they were fussy (n = 6), they were not visible to the coder (n = 2), or there was parental interference (n = 2).

Stimuli

Stimuli for this experiment were "lif" and "neem".\textsuperscript{11} Tokens were recorded from the same speaker, in the same manner as reported in Experiment 1.

Visual stimuli remained the same as in previous experiments.

Equipment

Same as Experiment 1.

Procedure

Same as Experiment 2. (Infants were habituated to a single word-object pair.)

Results and Discussion

Reliability Coding

Reliability coding was conducted as in previous experiments. A correlation equal to or greater than .95 was reached for all subjects coded.

Analysis of the Data

As in all previous experiments a contrast was conducted on the data from the first block, last block, and post-test. The results of the contrast indicate that the means for the last block were significantly different, suggesting habituation and recovery ($F (1, 13) = 759.300, p<.0001; M_{\text{first}}$ 

\textsuperscript{11} "Lif" may be transcribed as /lif/, "neem" may be transcribed as /nim/.
block" = 13.171, \( SD = 1.265 \); \( M_{\text{last block}} = 6.259, \ SD = 1.383; M_{\text{post-test}} = 14.431, \ SD = .213 \).

A \( t \)-test on "switch" and "same" revealed a significant difference, suggesting that the infants were able to discriminate between the labels \( (t(15) = 5.412, p < .0001, d = 1.75; M_{\text{same}} = 7.984, SD = 2.769; M_{\text{switch}} = 12.428, SD = 2.294) \) (See Figure 6).

Discussion

This result confirms that the difficulty experienced by 14-month-old infants in Experiment 2 was due to the phonetic similarity of the labels used, and not the use of these particular visual stimuli in the simplified procedure. I next needed to test the possibility that infants of this age can simply no longer discriminate syllables which begin with minimally contrastive consonants. This was the focus of the next experiment.

Experiment 5

In this experiment I wanted to test the speech discrimination abilities of infants, using a task that was as similar as possible to those used in my previous experiments. In this experiment, instead of pairing a word with an object, I paired the word with a checkerboard display. There is considerable evidence that unbounded, nonunitary displays, such as a checkerboard, are unlikely to be perceived as an object by an infant (Spelke, Vishton, & Van Hofsten, 1994) and are thus less likely to be labeled (Woodward, 1993). It is, nevertheless, a compelling visual display and has been used as the visual stimulus in many studies of simple auditory discrimination (e.g., Pegg, Werker & McLeod, 1992; Polka & Werker, 1994). In Experiment 5, then, infants of 14 months were shown a checkerboard
pattern paired with either the syllable "bih" or the syllable "dih". During the "switch" trial, the visual display remained the same, but the word changed to its minimal pair alternate. These changes should transform the task into one of simple speech discrimination. All other aspects of the procedure were identical to those used in the previous experiment.

Predictions
If the difficulty infants had in Experiments 1 and 2 is due to forming an association between a word and an object, infants should perform successfully in this task and dishabituate to a switch in pairing.

Method

Participants
In this study a new sample of 16 14-month-old infants (8 male, 8 female) with a mean age of 14 months 20 days (range, 14 months 13 days to 14 months 28 days) were tested. All subjects met selection criteria described previously. An additional 10 infants were tested in the procedure but their data were not included in the analysis because of fussiness (n = 7), equipment failure (n = 2), or because they were not visible to the coder (n = 1).

Stimuli
Instead of the visual stimuli used in the above experiments I presented infants with only a checkerboard pattern paired with either the syllable "bih" or the syllable "dih".

Equipment
Same as in above experiments.

Procedure
Same as Experiment 2, except that instead of hearing a label paired with the multicoloured visual stimuli, infants heard a label paired with the presentation of a checkerboard pattern during the habituation and test phases.

Results and Discussion

Reliability Coding

Reliability coding was conducted as in previous experiments. A correlation equal to or greater than .95 was reached for all subjects coded.

Analysis of the Data

As in all previous experiments a planned contrast was conducted. The results revealed that last block had means significantly lower than those observed in first block or post-test ($F(1, 13) = 108.756, p < .0001; M_{\text{first block}} = 10.794, SD = 2.264; M_{\text{last block}} = 4.244, SD = 2.126; M_{\text{post-test}} = 10.082, SD = 3.251$) suggesting habituation during the first phase, and recovery following the test phase.

The primary question of interest in this study is whether infants notice a switch in the word-object pairing. Infants of 14 months showed robust evidence of discriminating "bih" from "dih" by a $t$-test ($t(15) = 3.961, p = .002, d = .67; M_{\text{same}} = 5.005 s, SD = 3.491; M_{\text{switch}} = 7.166 s, SD = 2.959$) (Figure 7).

Discussion

This finding suggests that infants are able to discriminate the switch in label and eliminates the possibility that infants of 14 months can no longer make the fine phonetic discriminations necessary to successfully form the word-object associations in these experiments. Instead, it presents compelling evidence that it is only when infants are attempting
to learn the meaning of words that they fail to attend to fine phonetic information, and suggests that the amount of phonetic detail infants detect and use differs in speech perception as compared to word-learning tasks. These results clearly suggest that infants of 14 months have difficulty encoding fine phonetic detail when they begin to associate semantic content with the word to be learned. What remains to be done is to eliminate the alternative explanation that it is some particular characteristic of the auditory or visual stimuli, unrelated to the hypothesis being tested, that makes the task too difficult for infants. While I have tried to make the stimuli as accessible and natural as possible for the infants, the issue is significant enough to call for more careful examination.

