INFANT ATTENTION TO PHONETIC DETAIL IN WORD FORMS:

KNOWLEDGE AND FAMILIARITY EFFECTS

by

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Abstract

Several recent studies have shown that 14-month-old infants have difficulty learning to associate two phonetically similar new words to two different objects in the Switch task. Because infants can discriminate the same phonetic detail that they fail to use in word-learning situations, the argument is that this word-learning failure results from a processing overload on cognitive resources (resource limitation). However, an alternate explanation is that novice word learners fail in word-learning tasks because they have yet to build phonemic representations and rely on simpler phonetic representations in discrimination tasks (representational discontinuity). In Experiment One, these explanations were tested by exploring how infants perform in the Switch task with known minimally different words, which should ease processing since the object-label link is already established. Novice word learners succeeded in noticing the phonetic detail in these well-known words. These results are compatible with the limited resource explanation and discount the representational discontinuity argument by demonstrating that the relevant contrast is already present in words. Experiment Two further explored the resource limitation hypothesis by asking if familiarity with a word-object combination is enough to ease processing and allow access to phonetic detail in the word. Fourteen-month-old infants succeeded in noticing the phonetic detail both when the word-object combination was well-known and when it was familiar. Experiment Three (Part A) confirmed that the infants' success in Experiment Two was not due to the perceptual salience of the contrast or to the use of the one-object version of the Switch procedure. Experiment Three (Part B) again explored the resource limitation theory by investigating if familiarity with the object alone, without familiarity with the word form,

is enough to ease processing such that novice word learners could access phonetic detail. The standard analysis of total looking time did not reveal success in the task; however, an analysis of first looks indicated that the infants may be able to access phonetic detail when only the object is familiar. The studies presented in this thesis support continuity in the representation and differential access to phonetic detail as a function of processing load.

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Preface

The ideas presented in this thesis represent the work of the author, developed in discussion with his PhD advisor, Dr. J. Werker.

The infants in Experiments One, Two, and Three were recruited by E. Job, A. Almas, C. Merkel, E. Moon, and M. Jetté.

Experiment One was designed, conducted, and analyzed by the author, in consultation with Dr. J. Werker. The task was designed based on a procedure originally developed by Drs. J. Werker and L. Cohen. The study was written by the author, in consultation with J. Werker, and published in *Language & Speech* (full citation: Fennell, C. T. & Werker, J. F. [2003]. Early word learners' ability to access phonetic detail in well-known words. Language & Speech, 46, 245-264).

Experiment Two was designed, conducted, and analyzed by the author, in consultation with Dr. J. Werker. The study was written by the author, in consultation with J. Werker, and published in *The Proceedings of the 28th Annual Boston University Conference on Language Development* (full citation: Fennell, C. T. & Werker, J. F. [2004]. Infant attention to phonetic detail: Knowledge and familiarity effects. Proceedings of the 28th Annual Boston University Conference on Language Development. Cascadila Press).

Experiment Three was designed, conducted, and analyzed by the author, in consultation with Dr. J. Werker.

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Chapter 1: Introduction

At the beginning of the second year of life, infants face the challenge of word learning. Previous research has demonstrated that they come to this challenge equipped with the refined ability to discriminate the sounds of their language, or languages. One would assume that the infant would apply this skill to early word learning and would not confuse similar sounding words, like "boat" and "goat". However, there is strong debate over whether this is the case. Some researchers have demonstrated that infants at this age can notice the differences between similar sounding words, while others have found evidence of confusion. Some theorists have used these latter findings to argue that infants ignore what was learned in the first year of life with respect to the sounds of their language(s) and start anew when faced with word learning. Others disagree with this position and argue that there is continuity between years one and two. The evidence in support of these positions will be examined and experiments that will tease apart these competing hypotheses will be presented; thus giving us a clearer picture of how infants begin their journey into word learning.

1.1 Phonetic detail in infant word forms: Methodological and theoretical divides

Prior to 1997, much of the research concerning infants' attention to phonetic detail focused on either the phonetic perception abilities of young infants (e.g., Eimas, Siqueland, Jusczyk & Vigorito, 1971; Werker & Tees, 1984) or the comprehension and use of phonetic detail in word forms during late infancy and toddlerhood (e.g., Barton, 1978; Garnica, 1973; Shvachkin, 1948/1973). Werker and Pegg (1992) pointed to the lack of research concerning infants' use of phonetic perception in early word learning; however, it was not until the publication of Stager and Werker (1997) that a comprehensive set of studies explicitly addressed the connection between infants' phonetic perception and novice word learners' use of phonetic detail. Stager and Werker examined how young word learners (i.e., infants aged 14 months) use contrastive phonological information when beginning to learn words. They found that 14-month-old infants do not use fine phonetic detail in a word-object associative task. This surprising finding, in light of the assumption that young word learners would use their fine phonetic detection abilities when learning new words (e.g., Werker, 1995), inspired a line of research into the relation between phonology and word learning during the second year of life (Bailey & Plunkett, 2002; Fennell & Werker, 2003; Naigles, 2002; Nazzi & Bertoncini, 2003; Pater, Stager & Werker, submitted; Schafer & Mareschal, 2001; Swingley & Aslin, 2000; Swingley & Aslin, 2002; Werker, Fennell, Corcoran & Stager, 2002).

The growing literature investigating young word learners' attention to phonetic detail is a welcome addition to the field of psycholinguistics. However, there is debate over the richness of novice word learner's lexical representations. A review of the recent research reveals that while the data from some studies indicate that novice word learners cannot access phonetic detail in word forms (e.g., Stager & Werker, 1997; Werker, Fennell, Corcoran & Stager, 2002), other researchers have demonstrated that same-aged infants can use all the detail found in words (e.g., Swingley & Aslin, 2002). These discrepant results reflect a divide in the child phonology literature.

Some researchers in child phonology have argued that there is a discontinuity between the phonetic, or low level perceptual, representations used in speech discrimination tasks and the phonological, or meaningful and generalizable, representations required for language use[1] (e.g., Barton, 1980; Ferguson & Farwell, 1975). Here, it is suggested that only gradually, as they acquire words, do children come to represent the more detailed information which might distinguish one possible word from another (e.g., Brown & Matthews, 1997; Edwards, 1974; Garnica, 1973; Rice & Avery, 1995). On the surface, the Stager and Werker (1997) results would seem to support this position (but as will be argued herein, they need not). On the other side of the theoretical gulf, researchers (e.g., Swingley & Aslin, 2000; Werker & Fennell, 2004) argue that there is a continuity between the phonetic detail acquired in early infancy and the phonetic detail of early word forms. In other words, infants' lexical representations could be fully realized phonetically since the phonetic categories formed in the first year of life would be available for infants to use in word learning. The results of the Swingley and Aslin study mentioned in the last paragraph would support this hypothesis. Thus there are two conflicting theories with results supporting both sides. Although reflective of the theoretical divide, is the dichotomous question of whether or not novice word learners attend to phonetic detail in word forms the most informative approach?