One outstanding concern is the possibility that the labels “bih” and “dih” used in the previous experiments do not constitute proper word forms for the infants, and this interferes with their learning the word-object associations. The most common single syllable word form in English is CVC or CVV (McCarthy & Prince, 1995). There is some evidence that at least productively, infants are sensitive to these forms by one year of age (Fee, 1995). Charles-Luce and Luce (1995) also observed that CVC strings are the most commonly occurring single syllable word types in the lexicon of 5-year-old English-speaking children. There also exists, however, evidence which suggests that infants may tolerate “incomplete” word forms such as “bih” and “dih”. Kay-Raining Bird and Chapman (1998) have shown that 14-month-old infants tolerate phonetic substitutions to the final consonant in a CVC string in a newly learned word. Our concern about proper word form was also minimized as the syllable was produced in infant-directed speech, and thus the vowel was
bimoraic (so with respect to timing units it could be transcribed as CVV), although it remained a lax vowel. Thus it is very near the acceptable form CVV. Nevertheless, in order to explicitly rule out the possibility that it was the stimulus form that caused the difficulty for infants, I conducted a further study in which I used a CVC structure.

Experiment 6

This experiment was designed to test whether the difficulty 14-month-old infants have with learning similar-sounding words reflects the lack of proper word form used in the audio stimuli of Experiments 1 and 2. The stimuli used in this current experiment conformed to the rules of proper word form, and had the syllable shape CVC. The other aspects of the design matched those of Experiment 2.

Predictions

If the difficulty observed in Experiments 1 and 2 is due to the stimuli not being of proper English word form, infants should perform successfully in this task and dishabituate to a switch in pairing.

Method

Participants

In this study a new sample of 16 14-month-old infants (8 male, 8 female) with a mean age of 14 months 12 days (range, 14 months 1 day to 14 months 21 days) were tested. All subjects met selection criteria described previously. An additional 10 infants were tested but were not included in the analyses because of parental interference (n = 1), the
experiment had to be stopped because they were fussing (n = 7), experimenter error (n = 1), or equipment failure (n = 1).

**Stimuli**

Auditory stimuli for this experiment were "bin" and "din". Tokens were recorded from the same speaker, in the same manner as reported in Experiment 1. Although these stimuli are not true nonsense words, as used in our other experiments, I am certain they can be considered as such to infants of 14 months.

Visual stimuli remained the same as for Experiment 1.

**Equipment**

Same as Experiment 1.

**Procedure**

Same as Experiment 2. (Infants were habituated to a single word-object pair.)

**Results and Discussion**

**Reliability Coding**

Reliability coding was conducted as in previous experiments. A correlation equal to or greater than .95 was reached for all subjects coded.

**Analysis of the Data**

As in all previous experiments a planned contrast was conducted. Results of the contrast revealed last block was significantly different from first block or post test ($F (1, 13) = 539.550, p<.0001; M_{\text{first block}} = 12.032, SD = 1.313; M_{\text{last block}} = 5.367, SD = 1.329; M_{\text{post-test}} = 13.919, SD = .108$).

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12 "Bin" may be transcribed as /bin/; "din" may be transcribed as /din/.
The primary question of interest in this study is whether infants notice a switch in the word-object pairing. There was no significant difference between looking time on "switch" and "same" as determined by a $t$-test ($t(15) = .411, p = .687, d = .11; M_{\text{same}} = 7.121 \text{ s}, SD = 2.580; M_{\text{switch}} = 7.495 \text{ s}, SD = 4.020$) (See Figure 8).

**Discussion**

The results of this experiment suggest that it is not the structure of the words used in the experiments that caused the difficulty for infants of 14 months. This finding provides further evidence that it is the phonetic similarity of the words that causes the difficulty for infants of 14 months. Their performance on the "bin"-"din" stimuli was not different from their performance on the "bih"-"dih" stimuli used in Experiment 2.

Another stimuli factor that may be causing difficulty for the infants is the similarity of the visual stimuli. The visual stimuli used in the habituation and test phases of the experiments, while different on what I think is the most important factor, namely shape, are similar in a number of aspects such as colour, motion, and texture. There is some evidence that when learning the names of objects children do not use the feature of shape categorically, as adults do. They are understood to use shape as a much more continuous dimension (Abecassis, Sera, & Yonas, 1997). Thus the visual stimuli may appear more similar to infants than they do to adults. Therefore, infants may be exerting a large effort to distinguish these visual stimuli. Similarly, it is possible that they are classifying the objects as the same. If the Principles of Contrast (Clark, 1983) or of the Novel-Name Nameless-Category (Mervis & Bertrand, 1994) hold for these infants, this may not be encouraging infants to search for differences in
labels\textsuperscript{13}, in a way they might be prompted to if the objects were very
dissimilar visually. Alternatively, even if they think that the stimuli are
dissimilar, and deserving of different names, it could be that the amount
of cognitive resources required to make that visual discrimination does
not leave sufficient resources left over to form the word-object
associations. It may be that the infants' ability to encode the words would
be facilitated if the cognitive load of representing the visual stimuli was
lightened for the infants. One way to do this would be to use stimuli that
are very visually dissimilar. In the next experiment I used stimuli that
differed in shape, type of motion, colour, and texture in order to see if this
facilitated the formation of word-object associations of phonetically
similar words for infants of 14 months of age.

Experiment 7

This experiment was designed to test whether the difficulty infants
of 14 months had with learning similar-sounding words in Experiment 1
reflects the similarity of the visual stimuli employed. The stimuli used in
this experiment appeared very visually distinct, which may decrease the
cognitive processing load for the infants, thus allowing increased attention
to, and processing of, the phonetic detail of the auditory stimuli.