The present research project attempts to bridge the gap between these lines of research and theory by asking a more nuanced question. Rather than investigating if young word learners can or cannot generally access phonetic detail in words, the

[1] The division of phonetics and phonology is well-researched and defined in the field of linguistics. The former refers to the most basic level of language sounds (i.e., all sounds present in a language, but divorced from any meaning). The latter refers to the sounds of a language that contrast lexical meaning (e.g., /b/ and /p/ are phonemically different in English due to the fact that when you add them to the same ending, you have two different words – "bat" versus "pat"). However, the terms are often used interchangeably in psychology research, perhaps because the categories of interest are the same irrespective of whether they are described as phonetic or phonological. These issues will resurface throughout this thesis. In order to reduce confusion, only the term 'phonetic' will be used when dealing with the categorical perceptual differences present in the stimuli used in my experiments. As the major argument of this thesis is that there is continuity between the phonetic representations formed in infancy and the representations used in early word learning, the use of the term phonetic will serve as a reminder of that continuity. The term phonemic, or phonological, will only be used when discussing linguistic theory.

conditions under which infants demonstrate attention to phonetic detail will be explored using a well-established word-object associative task. Specifically, infants' ability to use phonetic detail in well-known words and minimal pairs, which are two words that differ in a single phonetic feature, will be investigated. These empirical studies will help to provide clear answers to the questions emerging from the literature on early word learners' use of phonetic detail, as well as provide critical tests of relevant theories of child phonology.

The specific hypothesis presented in this thesis is that the phonetic categories refined via perceptual learning in the first year of life are used in early word learning. In other words, there is a direct continuity between pre-lexical and post-lexical phonetic representations. This hypothesis, which is based in part on parsimony, predicts that any apparent discontinuity between pre- and post-lexical use of phonetic detail is the result of a third factor. The third factor hypothesized to interfere with use of phonetic detail is processing load.

The argument presented in the following chapters is that the apparent discontinuity seen in previous speech perception and word learning research, where novice word learners access phonetic detail in speech perception and fail when words are linked to meaning, can be accounted for by the claim that processing demands mask infants' underlying ability to access and use fine phonetic information. The specific processing demand explored in the experiments contained in the thesis is that of novel word – novel object association. For novice word learners, the linking of label and object is a complex task that places heavy demands on cognitive resources, such as memory and attention. The infant has to attend to the visual aspects of the object and acoustic properties of the word form, encode all this information, remember it, and retrieve the appropriate information – all the while linking the word and object together. The demands of this learning situation overtax the computational resources available to the novice word learner, and lead to a specific type of performance error - failure to access phonetic detail.

Although word learning is the focus of the current thesis, if one looks broadly at the resource limitation hypothesis, any factor that increases processing load could be investigated. For example, Wales and Hollich (2004) demonstrated that the presence of white noise, which no doubt increases processing load, interferes with 14-to 26-month-old infants' ability to use phonetic detail in novel words. Word learning is the current focus because of previous research that indicated that it could be a factor that interferes with access to phonetic (e.g., Stager & Werker) and visual (Casasola & Cohen, 2000) detail in infants. Moreover, word learning is developmentally specific in that it is especially difficult for infants of 14 months due to the fact that they are novices at word learning. After all, an adult would have little problem in the Stager and Werker task, but the same adult may miss detail in the Wales and Hollich task, as loud white noise could interfere with use of phonetic detail at any age. Finally, the key roles that phonetic perception and word learning play in language acquisition makes an investigation into their relationship important to the overall study of infant language learning.

The resource limitation hypothesis is tested via three experiments that systematically manipulate infants' level of familiarity with the words and objects. In the first experiment, the continuity of phonetic representations is demonstrated by eliminating the word-object linking burden. Specifically, 14-month-old infants were tested on their ability to access phonetic detail in words they understood well prior to being tested in the laboratory. The infants succeeded in noticing the same detail (i.e., [b] and [d]) that they failed to use in previous word-learning work. This result demonstrates that phonetic detail is present in the infants' representations of early words and provides strong support for the hypothesis that the requirement of linking words to objects masks access to said detail.

The second experiment tested whether familiarity with a word and/or object is enough to allow for access to phonetic detail, or whether the explicit word knowledge present in Experiment One is the key to phonetic access. The results from the second experiment demonstrated that word and/or object familiarity is enough to reduce the demands on cognitive resources and allow for the use of phonetic detail at 14 months of age.

The third experiment confirmed that the results of Experiment Two were not due to other facilitative factors, such as an easier procedure or greater acoustic/perceptual differences in the phones being tested. Experiment Three also tested if object familiarity, without word form familiarity, was enough to reduce the complexity of the linking task and allow for access to phonetic detail. The standard analysis of overall looking time suggests that familiarity with the object alone does not reduce the demands of the task enough for 14-month-old infants to use phonetic detail. However, a post-hoc analysis of first looks to the object indicated that object familiarity may play a role in allowing for access to phonetic detail.

Overall, the experiments presented in this thesis support a continuity between pre- and post-lexical phonetic representations. Moreover, the studies confirm that for young word learners, the task of associating words with objects is sufficiently difficult to block novice word learners' use of phonetic detail. When the task is simplified, it can be seen that the representations refined for use in the first year of life are used in early word learning. Before describing the experiments in further detail, an elucidation of the background theory and research that culminated in the current research program is in order.

1.2.: Phonetic perception in the first year of life

1.2.1.: Behavioural work

From the beginning of the first year of life, infants demonstrate sensitivities to phonetic contrasts. Eimas, Siqueland, Jusczyk and Vigorito (1971) conducted the classic study in infant phonetic perception. They investigated the ability of 1- and 4-month-old infants to discriminate phonetic contrasts by presenting pairs of CV syllables that only differed in the voice onset time (VOT)[2] of the initial consonant. There were equivalent differences in VOT between the items in each pair, but the paired items either crossed phonetic categories (e.g., ba vs. pa) or remained within a phonetic category (e.g., one ba vs. another ba). The infants of both ages were able to discriminate the stimuli that crossed categories, but not the stimuli from within a category, thus demonstrating that even 1-month-old infants are capable of categorical–like speech perception. Infants as young as 2 months can detect other consonant differences, including [r] versus [l] and [m] versus [n], in the initial position of a CV syllable (Eimas, 1975; Eimas & Miller, 1980). Other researchers have shown that very young infants can detect changes in vowel colour (Kuhl, 1979) and can detect changes when a consonant that is consistent over a set of

[2] Voice onset time is a measure of the time between the release of the stop and the beginning of the voicing of the following vowel. For example, a small amount of VOT distinguishes [b] from [p].

syllables (e.g., /ba/, /bi/, /bu/) changes to a new consonant (e.g., /di/). The same effect was found for vowels (Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy & Mehler, 1988; Jusczyk, Bertoncini, Bijeljac-Babic, Kennedy & Mehler, 1990). These results indicate that the range of phonetic contrasts that an infant can discriminate is quite broad (for reviews see Aslin, Jusczyk & Pisoni, 1998; Burnham, 1986; Werker & Tees, 1999).

Werker and Tees tested this breadth of infant sensitivities in 1984. Previous work had suggested that adults often have difficulty discriminating phonetic contrasts that do not occur in their native language (Strange & Jenkins, 1978; Werker & Tees, 1983). Other work indicated that young infants (1 to 7 months of age) could discriminate non-native contrasts (Streeter, 1976; Trehub, 1976; Werker, Gilbert, Humphrey & Tees, 1981). To examine when this change from broad-based to language-specific phonetic processing may occur, Werker and Tees tested the perception of non-native contrasts from Hindi and Nthlakampx in three groups of English-learning infants: 6-8 months of age, 8-10 months of age, and 10-12 months of age. While the 6-8-month-old infants discriminated the non-native contrasts, the older groups failed to discriminate these contrasts, with the oldest group showing the worst performance on the non-native contrasts. Importantly, Hindi- and Nthlakampx-learning infants continue to discriminate their respective native contrasts at 10-12 months. These results suggest that the narrowing of phonetic sensitivities is due to the language environment in which the infant is maturing. This age-related trend of moving from general to language-specific phonetic perception has been replicated using many different contrasts (Anderson, Morgan & White, 2003; Best, 1993; Best, McRoberts, LaFleur & Silver-Isenstadt, 1995; Burnham, Earnshaw & Clark, 1991; Pegg & Werker, 1997; Polka & Werker, 1994; Tsao, Liu, Kuhl

& Tseng, 2000; Werker & Lalonde, 1988). The above research demonstrates that the perceptual salience of phonetic information becomes language-specific during the first year of life (for review see Werker, 1995).

1.2.2: Electrophysiological research

A similar set of findings can be drawn from research using event-related potentials (ERPs), an electrophysiological approach that measures the electrical signals generated by the brain in response to stimuli presentation. Cheour, Alho and Sainio (1997) have demonstrated, using the mismatch negativity (MMN) ERP response, that infants as young as 3 months of age can discriminate phonemes. The MMN is elicited by infrequent discriminable changes in auditory stimuli and usually occurs around 100-200 msec post-stimulus presentation (Näätänen, 1992). For example, for an infant hearing "da" nine times in a 10-item stimuli set, the single "ba" elicits a MMN, indicating that the infant can discriminate "ba" from "da". Dehaene-Lambertz and Dehaene (1994) have also shown that infants can discriminate phonemes at 2 to 3 months of age. In their experiment, sixteen infants listened to sets of syllables where the standard syllable (ba) was repeated four times and a deviant syllable was presented once (ga). The waveforms generated by the infants revealed two distinct peaks, one at 220ms and one at 390ms. The amplitude of the first peak decreased as the number of syllable repetitions increased and it did not recover to the deviant syllable. The amplitude of the second peak also decreased after the presentation of the first syllable, but it did recover when the deviant syllable was presented. Thus, a positive peak at 390ms, or a P400, was the key phonetic discrimination component in this study.

It is interesting to note the differences in the above studies. Cheour et al. (1997) found an infant MMN response, whereas the infants in the Dehaene-Lambertz and Dehaene (1994) study demonstrated a positive peak at 390ms. While the MMN found in 3-month-olds is adult-like in its timing, it is possible that the "P400" seen in the Dehaene-Lambertz and Dehaene study may be an immature version of the P3 component[3], an ERP waveform that is thought to reflect directed attention to significant stimuli (e.g., Bartgis, Lilly & Thomas, 2003; Molfese & Molfese, 2001). Perhaps the "delayed" P3 denotes a beginning of the realization that phones are significant stimuli and not just simple acoustic waveforms. It is plausible that the sleeping 3-month-old infants in Cheour et al. (1997) were processing the phones at this level, as evidenced by their MMN response, a basic-level, attention-independent component. At the phonetic level, infants have organized speech sounds into categories. The potential "P3" response seen in the Dehaene-Lambertz and Dehaene study, which is a component thought to reflect voluntary attention to important changes in stimuli, could be an indication that even 3-month-old infants have begun to attend to phonetic categories as important units of language. Whether the delayed P3/phone importance hypothesis is true or not, all of the above studies clearly demonstrate that infants as young as 3 months of age can discriminate phonetic information.

The results from ERP work also replicate the finding that listening experience changes speech perception performance during the first year of life. Cheour, Ceponiene,

[3] It should be noted that Molfese and Molfese (2001) warn against comparing infant and adult ERP data. They argue that neuroanatomical differences between infants and adults are too great and that similar wave components found across the two ages could be supported by different structures. They even use the P3 component as an example (although they present no evidence for their argument). In support of the argument for adult-infant similarities, Kushnerenko, Ceponiene, Balan, Fellman and Naantanen (2002) have recently discovered that the positive component masking the MMN in infant tone discrimination research appears to be the analogue of the adult P3 response.

et al. (1998) used three vowels and two language groups to examine changes in phonetic perception in infancy. The three vowels were: [e], which is in both Finnish and Estonian; [ö], which is also in both languages; and [õ], which is only in Estonian. Finnish and Estonian 6-month-old infants showed the standard MMN response to both [ö] and [õ] when they were the deviant stimuli embedded in a set of [e] phones. However, Finnish 12-month-old infants only showed the MMN response to the Finnish [ö] and not to the Estonian [õ], whereas Estonian 12-month-olds showed the MMN response to both vowels.

Now that a refining of perceptual sensitivities to phonetic information has been demonstrated using both behavioural and electrophysiological measurements, we can turn to the possible ways that infants carry out this reorganization.

1.2.3. Potential mechanisms for refining phonetic sensitivities

What is the mechanism driving the reorganization seen in phonetic perception over the second half of the first year of life? Pegg and Werker (1997) found that infants of 10-12 months of age fail to discriminate phonetic information that they are exposed to but which is not used to contrast meaning in their native language (i.e., allophonic variation). Specifically, English-learning infants failed to discriminate the syllable /ta/ from a syllable created by removing the [s] from the syllable /sta/. This modified syllable - /t=a/ - is treated by English adults as an acceptable instance of /ta/, although they can discriminate the natural /ta/ from the modified syllable. Thus, the /ta/ - /t=a/ contrast, while discriminable, does not indicate a meaning difference in English. The finding that 10 to 12-month-old infants fail to discriminate /ta/ - /t=a/ indicates that, as infants become attuned to the phonetic inventory of their native language, they attend less to contrasts that do not distinguish *meaning* in their language. This is consistent with the fairly common hypothesis that it is the beginnings of word comprehension that are driving the perceptual change (e.g., Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Werker & Pegg, 1992).

Maye, Werker and Gerken (2002) have postulated a mechanism for native-language phonetic refinement that does not rely on word meaning: statistical learning. They trained infants of 6 to 8 months using an eight-step continuum of the same contrast used in the Pegg and Werker (1997) study (i.e., /da/ - /t=a/). The key variable was that the infants were either trained on a unimodal distribution (steps 4 and 5 presented more often) of the continuum or a bimodal distribution (steps 2 and 7 presented more often). Infants exposed to the bimodal distribution successfully discriminated the end points of the continuum (1 vs. 8) at test, whereas those infants trained on a unimodal distribution did not. These results indicate that a meaning-devoid analysis of linguistic input over the first year of life can account for the phonetic perceptual reorganization. However, the Pegg and Werker data challenge a reorganization model that only includes statistical learning as the mechanism, since the meaningless contrast tested in their study was less salient to the infants. On the other hand, infants are rarely exposed to [t=] in syllable initial position, which, according to a statistical learning model, would not allow for a [t=] category to be maintained, as the [d] mode would overshadow and envelop the [t=] phoneme. This debate over the importance of word meaning to phonetic perception will resurface throughout this paper.