Predictions

\textsuperscript{13} The principle of Contrast proposes that different names are used to label different objects.
For example, the referent for "dog" would not be the same as the referent for "cat". The Novel-
Name Nameless category principle is similar in that if a new name is heard in the presence of a
labeled object and an object with an unknown name, that new name is taken to refer to the
unlabelled object.
If the difficulty observed in Experiments 1 and 2 is due to the similarity of the visual stimuli, infants should perform successfully in this task and dishabituate to a switch in pairing.

Method

Participants

Participants were solicited in the same manner as in the previous studies. Sixteen 14-month-old infants (8 male, 8 female) completed the study (mean age, 14 months 10 days; range, 14 months 1 day to 14 months 23 days). All subjects met selection criteria described previously. An additional 19 infants were tested but were not included in the analyses because the experiment had to be stopped because they were fussing (n = 9), experimenter error (n = 1), the infants were not visible to the coder (n = 2) or because they did not habituate (n = 7).

Stimuli

Auditory stimuli for this experiment were the same tokens used in Experiments 1-5: "bih" and "dih" were used in the habituation and test phases and "pok" during the pre- and post-test trials.

The visual stimuli used during the habituation and test phases were the water wheel ("spinner") which had been used in the pre- and post-test phases of the previous experiments, and "poky" which was used in the habituation and test phases of the previous experiments. These stimuli differed in colour, form, and pattern of movement. In the pre- and post-test phase of this experiment a blue and green "molecule" which moved back and forth across the screen was used (See Figure 9).

Equipment
Same as in Experiment 1.

Procedure

Same as Experiment 1. (Infants were habituated to two word-object pairs.)

Results and Discussion

Reliability Coding

Conducted as in all previous experiments. Pearson product-moment pairwise correlations of on- and off-line scores reached .95 in all subjects.

Analysis of the Data

Results of a planned contrast revealed that the first block (the first four habituation trials) and post-test are significantly different from the last block (the last four habituation trials) \( F(1, 13) = 273.103, p < .0001; M_{\text{first block}} = 12.350, SD = 1.273; M_{\text{last block}} = 6.580, SD = 1.148; M_{\text{post-test}} = 12.547, SD = 1.545 \).

The critical test of interest is the difference in mean looking times on the “same” and the “switch” trials. A t-test revealed no significant difference \( t(15) = 1.241, p = .234, d = .41; M_{\text{same}} = 5.903, SD = 3.710, M_{\text{switch}} = 7.287, SD = 3.002 \). (See Figure 10).

Discussion

The results of this experiment suggest that it is not the visual similarity of the objects that caused difficulty for the infants. The results of this final experiment support the notion that it is the phonetic similarity of the words, in conjunction with the task of attaching sound to meaning,
that makes learning similar-sounding words difficult for 14-month-old infants.
General Discussion

Taken together, the results of these seven experiments provide convincing evidence that learning similar-sounding words is difficult for 14-month-old infants when they engage in a form of word learning that involves associating some meaning with the label. This conclusion helps reconcile the apparently contradictory results of Hallé and de Boysson Bardies (1996) and Jusczyk and Aslin (1995), with the explanation that it may be an increase in attention to semantic information by the older infants that accounts for an apparent decline in the phonetic detail encoded between the ages of 7 1/2 and 11 months. Previous studies have shown that children have difficulty in learning similar-sounding words. However, these previous studies tested older children and have used tasks that assess full referential comprehension, in which a child uses the word alone to stand for the object. I was interested in assessing the perceptual sensitivities in the earliest stages of word learning, and thus decided to focus on "recognitiontory comprehension" or "goes with" understanding (Oviatt, 1980, 1982; see also Stager & Werker, 1998). I tested infants using an habituation procedure that assumes minimal cognitive abilities on the part of the child, eliminating potentially confounding demands such as understanding verbal instructions for the task.

The results from Experiment 1 suggest infants of 14 months fail to make word-object associations when the words are phonetically similar. Experiment 2 demonstrates that indeed infants of 14 months do not appear to encode fine phonetic detail as they fail to demonstrate a response to a change to a phonetically similar label following habituation to a single word-object pair. This result is striking given the results of Experiment 5 which suggest
14-month-old infants can easily detect the same change in phonetic information in a simple syllable discrimination task. Experiment 4 was conducted to ensure that the failure of infants of 14 months to detect a change in label was due only to the nature of the audio stimuli and not due to any other aspect of the experiment. I used the simplified procedure to test infants with phonetically dissimilar stimuli, and infants had no difficulty detecting a change. It appears that the decline in ability to use phonetic detail in word learning tasks takes place as infants attempt to pair meaning to the words they are hearing. This interpretation is supported by the results of Experiment 3, in which infants of 8 months passed the single word-object association task. I propose that at 8 months infants are not yet mapping the sound onto meaning.

Two control experiments were then conducted. These experiments were designed to test whether the difficulty the 14-month-old infants demonstrated in the present experiments was due to characteristics of the stimuli unrelated to the hypothesis of interest. Experiment 6 was a replication of Experiment 2, except I used stimuli that had proper English word form. Infants failed to notice a switch in pairing using these stimuli. In Experiment 7, I used objects that were very distinct visually, to ensure that it was not the similarity of the visual stimuli I used in Experiment 1 that made the task difficult. Infants failed to perform in the task even with visually distinct stimuli.