1.2.4. A broader view of language specificity during infancy

It is important to note that other aspects of speech perception become language-specific over the first year of life. Jusczyk, Luce and Charles-Luce (1994) demonstrated that infants are sensitive to the phonotactics[4] of their language, English in this case. They presented 6- and 9-month-olds with lists of high frequency and low frequency phonetic sequences. The 9-month-olds, but not the 6-month-olds, listened significantly longer to the high frequency sequences. Friederici and Wessels (1993) found that Dutch infants also show sensitivity to the permissible phonotactic sequences at 9 months. In a cross-language study, Jusczyk, Friederici, Wessels, Svenkerud, and Jusczyk (1993) discovered that 9-month-old English infants preferred words with English sound patterns (i.e., conforming to English phonetics and phonotactics) to those with Dutch sound patterns. The reverse pattern was found for 9-month-old Dutch infants. Infants also become sensitive to the stress patterns of their native language over the first year of life. Jusczyk, Cutler and Redanz (1993) found that 9-month-old, but not 6-month-old, infants displayed longer listening times to lists of words that conformed to the dominant stress pattern of their native language. All these findings demonstrate that infants' experience with their native language has an organizing role for language discrimination abilities and preferences.

1.3. Does phonetic specificity help in early word learning?

By the end of the first year of life, infant phonetic sensitivities have narrowed to those contrasts used in their native language (e.g., Werker & Tees, 1984). The young word learner at 14 months of age therefore has the ability to attend to the language-specific variation in the phonetic information present in the speech stream. The question

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[4] Phonotactics are the rules that govern acceptable phoneme sequences in a language. For example, "tr" is acceptable in English, but not in Japanese. "Lba" is not acceptable in English, but it is in Russian.

naturally arose whether these novice word learners would use their language-specific phonetic categories to aid in vocabulary acquisition. Can infants extract detailed word forms from the speech stream and can they use phonetic detail when attaching word forms to meaning?

1.3.1. Infants' recognition of phonetic detail in word forms

Perceptual tuning to the prosodic, phonetic, and phonotactic characteristics of the native language provides infants with a set of sensitivities that enable them to segment words from the speech stream and to learn to recognize familiar word-sized units. Mandel, Jusczyk and Pisoni (1995) reported that 4.5-month-old infants listened preferentially to their own names over other names that were matched on stress patterns, thus showing recognition of familiar word units. Hallé and de Boysson-Bardies (1994) tested 11-month-old infants' recognition of familiar words. Infants listened significantly longer to the familiar words over unfamiliar words that were matched on phonetic details. These studies indicate that infants are using some phonetic detail to pick out familiar words, but the level of detail used was still unknown.

Jusczyk and Aslin (1995) investigated the amount of phonetic detail used by infants in word recognition. First, they demonstrated that 7.5-month-old infants could detect familiar words in fluent speech. The researchers familiarized infants to pairs of words, such as "cup" and "dog", for 30 seconds. The infants then listened to four passages, two of which contained the familiarized words. The infants listened longer to the passages that included the familiar words. In an interesting reversal of the first experiment, Jusczyk and Aslin trained 7.5-month-olds on sentences that contained a target word. They then tested the infants on single words, including the target word. The infants listened longer to the target word. To investigate the level of phonetic detail used in the infants' recognition of word forms, Jusczyk and Aslin used the same procedure as above. However, they altered the initial phoneme of the word in the training phase. For example, instead of being trained on the word "cup", the infants heard the non-word "tup", which only differs on one phonetic feature from "cup". The infants were then tested on the same phrases as before (i.e., the ones containing "cup"). The infants showed no preference for the phrases containing the phonetically similar word. These results demonstrate that infants have encoded very detailed representations of word units[5] at 7.5 months.

Hallé and de Boysson-Bardies (1996) found seemingly divergent results in a study examining the amount of phonetic detail that older infants use to recognize high frequency words. They found that 11-month-old infants did not notice a difference in high frequency words when the voicing of the initial consonant changed (e.g., "*b*onjour" and "*p*onjour" were treated the same) or when the initial consonant was omitted (e.g., "*b*onjour" and "onjour" were treated equally)[6]. Paradoxically, these results indicate that 11-month-old infants are not encoding as much phonetic detail in word units as the 7.5-month-olds from Jusczyk and Aslin (1995).

Hallé and de Boysson-Bardies (1996) postulated that it is the movement to word learning that accounts for the less detailed representations at 11 months. Jusczyk and Aslin (1995) consistently stressed that their task requires only listening to word forms without knowledge of word meaning, while Hallé and de Boysson-Bardies speculated

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[5] These are not words in the truest sense. This is due to the fact that the units of sound are not being associated with any meaning.
[6] The infants did notice a difference when the manner of articulation of the initial consonant was altered (e.g. "*b*onjour" to "*v*onjour").

that infants of 11 months failed to notice phonetic detail precisely because they were listening for meaning, although it is important to note their task did not *require* the infant to listen for meaning. Hallé and de Boysson-Bardies' hypothesis is in line with the child phonologists mentioned earlier in the introduction who argue for a restructuring of phonetics into phonology. These discontinuity theorists would argue that the 11-month-old infants are in the process of building their phonological inventory and thus cannot pick out the relevant distinctions to discriminate the target words. However, as will be seen in the next section, subsequent studies inspired researchers to formulate the resource limitation hypothesis, which can also account for the Hallé and de Boysson-Bardies findings.

1.3.2.: Attention to phonetic detail in meaningful word forms

1.3.2.1. Behavioural work with older infants and toddlers

To inform the hypothesis that associating meaning to words affects attention to phonetic detail, one can examine the behaviour of older infants and toddlers in minimal pair tasks. The existing research on older infants' and toddlers' ability to attend to detail in words provides a somewhat confusing picture of whether they use detailed phonetic information when learning words. On the basis of a series of experiments with minimal pairs, Shvachkin (1948/1973) provided evidence that, although infants may initially fail to differentiate similar words, they fill out their phonological inventory by the end of the second year of life and no longer confuse minimal pair words. However, Barton (1978, 1980) reported that 2-year-olds still confuse minimally different words if they do not already know them well. Eilers and Oller (1976) reported that three-year-olds confuse minimal pairs in that they treat single feature phonetic substitutions in well-known words as acceptable pronunciations. Brown and Matthews (1997) tested 15- to 28-month-old infants in a forced-choice minimal pair picture selection task and found that the infants succeeded in using some phonetic contrasts before others. Similar findings of minimal pair confusion have been reported by Edwards (1974), Garnica (1973), Gerken, Murphy and Aslin (1995) and Kay-Raining Bird and Chapman (1998), among others.

This inconsistent pattern of results left the question unresolved of whether young word learners have the ability to use phonetic detail to distinguish lexical items in word comprehension tasks. As mentioned earlier in the introduction, to address this ambiguity, a 1997 study by Stager and Werker used a task that requires the infant to link objects and labels. Because Stager and Werker wanted to test infants as close to the beginning of the word learning period as possible, they chose a task that should be easy for infants. The picture selection and pointing tasks used in the earlier child phonology studies could be too difficult for infants, and arguably even for toddlers. Thus, task difficulty alone may have led to the findings that young children do not attend to phonetic detail. Also, the claim that associating meaning to a word diminishes use of phonetic detail is difficult to evaluate because the tasks used in the infant studies, including the Hallé and de Boysson-Bardies (1996) study, did not require the infant to understand that the labels referred to objects. To address these potential confounds, Stager and Werker turned to a word-object associative task called the "Switch" procedure that Werker had developed in collaboration with Leslie Cohen's laboratory at the University of Texas at Austin[7].

[7] Prior to using the Switch procedure, Stager and Werker (1997) attempted to use the Intermodal Preference Paradigm and the Known-Object/Variable-Word Single Display Task. They found that the Intermodal Preference Paradigm required the infants to have a robust understanding of the Novel Name-Nameless Category (N3C) principle (i.e., an unfamiliar object and an unfamiliar label probably go together), which does not emerge until 16-20 months of age (Mervis & Bertrand, 1994). This is well past the age they wanted to test. Stager and Werker found, via a test-retest analysis, that the Known-Object/Variable-Word

In the Switch procedure, infants are habituated to two word-object pairings and tested on their ability to detect a switch in the pairing (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). To assess whether infants have learned not only about the words and objects individually, but have linked object A to word A and object B to word B, they are then tested in the Switch design. This involves two test trials. On both trials a familiar object accompanied by a familiar word is presented. On the control trial (the 'same' trial) the familiar word and object are presented in a familiar combination; e.g., Object A with Word A. On the test trial (the 'switch' trial) a familiar word and object are presented, but in a new combination; e.g., Object A paired with Word B. If the infants have learned about the words and the objects but have not learned the associative link, the 'same' and 'switch' trials will be equally familiar, and should attract equal looking times. However, if the infants have learned the link between the specific words and objects, the "switch' trial, as a violation of that link, should attract greater looking time than the 'same' trial.

Using the Switch procedure, Werker et al. (1998) demonstrated that 14-month-old infants can learn dissimilar sounding labels (e.g., "lif" vs. "neem"); however, Stager and Werker (1997) found that infants could not learn phonetically similar labels in this word-object associative task (e.g. "bih" vs. "dih")[8]. This was unexpected because the earlier work on infants' refining of phonetic sensitivities during the first year of life would predict that the [b] – [d] contrast, which is phonemic in English, would be easy for a 14-

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Single Display Task was unreliable. Thus, in comparison to the above procedures, the Switch procedure was the best task to test the connection between pre-lexical phonetic perception and post-lexical phonology.
[8] This result has since been replicated under many different conditions. Pater, Stager and Werker (in press) used different phonemic contrasts, including a voicing contrast ([b] vs. [p]) and a place + voicing contrast ([d] vs. [p]). Pater et al also used more valid CVC word forms ("bin" vs. "din"), rather than the unnatural, at least in English, CV (lax vowel) word forms used in the original Stager and Werker article. In both cases, the 14-month-olds failed to notice the difference in the similar sounding labels. Fourteen-month-olds continue to fail to learn minimal pairs in the switch task even if the objects are made more distinct and longer habituation trials are given (Experiment 2, Werker et al, 2002).

month-old English-learning infant to discriminate, and presumably to use in word learning. Thus, Stager and Werker conducted a series of control studies to further investigate why the 14-month-olds failed to apply their language specific phonetic sensitivities to word learning.

In their first set of control studies, Stager and Werker (1997) tested 8- and 14-month-old infants in the single-object variant of the Switch task. Infants were only habituated to one word-object combination in this task and the 'switch' trial entailed a switch from the habituated label to a novel label. Werker et al. (1998) had shown that infants as young as 8 months can succeed in this version of the task (which does not require linking the word to the object, but can be solved as only a discrimination task) when the words are phonetically dissimilar (i.e., 'lif' vs. 'neem'). Stager and Werker tested whether infants of 8- and 14- months could succeed on the [b] – [d] contrast. The 8-month-old infants in this study looked significantly longer to the switch from "bih" to "dih" (or vice-versa), but once again the infants of 14 months failed. Stager and Werker hypothesized that the 8-month-old infants succeeded in the Switch procedure because they treated it as a straight discrimination task while the14-month-old infants, due to their status as word learners, shifted into a word-learning mode when conditions made word-learning possible (even if word learning was not required). They speculated that the presence of a moving, nameable object enables word learning in infants this age and that, once word-learning is evoked, attention to fine phonetic detail is no longer evident. To investigate this hypothesis, they tested 14-month-old infants in the single-object variant of the Switch procedure. In this control study, the two similar-sounding labels were paired with one visual presentation that was unlikely to be treated as an object by the infants - a stationary, unbounded checkerboard (see Spelke, 1994). The infants looked longer to the switch in labels under these conditions. Based on all the above findings, it would seem that infants of 14-months only have difficulty accessing phonetic detail when they are placed in a word-learning situation.

The findings presented above make it clear that under a variety of testing conditions, infants aged 14 months have difficulty *learning* phonetically similar words in a brief, laboratory-based habituation procedure. However, it is always problematic to draw conclusions on the basis of negative results with infants. One never knows whether the continued failure of infants aged 14 months to learn phonetically similar words really reveals something about the novice status of the infants, or instead whether for any other of an infinite number of reasons, the task simply failed to reveal an underlying capability.

1.3.2.2. Electrophysiological work

Electrophysiological measures that provide a positive result, rather than a negative result, would confirm (or falsify) the difficulty using fine phonetic detail seen at 14 months. At the same time, this technique could address the question of whether expert word-learners would be more likely to have more detailed phonetic information in their lexical representations. Previous work by Mills, Coffey-Corina, and Neville (1993, see also Mills, Coffey-Corina & Neville, 1997) revealed that infants show higher amplitude ERP responses at 200-450 msec following presentation of known versus unknown words (N200-400). At 13-17 months, this difference is detected in both hemispheres, and shows up over frontal, temporal and parietal lobe sites. By 20 months, it is only observed from electrodes over the LH (left hemisphere) temporal and parietal lobes, suggesting the emergence of specialized brain systems for processing words by that age. The infants aged 20 months who were post (> 150 words) vocabulary spurt showed the localized LH response whereas infants with smaller vocabularies (<50 words) showed the more distributed response, indicating that the increasingly local nature of the differential ERP signature seen in older infants reflects greater sophistication in word knowledge rather than age per se. On the basis of these findings, Mills and colleagues hypothesized that the establishment of a specialized system for word learning makes the word spurt possible (Mills et al., 1997; see also Mills et al., 1993). Of course, no source localization techniques were used and a limited number of electrodes were used. While these data are suggestive, there can be no definite conclusions about the actual brain systems involved.

Mills, Prat, Zangl, Stager, Neville & Werker (in press) decided to take advantage of the finding of a high amplitude ERP response to known words, in order to examine the phonetic representation of words in new and more experienced word learners. They tested infants of 14 and 20 months of age in the same ERP procedure as used by Mills et al. (1997). This time, however, instead of presenting the infants with randomly varying presentations of 10 known and 10 unknown words (as Mills et al., had done), they added 10 unknown words that are phonetically similar to the known words. For example, as a direct replication of the previous work, they presented infants with known words such as "dog, cat, shoe, milk" and phonetically dissimilar nonce words such as "neem, blick, zav, kobe", but as an extension added to that a set of nonce words that are phonetically similar to the known words, such as "bog, gat, zue, nilk". As a replication, they predicted that infants of 14 and 20 months would show higher amplitude ERPs to the known versus the phonetically dissimilar unknown words, and that this would be seen across most electrode sites at 14 months but would be more focal at 20 months. As an extension, they were interested in the pattern of responses to the phonetically similar nonce words. They reasoned that if there is sufficient detail in the lexical representation, the ERP signature to these phonetically similar foils should be like that of phonetically dissimilar unknown words. However, if the lexical representation is not detailed, these should be confused with known words.