The results of these experiments suggest that infants use different information in word-learning and speech perception tasks. When the 14-month-old infants were presented with semantic information in addition to the phonetic information inherent in the label, as in Experiments 1, 2, 6, and 7, they do not appear to use contrastive phonetic detail. When presented with
only phonetic information, as in Experiment 5, 14-month-old infants had no difficulty making the discrimination. The 8-month-olds in Experiment 3 may not be processing the task as one of word learning (or may not be trying to link the audio stimulus with the visual stimulus), and may thus be successful in the task because they perform it using simple speech discrimination.

Thus, the results of these studies of associative word learning show that 14-month-old infants do not use contrastive phonetic detail when they are first learning the association between a novel word and a novel object. Importantly, they fail to use this phonetic detail even though they are quite capable of discriminating it if tested in a simple speech discrimination procedure.

Since the completion of these studies, several researchers have further explored this effect. Preliminary results from a study by Mills, Werker, Neville, Prat, Stager, Mitchell, Adamson, and Sanders (1999) show that the event-related potentials of 14-month-old infants do not show different patterns for known words and phonetically-similar nonsense words (e.g., "bear" and "gare"). However, the patterns do show a difference between known words and phonetically-dissimilar nonsense words (e.g., "bear" and "kobe"). These results suggest that the effect that has been demonstrated in this thesis using a behavioural measure, can also be seen at the level of stimulus processing. Another line of research has been conducted by Schafer (1999), who has conducted computational modeling of the process of learning phonetically-similar words in infancy. The results of his models replicate the findings reported in this thesis. The networks cannot discriminate fine phonetic detail when forming a word-object association, but they are able to make the discriminations if the visual stimulus is not object-like.
Below, I explore how, although the notion is seemingly counterintuitive, these findings are consistent with others reported in the literature and are also consistent with the process of development. I also rule out several possible alternative explanations. Although the lack of access to fine phonetic detail in the task of word learning may be viewed as a step backwards for the infant in that they are not using their excellent speech discrimination skills, I would propose we see it as progress forwards. It appears as if infants are using only more global information about sound structure or partial word forms. These minimal lexical representations may not be interfering with infants' functioning in any way; in fact I propose that inattention to fine detail may be beneficial to the child beginning to learn words.

Global representations

That infants seem to represent only partial word forms in the early stages of building a lexicon suggests a possible explanation for the present findings. If fine-grained representations are not normally required at early stages of word learning, children may fail to encode fine phonetic detail readily. This hypothesis has long been discussed in the child phonology literature (e.g., Ferguson, 1986; Ferguson & Farwell, 1979; Menyuk & Menn, 1979; Studdert-Kennedy, 1986; Walley, 1993). Experimental work has suggested, for example, that perhaps infants in these studies have represented only the vocalic nucleus of the word, thus potentially encoding no contrastive information (Ferguson & Farwell, 1979). Ferguson and Farwell studied seven infants longitudinally and report that in their early productions children readily substitute many different consonants for others that share at least one phonetic feature (e.g., they would substitute /p/ for /t/), and insert the initial consonant in various positions, in some cases.
eliminating it altogether. The only relatively constant factor in the productions was the vocalic nucleus. Similar findings have been reported in the research in comprehension. Kay-Raining Bird and Chapman (1998) show infants might not fully represent the initial consonant in their comprehension lexicons, also suggesting a globally specified representation. Additional evidence for global specification comes from Gierut (1996) who found that even at 3;1-5;10 children use only one feature value to define membership in a phonological category, suggesting initial representations are underspecified for featural information.

Global representations may be a secondary characteristic of having a small lexicon. It may be that the ability to discriminate the fine phonetic detail required to differentiate phonetically-similar words is necessitated only by increasing the size of the lexicon (Walley, 1993). Support for this hypothesis comes from the research of Walley and colleagues who found increasing attention to individual phonetic segments with development (Walley, Smith, & Jusczyk, 1986). As words are added to the comprehension lexicon, the amount of detail required to distinguish one word from another might change (Walley, 1987). It has been suggested that as infants learn more words there is increased pressure to fill in more phonetic detail (Walley, 1987). At 14 months of age, however, limited phonetic information is all that is needed to avoid confusing a new word with the few other words in the infants' comprehension lexicon (Charles-Luce & Luce, 1995).

While vocabulary size may be a factor, some researchers have hypothesized that global representations may be sufficient, as children may not be learning similar-sounding labels. Charles-Luce and Luce examined the comprehension (1995) and production (1990) lexicons of 5- to 7-year-old children. They found that children have sparsely populated “phonetic
neighbourhoods”, that is, their lexicons are comprised primarily of words that are highly phonetically dissimilar. They suggest this strategy allows children to use more global recognition strategies because words are more discriminable in memory. As the number of words in their lexicons increases it is assumed that the representations must become much more detailed in order to make discriminations amongst structurally overlapping words.

While 14-month-old infants may still be able to make fine phonetic discriminations, this ability may now be masked by other cognitive or linguistic functions that may interfere with, or inhibit, the infant's use of finer discrimination skills. If this were the case, older infants would not necessarily discriminate fine phonetic detail in a word-learning task.

Less is More

Gleitman (1981) has observed that we cannot explain developmental stages as straightforward progressions proceeding by simple additive processes. Indeed, many recent theoretical perspectives further the idea that during the course of development infants use simpler processing or representation strategies than might be expected on the basis of other skills demonstrated by infants. These perspectives have as a unifying theme the stance that these simpler strategies are not detrimental or retarding to the child, but exist as either byproducts of other changes or are in fact a necessary step en route to the acquisition of complex skills.