The infants aged 14 months (most of whom still had relatively small vocabularies) showed the same whole brain pattern of high amplitude ERP activation to known, but not phonetically dissimilar nonce words replicating what had been previously reported by Mills et al. (1997). Of interest, however, their ERP activation to the phonetically similar nonce words looked just like that to the known words. In other words, when the infants of 14 months were presented with nonce items like "bog", the ERP signature revealed recognition, indicating confusion – likely with similar sounding known words such as "dog". At 20 months the pattern was reversed. Again, the results of Mills et al. were replicated such that the higher amplitude ERP response to known words was only found in electrodes over the LH temporal and parietal electrode sites, but this time the phonetically similar nonce words revealed an ERP signature just like the other nonce words. The brains of the infants of 20 months, all of whom were post-vocabulary spurt, did not confuse words like "bog" with the known word "dog", but instead treated them like unknown words, such as "zav" (Mills et al., in press).

These findings provided confirmation that infants of 14 months do indeed have difficulty distinguishing similar-sounding words. On the basis of the behavioural work one had to draw this conclusion by comparing a series of positive findings to the failures of the infants aged 14 months. In the ERP task, the infants of 14 months did not fail anything. Indeed, they showed a special "known word" ERP signature to the phonetically similar non-words. Confirmation of the failures in the behavioural tasks with an interpretable response in the ERP task significantly strengthens the finding. An explanation for why this difficulty exists is required.

1.4. Representational discontinuity vs. continuity

1.4.1. Theoretical positions

As mentioned before, according to one line of reasoning, infants must gradually construct a phonology in which, among other things, the contrastive phonemic inventory of the language is represented. This is believed to be a gradual process that comes about through the establishment of a lexicon and more experience with specific word forms (e.g., Charles-Luce & Luce, 1995; Metsala, 1999; Metsala & Walley, 1998). To deal with the apparent inconsistency between the fine phonetic abilities shown in speech perception studies and the mistakes made in early word acquisition, Brown and Matthews (1997) postulate that two separate developmental patterns exist for phonetic versus phonological development. Phonetic development is described as involving "pruning": the infant begins life with a fairly comprehensive phonetic repertoire and stops discriminating those differences that do not occur systematically in the input. Phonological development requires "building": the infant must gradually build a phonology on the basis of the phonemic oppositions encountered in building a lexicon.

Brown and Matthews' (1997) argument for a separation of phonetic and phonological development is based on their finding that older infants appear to acquire certain phonological contrasts before others. They reason that if there were continuity between phonetic and phonological representations, all native contrasts should have been available for use in the word forms present in their research, since native-language phonetic categories are refined in the first year of life. Furthermore, the hierarchical acquisition of phonological contrasts found in their study indicates a building process. While their experiment had major methodological problems (e.g., varied ages, demanding picture selection task), their hypothesis cannot be dismissed out of hand, as other researchers have also found evidence for phonological hierarchies (e.g., Jakobson 1941/1968; Rice & Avery, 1995). Brown and Matthews used the notion of a hierarchy as a basis for arguing that phonological representations must be built up, not pruned back like the phonetic categories in the first year of life. This account assumes then a representational discontinuity between phonetic perception and phonological acquisition.

The other class of explanations rejects the notion that the processes of phonetic and phonological development are independent and argues instead for a continuity between phonetic and phonological representations (Swingley, 2003; Werker & Fennell, 2004; Werker, Fennell, Corcoran & Stager, 2002). Here the theoretical arguments are based largely on notions of parsimony. According to this line of reasoning, if the information is discriminable phonetically, it must be available - barring performance limitations - for phonological use.

The explanation put forth by Stager and Werker (1997) falls into the representational continuity class of explanations. They focused on the complex nature of word learning. For a novice word learner, forging a link between a label and an object is a computationally demanding task, as the infant has to accurately attend to, store, and retrieve details about both the word and object while also processing their co-occurrence and relationship. Thus, the cognitive resources (e.g., perception, memory, attention) available for attending to, remembering, and using the fine phonetic detail of the word are limited. This limited resource explanation rests on the assumption that, in any difficult task, cognitive processes are taxed and information is potentially lost (Casasola & Cohen, 2000; Cohen, 1998). This hypothesis follows the tradition of Kahneman (1973) in postulating attention as a resource pool and adds to a literature relating to attentional demands on sublexical processing and lexical access, and the subsequent processing difficulties that arise from those demands (for a review see Fischler, 2000). In this case, it is the fine phonetic detail that the child sacrifices. It can be argued that this "less is more" approach is adaptive (Newport, 1990). The benefits of reducing information load to more quickly learn the word outweigh the "cost" of not using fine phonetic detail. With only a small lexicon, it is likely not necessary to attend to and pick up the fine phonetic detail, as estimates of child vocabularies confirm that children have few phonetically similar words in their early lexicons (Charles-Luce & Luce, 1995).

The resource limitation hypothesis offers an alternative account to the discontinuity theories of why infants might fail to distinguish minimally different words even though they can discriminate those same phonetic differences in a simple speech discrimination task. Specifically, the resource limitation hypothesis assumes a continuity in the underlying representation with the difficulty lying in the access to the phonetic detail. As such it does not require the child to completely rebuild the phonology *de novo*. It acknowledges that at least the phonetic detail is represented, and suggests that the problem lies in using that phonetic detail in a word learning situation. In this way it maintains the parsimony of a continuity model while offering an alternative account for the data showing that under some conditions infants and children confuse minimally different words (for a similar arguments regarding syntax and orthography, see Naigles, 2002, and Burnham, Tyler & Horlyck, 2002, respectively).

1.4.2. Recent investigations

The resource limitation explanation predicts that infants who have had more experience and more success in word learning should find the act of word learning easier and should thus be able to devote more cognitive resources to accessing the detail in the word form. One proxy that has been used for proficiency in the past is vocabulary size. Proponents of the resource limitation hypothesis have predicted that there should be a correlation between vocabulary size in the early stages of word learning and success in the minimal pair word learning task (for a more complete discussion of the relation between vocabulary size and the ability to access phonetic detail, see Werker et al., 2002; see also Beckman & Edwards, 2000). To examine this hypothesis, Werker et al. (2002) tested infants aged 14-, 17- and 20-months using the same similar-sounding labels and procedure as Stager and Werker (1997)[9]. As with the previous studies described above, the infants aged 14-months failed to notice a switch in the minimally different labels. The 17- and 20-month infants learned the minimal pair, as indicated by their significantly longer looking times to the 'switch' trial. Another important finding was the significant correlation in the 14-month group between vocabulary size and success in the task. This indicates that infants aged 14-months with larger vocabularies act more like older infants and successfully learn similar-sounding word-object pairings. These findings support the predictions from the resource-limitation hypothesis.

[9] The procedure and stimuli, while similar, were not completely identical to Stager and Werker (1997). The objects were visually more distinct and the infants had greater exposure to the object-label combinations.

To summarize thus far, previous work indicates that, at the beginning of the word-learning period, infants do not use all of the phonetic detail available to them when placed in a word-learning situation. They are able to discriminate the difference between the minimally different labels in a speech discrimination task, but cannot use this ability when linking words to objects. It is not until they become more proficient at word learning that they begin to access the detail present in words. This pattern of results can be explained by the resource limitation hypothesis. The complexity of learning the link between the object and the word form leads to decreased attention to the word form. This hypothesis appears viable based on studies from the Werker laboratory but it must be evaluated in relation to other laboratory studies examining similar-aged infants' access to phonetic detail.

1.4.3. Recent behavioural investigations in other laboratories

Werker et al. (2002) demonstrated that 17- and 20-month-old infants are able to use fine phonetic detail in the Switch procedure. This appears at first to contradict the many studies with slightly older children showing confusion of similar sounding words (Barton, 1978, 1980; Brown & Matthews, 1997; Edwards, 1974; Eilers & Oller, 1976; Garnica, 1973; Gerken et al., 1995; Kay-Raining Bird & Chapman, 1998; Shvachkin, 1948/1973). The resource limitation hypothesis can account for this disparate set of findings by pointing to the more difficult nature of the tasks used in the studies that report failure. In virtually every case, they have required the child to show a more differentiated understanding of the meaning of a word by pointing to, or otherwise explicitly selecting, the appropriate referent for the word (see Swingley, 2003, for a similar argument). It is possible that under these even more demanding lexical use situations the infant is again taxed, reducing the availability of computational resources necessary to attend to fine phonetic detail (see Werker & Tees, 1999, for a discussion of different levels of difficulty in word recognition tasks).

In a recent set of studies, Swingley and Aslin (2000, 2002) used a visual fixation task to determine young word learners' ability to attend to correct and incorrect pronunciations of word forms. Their task is less demanding on the infant's cognitive resources than the Switch task since no word learning (i.e., habituation) is required. Swingley and Aslin (2000) presented 18- to 23-month-old infants pairs of objects (e.g., baby and dog) on a computer screen. While viewing both objects, the infant heard either a correct (e.g., baby) or incorrect pronunciation (e.g., vaby) of one of the object labels. The infants' looking times to the visual "match", which was the baby in both conditions, were significantly delayed in the mispronunciation condition as compared to the correct pronunciation condition, thus indicating access to the fine phonetic detail in the word forms. The infants also looked longer to the correct picture after hearing the correct pronunciation[10] than after hearing the mispronunciation, although the looking time to target in the mispronunciation condition was also above chance. These results are consistent with research that involved using the Switch procedure with older infants (the 17- and 20-month data from Werker et al., 2002).

But how does the resource limitation explanation deal with the studies showing success at minimal pair use at a younger age than shown in the Switch task? A new paper by Swingley and Aslin (2002) provides an interesting challenge to previous findings with

[10] Unlike the Switch task, the visual fixation task is an online task with two simultaneously presented choices. The two indicators of success are: shorter latency to look away from the incorrect object and longer looking times overall to the correct match. The habituation phase in the Switch task leads to the prediction of a novelty preference in the test phase (i.e., longer looking times during trials in which the incorrect pairing is presented).

novice word learners. Testing infants aged 14-months in the same visual fixation procedure used in their work with older infants, Swingley and Aslin included an additional condition. Half of the infants heard a minimally different pronunciation in the mispronunciation condition, as in Swingley and Aslin (2000). The other half of the sample heard a mispronunciation that differed from the accurate label in additional phonetic features. For example, if the target object was "baby" in the mispronunciation condition, half the infants would hear "vaby" as the label (the close mispronunciation condition) and half would hear "raby" (the distant mispronunciation condition). Focussing only on looking time to the match, Swingley and Aslin reported that the infants of 14-months look significantly longer to the match in the correct pronunciation condition than in either the close mispronunciation or distant mispronunciation conditions. Therefore, the 14-month-old infants in this study appear to attend to and use all the fine phonetic detail in the word form, unlike the same-aged infants in Stager and Werker (1997) and Werker et al. (2002). This thesis will attempt to provide an explanation for these seemingly discrepant results and will provide strict tests for the resource limitation explanation regarding novice word learners' ability to notice detail in word form.

1.5. Returning to the question of resource limitation or representational discontinuity

A review of the evidence presented so far shows that it is difficult to disentangle the resource limitation from the representational discontinuity explanations. Attempts to simplify the task for novice word learners through the use of more distinct objects and increased exposure time were not sufficient to enable minimal pair word learning (Werker et al., 2002). Nor was the use of nonce words that have a more typical word form (CVC, rather than CV). Moreover, infants of 14 months still failed when they were presented with nonce words that contrasted in a different phonetic feature (voicing rather than place) and even in two phonetic features (voicing + place as in "din" vs. "pin"), suggesting that neither place nor voicing information is detected in this word-learning task (Pater et al., in press). Yet, infants of just a few months older (17 and 20 months), and even infants aged 14 months with larger vocabularies, succeeded at the minimal pair word learning task. These results are all consistent with either a representational or a resource limitation hypothesis.

The ERP data, on the other hand, provide relatively strong evidence that at least at the level of processing picked up by the particular electrodes used in the time course that is being measured, the lexical representation of known words does NOT contain fine phonetic detail at 14 months of age. However, even here a closer examination shows that the processing explanation is not entirely ruled out. It is possible that the context of hearing known words, like the presence of an object in the original Stager and Werker (1997) work, predisposed the infants to listen for meaning when listening to the words. Because they are still novice word-learners, listening for meaning might invoke more processing demands. Under this type of listening context, minimally different non-words (like in the Switch procedure) would be confused with their real word counterparts, which were also being presented, and only non-words that were not at all similar to any known words would avoid being captured by the "semantic" net.

These studies all confirm the difficulty experienced by the 14-month-old word learner, but they do not provide definitive tests of the question of whether it is a resource limitation or a representational discontinuity that accounts for the difficulty. All the findings are consistent with the hypothesis that the phonetic detail is not available for lexical representation by the infant of 14 months, but they are also consistent with the possibility that the information is available, but is simply not used, perhaps due to a limitation in cognitive resources. It could be that the attempts made to simplify the task were not sufficient, and that even greater simplification might enable minimal pair word learning. A further exploration of the conditions that may allow for access to phonetic information in word forms is needed in order to find the definitive test of resource limitation versus representational discontinuity.

This controversy is important. At a general level, it concerns the question of whether the kind of perceptual learning that takes place in infancy plays a functional role in the establishment of more complex systems. At a more specific level, it concerns the issue of whether phonological bootstrapping really does play a role in language acquisition. If it turns out to be the case that when constructing a lexicon, infants have to start anew in learning about the phonetic properties that are useful in their native language, then the motivation underlying our studies of speech perception in infancy will be seriously undermined. But if there is a link between pre-lexical perceptual learning and post-lexical phonological use, then we will be able to see a way in which experience during infancy has played a significant role in propelling the child into language acquisition.