Some evidence appears to support the notion that children are using simpler processing or representation strategies than might be expected. Shipley, Smith and Gleitman (1969) examined syntactic complexity in acquisition and suggest that children may be filtering some of the speech around them such that they are not attending to very complex syntactic structures. Drawing on evidence from the infant categorization and causal
perception literatures, Cohen (1988) has proposed that infants drop down to a simpler level of processing when faced with more information than can be processed by their cognitive systems, and that over the course of development infants move from processing parts to processing wholes. These findings lend credence to the hypothesis that infants may process the same stimuli in different ways at different ages, and that, as Gleitman suggested, they may not progress through development in a simple linear progression.

A number of other theorists posit the changing weighting (or importance) of various sources of information or tasks throughout development. The same underlying components might be present, and with development may change their relative weightings and the form of their interaction (see Thelen & Smith, 1994). Language researchers such as Nittrouer (e.g., Nittrouer & Crowther, 1998; Nittrouer, Crowther, & Miller, 1998) and Echols (1993) have shown that infants and adults use different cues to perceive speech. Which components are given the most weight may depend on factors such as functional relevance and practice. The studies reported in this thesis suggest that it is not the ability to locate phonetic information that is missing in infants of 14 months. Rather, the task of mapping sound to meaning requires the greatest expenditure of cognitive resources at this time, and thus, this is where their cognitive resources are allocated.

Closely related to this explanation is the possibility that the results presented in this thesis may be considered another example of "functional reorganization" (Werker, 1995). With a functional reorganization, there is an increase in linguistic efficiency as the infant is then able to do a better job at attending to key features of the ambient language. The decrease in the amount of phonetic detail used by infants as they move from speech
perception to word learning is analogous to the earlier decline in infants' ability to discriminate non-native phones. In reminder, infants are initially able to discriminate sounds in ambient and non-ambient languages, but by around one year of age, they do not show the ability to discriminate phones that are not contrastive in their native language (Werker & Tees, 1984). In this thesis, we see that, although infants can discriminate phones that are contrastive in their native language, in the initial stages of word learning they are unable to use the phonetic detail. In both cases, an apparent decline in one kind of ability is evidence of a developmental progression.

Newport (1990, 1991) interprets findings such as these in a positive manner. She has proposed the "Less is More" hypothesis, in which it is these very processing limitations and other types of limitations that allow for successful language acquisition or for learning about other complex stimuli. She, like Cohen (1988), believes children process complex stimuli at the level of the component parts thus allowing them to locate the components effectively, while adults operate at the level of the whole stimulus. Newport asserts this difference in processing strategy may in part explain critical periods in language learning. Componential analysis is necessary for optimal language learning, and componential analysis occurs only in childhood rather than during acquisition per se. She has based her theory in part on observations she made of learners in the early stages of acquisition of morphological forms in American Sign Language. Only children make errors at the levels of components, in which structures are produced in part, while older learners make errors of whole-word unanalyzed signs (Newport, 1988).

Componential learning arises because of the limited processing capacities of children: they do not have the capacity to retain the entire stimulus. However, this cost results in an advantage as determined through
computational modeling (Newport, 1990). The limited processing capacity of early learners means that there are fewer possible mapping relations to be considered, which may also result in an incidental perceptual highlighting of the units that would otherwise require computational determination. Newport (1990) illustrates this problem by giving the example of trying to map the relationship between abc (form) and mno (meaning). In this example, there are a large number of possible pairings to be made between any component of the form and any component of the meaning (not unlike Quine's famous "Gavagai" problem). If initially the child is limited to pick out only some of those components of both form and meaning, they can calculate only a small set of possible pairings and test those hypotheses, allowing them to deduce, for example, morphological rules. Processing the whole rather than the component parts would require that the infant determine components by deductive reasoning, which is likely to be a longer process. In considering the data presented in this thesis it may be that the 14-month-old infants are limited to processing only part of the stimulus, one possibility being the vocalic nucleus in the word-object association studies.

More support for the notion that this "decline" in ability is advantageous comes from Turkewitz and Mellon (1989) who observe that in many perceptual domains during development it appears advantageous to limit the amount of detail. Limitations in the amount of detail can facilitate optimal development. The protracted period of development with limitations that appear unnecessary from a biological or physiological perspective may be necessary in order to master some of the complex skills required.

En masse, these theories support the notion that inattention to phonetic detail may be beneficial to the child who is on the cusp of word
learning. The task of linking words with objects is computationally more demanding than just listening to words as sounds, and this difficult task may be made easier by omitting phonetic detail.

**Alternative explanations**

Two alternative accounts maintain that the decrease in phonetic information used in the present tasks does not stem from the infants' attempt to form word-object associations, but rather from the difficulty infants have with dividing their attention. The first explanation attempts to explain why the 8-month-old infants use fine phonetic detail while the 14-month-olds did not, and the second attempts to explain the difference between the object and checkerboard results for the 14-month-olds.

The first alternative explanation posits that the reason the 14-month-old infants seem to use less phonetic detail than the 8-month-old infants is that the older infants might be attending to objects as well as labels, while the 8-month-old infants are simply attending to labels. Thus, the 14-month-old infants can't maintain the phonetic detail when faced with the additional processing load of attending an object. This argument can be countered by the evidence from previous research (Werker, Cohen, et al., 1998) showing that 8-month-old infants, in the same procedure, are able to detect changes in the object. This suggests that even younger infants, who can discriminate phonetically-similar words in a single object condition are attending to the object as well as the label, and are processing sufficient information to distinguish one object from another object in a habituation task. Thus, it is not simply attention to the visual object that is causing difficulty for the infants of 14 months.

The second alternative explanation is that the 14-month-olds are able to make the phonetic discrimination in the checkerboard condition
(Experiment 5) because they are less engaged in the visual display than in the word-object association task (Experiment 2), leaving a greater store of "resources" for auditory processing. To some extent this is certainly true. However, I do not think it is simply how "distracted" infants are. I conducted a number of exploratory statistics to investigate this possibility. I examined the looking times in Experiments 2 versus 5 on the initial criterion-setting trials, the last trial of the habituation phase, the "switch" trial, and the "same" trial. I conducted four separate t-tests and found no significant differences between groups. These results (using a liberal statistic) confirm that the infants were equally engaged in the task when the checkerboard was used. Therefore the notion that the difference in the results of Experiments 2 and 5 can be explained solely by a simple difference in the infants' engagement seems unlikely.

**Future Directions and Questions**

One of the remaining questions to be asked is: When does it become possible for children to easily incorporate contrastive phonetic detail in their initial lexical representations? At an older age, when word learning is no longer difficult, we would expect fine phonetic detail to again be accessed.\(^{14}\) We have attempted to use the same procedure with older infants but are currently experiencing difficulty determining how to make a task that is engaging for infants of 14 months also engaging for older infants. In one attempt, we adapted a task often used with toddlers (Taylor & Gelman, 1989). Infants were taught labels for two unknown objects, and then asked to perform tasks with the requested object. We found that while some children are using fine phonetic detail by 3 years of age, many are still struggling with

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\(^{14}\) A problem with this process may, however, underlie the difficulty some children have in reading, in which they are unable to form a mapping between the orthography and the speech sounds.

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the minimal pair contrast. This is not surprising given the report of Gerken, Murphy, and Aslin (1995). They presented 3- to 4-year-old children with a target word and then asked if a series of test words differing from the target by two features on a single target or by a single feature on each of two targets matched the target. Young children confused the test word and minimally different target words. However, Barton (1978) has shown that by 3 years of age English-learning children can distinguish most similar sounding words. Recent research has also shown that infants of 24 months of age use fine phonetic detail with very familiar words. Swingley, Pinto, and Fernald (1998) show that infants recognize "doll" and "ball" as quickly as they do a non-minimal pair in a preferential looking task. Given these findings, I would predict that if familiar labels were used it would be possible to demonstrate acquisition of fine phonetic detail in slightly older children, using a minimally demanding task. Familiarity is often accompanied by words that serve a very functional purpose, such as food or favourite toys. It would also be interesting to test the effect of using a functional task for children.

Another related idea that remains to be tested is the near-neighbourhood effect. I picked stimuli that I calculated would come from the most densely populated neighbourhoods for infants, partly in an attempt to increase the pressure to incorporate fine phonetic detail. The contribution of this factor warrants future investigation. In particular, we need to assess comprehension inventories to determine if infants who have denser neighbourhoods for the word being taught represent more phonetic detail. For example if we were to use the /bl/ and /dl/ stimuli used in these studies, we might predict that those infants who understand more words that contain the vowel /i/ in nucleus position might encode the contrastive phonetic detail /b/ and /d/ to help keep the words distinct in their lexicons.
Related to the notion of vocabulary composition is the question: What is the effect of the child's productive inventory on word learning? It may be that those sounds that the child produces very well are learned more easily than those that are not, irrespective of the make-up of the child's comprehension inventory. This hypothesis is supported by the research of Leonard, Schwartz, Morris and Chapman (1981) who found that words containing consonants that the child could produce were acquired more readily than those that were not.

One way in which this research could be extended would be to examine the notion of specific orders of acquisition of phonological contrasts. I picked a contrast that by most accounts should be in place for most children by 14 months. As discussed earlier, Jakobson (1941/1968) was the first to propose that there might be a fixed order in the acquisition of consonants, although there is little support for a universal order of acquisition (e.g., Garnica, 1973; Shvachkin, 1948/1973). It should be noted, however, that these early approaches assumed a more structuralist model of phonological oppositions. More recently Brown and Matthews (1997) and Rice (1996) have proposed a hierarchy of phoneme oppositions within a model of feature geometry. To determine possible hierarchies Brown and Matthews (1997) tested children 1;3-2;4 in a forced choice picture selection task using stimuli containing minimal pairs. The result is a systematic, predictable order of acquisition that permits individual variability. Gierut (1996) has also proposed an alternative theory, in which the child adds increasingly more complex featural distinctions as phonemic contrasts of the language are discovered. These theories suggest an interesting extension of this work would be to explore various contrasts to determine the construction of a phonological system (Pater, Werker, & Stager, 1999).
Also of interest is the question: What entails a labeling opportunity for the child? The results of this series of studies confirm that there is something about naming an object that changes the nature of the acoustic representation, at least at some level. One important question that remains to be clarified is: What makes a visual stimulus a namable "object" to an infant and what is it that makes a sound a possible "word"? The objects I used in all the experiments except Experiment 5 have all the quintessential properties that signal "objectness" for infants (an unambiguous form that moves as a cohesive bounded unit, Spelke, Vishton, & Von Hofsten, 1994). The checkerboard used in Experiment 5 exemplifies a non-object (no integral form, no clear definition of beginning and end, Spelke, Vishton, & Von Hofsten, 1994). Preliminary research suggests that there is also something special about speech labels that facilitates label-object mapping. We have conducted some preliminary studies which suggest that infants are unable to form word object associations using sine-wave analogs of speech in a procedure identical to that used in experiments described in this thesis (Werker, Bird, Stager, & Corcoran, 1999).

The possible future directions outlined above all omit one of the most important remaining questions: Where in the processing do infants encounter difficulty? Is it at the level of the lexical representation,15 or does it come earlier or later? We have ruled out the possibility that infants of 14 months are no longer able to perceive the difference, but the exact position of the breakdown remains to be determined. The answer to this question has far

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15 Throughout the rest of the thesis I have used the term "representation" in the broader sense. This broader definition does not differentiate between the representation itself and operations performed on it. This broad definition is used throughout the literature as little research has been conducted thus far to determine the exact components involved.
reaching implications for theories of word learning. This is a fascinating topic for further research.

Conclusions

As infants begin the challenging task of forming an association between a word and an object, they do not appear to incorporate minimally contrastive phonetic detail. I have eliminated the possible explanations of a change in speech perception abilities (Experiment 5), or of some difficulty with the stimuli unrelated to the hypothesis (Experiments 6 and 7). The explanation of divided attention being the limiting factor can also be ruled out by previous findings. I propose that this failure to use contrastive phonetic detail in early word learning does not disadvantage the infant and may in fact be a necessary part of language development.
References


Appendix A: Factors in selection of stimuli.

Factors in the selection of auditory stimuli

While selecting my auditory stimuli I considered a number of factors: familiarity, frequency, selectivity, and perceptual distinctiveness.

Research has shown that familiarity facilitates word learning in children, and specifically familiarity has been shown to affect learning of phonetically-similar words (Barton, 1978). This would suggest that in selecting the stimuli, level of familiarization should be fully balanced. To ensure this was the case, I decided to use all unfamiliar word forms.

I also considered the evidence from early speech perception that children are sensitive to the frequency of the sounds presented around them (Jusczyk, Luce, & Charles-Luce, 1994). Nine-month-old infants (but not 6-month-old infants) presented with lists of words that contain high-probability phonotactic sequences and lists that contain low-probability phonotactic sequences for their languages, listened longer to the high-probability lists. In accordance with this I developed stimuli which have high conditional probability phonotactic sequences. I deviated from following high-probability syllable forms. While high-probability forms include CVC and CVV, I chose to use a CV form. A pilot study using a CVC form ("bif" and "dif") suggested that there may be some backward masking by the final consonant which could interfere with discrimination.

When designing the stimuli I also considered the work investigating children's phonological productive selectivity. Children attempt to say only words they are currently able to articulate, at least up until two years of age (Dobrich & Scarborough, 1992). This phonological selectivity effect has been
observed in naturalistic (Ferguson & Farwell, 1979) and experimental settings (Schwartz & Leonard, 1982). This selectivity effect appears to be strongest for word-initial consonants (Ferguson & Farwell, 1979; Shibamoto & Olmsted, 1977). There is some evidence, however, that childrens' productive selectivity does not appear to reflect a comprehensive selectivity (Schwartz & Leonard, 1982; Schwartz, Leonard, Loeb, and Swanson, 1987). Young children are reported to avoid learning words with sounds that are difficult to produce (Ferguson & Farwell, 1979; Vihman, Ferguson, & Elbert, 1986).

Leonard, Schwartz, Morris, and Chapman (1981) examined the production inventories of infants 1;0-1;4 and report that words containing consonants consistent with the children's phonologies were acquired more readily than those that were not.

As I was uncertain whether the observed selectivity is due to perceptual or production factors, it seemed most conservative to use phonemes that are generally thought to be in children's vocal repertoire. The stimuli selected, "bih" and "dih" were comprised of the phones: /b/, /d/, and /i/. Both /b/ and /d/ are common in babbling and in children's early words (Bernhardt & Stoel-Gammon, 1996; Locke, 1983; Vihman, Ferguson, & Elbert, 1986), and are easily discriminated by children 1;5 to 1;10 (Shvachkin, 1948/1973; Garnica, 1973). Similarly, /i/ is in the vocal repertoire of children of this age.

There are also reasons to select these stimuli on the basis of previous perception studies. Difference in place of articulation is a relatively easy discrimination for infants to make (Jusczyk, Copan, & Thompson, 1978; Jusczyk & Thompson, 1978; Kuhl, 1987; Trehub, 1976). Several studies specifically testing /b/ versus /d/ have shown that young infants can discriminate /ba/ from /da/ (e.g., Werker, Gilbert, Humphrey,
& Tees, 1981; Jusczyk, Murray, & Bayley, 1979; Eimas, 1974). I did not want to use /ba/ and /da/, however, because they are often in the productive vocabularies of 14-month-old infants as labels for other objects (e.g., 'ba' for 'bottle' or 'ball', 'da' for 'Dad'). Theories such as those of Mutual Exclusivity (e.g., Markman, 1991) and Contrast (e.g., Clark, 1983) hold that infants expect each object or class of objects to have only a single label. This may be a problem if the inverse is also true for infants, where they expect every label to only apply to a single object or class of objects. Recent research suggests, however, that even by 18 months of age infants are not using the Principle of Contrast (Schafer, Plunkett, & Thal, 1998). Many other vowels paired with [b] and [d] also constitute possible words for young infants. The syllables “bih” and “dih” were the best examples of CV forms using /b/ and /d/ that were not likely to be words to the infant. As a control for discriminability, 5 adults were tested on their ability to discriminate “bih” from “dih”, in the infant testing room, under the same testing conditions as those used for infants, and all achieved 100% accuracy.

An additional aspect I considered was whether to present the words in isolation or in sentence context. This decision was made in an attempt to lighten the cognitive load for the children and to facilitate focus on the words and objects. Some evidence however suggests that placing a word in sentence context may facilitate word learning for the infant. Namy and Waxman (1998) examined acquisition of new words for object categories when the words were presented in ostensive naming phrases versus when they were presented in isolation. They report 18-month-old infants learned better when the words were presented in phrasal context. Aslin (1993) had mothers teach their 12-month-old infants 3 new labels. His results show mothers use words
in isolation and in phrasal context. Although, seventeen of the 19 mothers used words in isolation sometimes, 11 of the mothers used sentential context more than 70% of the time. Fernald and Mazzie (1991) found that mothers attempting to target new words for their 14-month-old children presented the word in sentence context 84% of the time and in isolation only 16% of the time. Woodward, Markman, and Fitzsimmons (1994) used phrasal context to successfully teach new words to infants of 13 months, however in their study a conscious effort to provide social and contextual cues was made, which may have greatly simplified extracting the target word from the phrase.

However, evidence that is more directly related to our work suggests that in the present procedure ostensive sentential context does not facilitate forming word object associations. Lloyd, Werker, Cohen, and Swanson (1998) found that 14-month-old girls could learn word object associations for phonetically dissimilar words when the words were presented in isolation. When presented with the words in sentential context however, infants could not learn the association.

There is some evidence to suggest presenting words in isolation may be optimal for infants of 14 months. Shipley, Smith, and Gleitman (1969) found that the form that most facilitated comprehension depended on the individual infant's level of linguistic development. Infants of 18 to 33 months of age who produced only holophrastic speech (the level most representative of 14-month-olds) responded better to single item commands, whereas infants who produced telegraphic speech responded best to more complete commands.
Factors in the selection of visual stimuli

There is a notable lack of research on the influence of perceptual attributes on conceptual judgments in young infants (for a review see Jones and Smith, 1993). The existing research on infant category perception does suggest, however, that when labels are involved, the most salient factor is overall object shape (Baldwin & Markman, 1989). The stimuli used in these experiments differ in overall shape. Colour was held constant, but there were differences in the shape and number of elements comprising the objects. To ensure that one figure was not inherently more attractive than the other, the habituation objects ("poky" and "roundy") were composed of equivalent amounts of red, blue and yellow clay, and were balanced for size, brightness and colour. Although there is evidence that children come to realize that the rules for category membership can entail more than surface similarities, this realization is generally not seen until later in development than the 14 month period I was interested in (e.g., Davidson & Gelman, 1990).

I decided to use moving objects as in earlier related work, infants were unable to learn the word-object pairing if the stimuli were static (Werker, Cohen et al., 1998). Werker and colleagues (Werker, Cohen et al., 1998) suggest that movement may increase infant's attention, thereby helping infants to make the association between word and object. In work with adults and monkeys it has been shown that movement facilitates attentional focus and may also facilitate the abstraction of critical properties of objects (Washburn 1992, as cited in Washburn 1993). Some work with infants suggests that moving stimuli may have a similar facilitatory effect in infants (Burnham & Day, 1979; Mandler, 1992).
Appendix B: Object switch study

This experiment was designed to determine if infants respond to a switch in object after being habituated to a single word-object pair. It was originally reported in my Master’s thesis (Stager, 1995).

Method

Participants

A new sample of 16 14-month-olds was tested. All subjects met selection criteria described previously. An additional 9 infants were tested but were not included in the analyses because of experimenter error (n = 1), they were not visible (n = 4), the experiment had to be stopped because they were fussing (n = 3), or they did not habituate (n = 1).

Stimuli

Remained the same as for Experiment 2.

Apparatus

Same as Experiment 2.

Procedure

The experiment differed from that of Experiment 2 in only one way. The "switch" trial in this experiment was a switch in object, as opposed to a switch in label. The same objects and words were used as in Experiment 1.

Results and Discussion

Reliability Coding
Reliability coding was conducted as in all previous experiments. A correlation equal to or greater than .95 was reached for all subjects coded.

Analysis of the Data

As in all previous experiments a planned contrast was conducted. Results of the contrast revealed last block was significantly different from first block or post test ($F(1, 13) = 349.319, p < .0001$).

The primary question of interest in this study is whether infants noticed a switch in the word-object pairing. There was a significant difference between looking time on "switch" and "same" as determined by a $t$-test ($t(15) = 4.791, p < .0005; M_{same} = 6,495$ s, $SD = .877; M_{switch} = 10.710$ s, $SD = .746$).

Discussion

The results of this experiment indicate that infants have no trouble visually discriminating the objects. The infants may be noticing a new object paired with a familiar word, or may simply be noticing a new object and not even be listening to the word.
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Testing Booth

Video Camera

Speaker

Stimulus presentation

Child

Parent

Observation Booth

Monitors for observer (stimulus and child)

Observer

Figure 2
Figure 3
Figure 4

Mean Looking Time (s)

<table>
<thead>
<tr>
<th></th>
<th>Same</th>
<th>Switch</th>
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<tr>
<td>Value</td>
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Figure 5
Figure 6
**Figure 7**

Mean Looking Time (s)

Same | Switch
---|---
6.0 ± 1.2 | 8.0 ± 1.4
Figure 8
Figure 10

Mean Looking Time (s)

Same

Switch