Chapter 2: The impact of word knowledge

A potential solution to the problem of disentangling the two competing hypotheses, representational discontinuity versus resource limitation, arose from the discrepant results of the Stager and Werker (1997) and Swingley and Aslin (2002) studies. The proposal found in the following experiment is that explicit word knowledge was the key to facilitating access to phonetic detail in the Swingley and Aslin study. By demonstrating infant access to the exact same phonetic contrast that previous work has failed to find, the argument is that the representational discontinuity hypothesis cannot hold. This chapter is adapted from Fennell and Werker (2003), published in *Language and Speech.*

2.1. The Problem

Why would the 14-month-old infants in Swingley and Aslin's (2002) study readily access and utilize phonetic detail while the same-aged infants in previous studies fail to access and use similar detail? Two likely explanations should be considered. The first possibility is that the Switch procedure is too difficult for the infants to demonstrate the ability seen in the Swingley and Aslin study. The task demands are indeed much greater in the Switch procedure, as compared to the visual fixation task. In order to notice the violation of the object-label link present in the 'switch' trial, the infant must, at the very least, remember that the word being presented does not "go with" the object. Better yet would be to remember the other object-label combination and compare it to the one being presented during the switch trial. In the visual fixation task, both objects are presented simultaneously, thus reducing the memory load placed on the infant. The infant can continuously check Object B to confirm or disconfirm his hypothesis that

Object A goes with the presented label. The reduction in task complexity could free up cognitive resources, allowing the infant to use fine phonetic detail. The author is involved in research in collaboration with Daniel Swingley, Katherine Yoshida, and Janet Werker that is investigating and finding tentative support for this possibility.

The other possible explanation for the disparate results seen at 14 months concerns the infants' prior knowledge of the words and objects. Swingley and Aslin (2002) used well-known object-label combinations for their stimuli whereas Stager and Werker (1997), as well as Werker et al. (2002), presented the infants with novel object-label combinations. The infants' *a priori* knowledge of both the words and objects in the Swingley and Aslin study could account for the difference in results. According to the resource limitation hypothesis, novice word learners have difficulty accessing the detail in newly learned words because of the cognitive complexity involved in mapping a novel label to a novel object. However, this degree of complexity is not present when recognizing a familiar word that has an established link with its referent. By using known words and objects as the stimuli, the task changes from one of word learning to word recognition, a potentially easier task.

Contrary to the prediction from the resource limitation hypothesis, strong representational discontinuity theorists would predict that 14-month-old infants would not have a full phonemic inventory. Thus, they would not necessarily notice phonemic contrast, even in well-known words. Previous studies (e.g., Pater et al., in press; Stager & Werker, 1997; Werker et al., 2002) have demonstrated that 14-month-old infants have been unable to use the contrast found in the present experiment ([b] – [d]). Thus, it would seem, according to this theory, that this specific contrast is generally absent from the phonemic inventory at this age and would not be noticed in the task.

It should be noted that, although a facilitation effect is predicted when well-known words are used, some previous work using well-known words with this age group has demonstrated an inability to access phonetic detail. The ERP data discussed earlier from Mills et al. (in press) is the best example of this scenario. The data indicate that 14-month-old infants confused well-known words with minimally different foils. Thus, although the presence of word knowledge in the Swingley and Aslin study is hypothesized to facilitate phonetic access, it is possible, based on the ERP data, that infants this age will still fail to attend to the detail in well-known words, unless a particularly simple task, such as the visual fixation procedure, is used.

The effect of *a priori* word-object knowledge was explored by testing a group of 14-month-old infants using the Switch procedure. The key difference between the current study and past studies conducted in our laboratory is that the infants were presented with two familiar, rather than two novel, object-label combinations. As before, the labels differed only in place of articulation and, once again, the precise contrast was [b] versus [d]. This contrast was not present in the study by Swingley and Aslin (2002), so it was unknown whether infants could succeed in noticing this specific detail in well-known words. The resource limitation hypothesis (Stager & Werker, 1997; Werker & Fennell, 2004; Werker, Fennell, Corcoran & Stager, 2002) predicts that the use of familiar objects and labels should reduce the task demands placed on the infant and, in turn, allow infants to attend to and utilize the fine phonetic information present in the minimally different labels. The representational discontinuity view is that the [b] and [d] phonemes are not yet built up and fully available, thus the infants would fail to notice the contrast even in well-known words.

2.2. Experiment One

2.2.1. Method

2.2.1.1. Participants

Sixteen 14-month-old infants completed this study, 8 girls and 8 boys (mean age, 14 months 9 days; range, 13 months 27 days to 15 months 4 days). All subjects were without apparent health problems, were at least 37 weeks gestation, and were exposed to English at least 80% of the time. An additional 10 infants were tested but were not included in the analyses because they were too restless during testing (n = 9) or they were not visible to the coder during at least one trial (n = 1).

Subjects were recruited through visiting new mothers at BC Women and Children's Hospital, and through voluntary response to public service announcements. Participating infants were given an "Infant Scientist" t-shirt and diploma. These same recruitment methods were used for all the experiments found in this thesis.

2.2.1.2. Stimuli

The audio stimuli were two CVC words that formed a minimal pair: "ball" and "doll"[11] recorded in infant-directed speech (IDS). IDS is effective in gaining and maintaining infant attention (Fernald, 1985; Werker & McLeod, 1989) and in facilitating word learning in infants (Fernald, McRoberts, & Herrara, 1991). The use of IDS also facilitates infant phonetic discrimination (Karzon, 1985). These stimuli differ only in the

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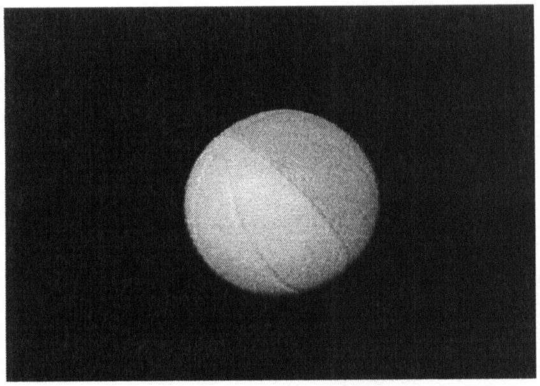
[11] These stimuli can be phonetically transcribed as: [bɔ:l] and [dɔ:l]. While not the case in all English accents and dialects, these two words share a vowel in the Canadian English spoken in the Vancouver area and thus form a minimal pair.

place of articulation of the initial consonant. An additional, highly dissimilar nonsense label, “neem”[12], was used during the pre- and post-test trials.

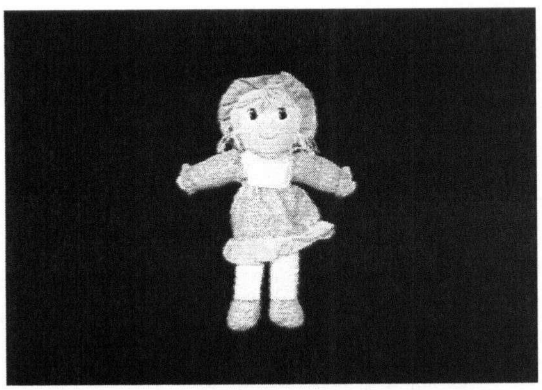
In a soundproof room, the experimenter recorded an English-speaking female producing several exemplars of each word in an infant-directed, rise-fall intonational phrase. Final stimuli comprised ten exemplars of approximately 0.6 s in duration each, with a 1.5 s silent interval between exemplars, resulting in two audio files of 20 s in duration, one for each word.

The two objects presented during the habituation and test phases were a green and red ball and a doll with light blue clothing and bright yellow hair. These objects are not only distinct in colour and shape, but also highly representative instances of their respective categories (see Figures 1a and b). A multi-coloured toy water wheel (“spinner”) was used for both the pre- and post-tests (see Figure 1c). The experimenter took individual digital pictures of the ball and doll objects on a black background. These digital pictures were animated to move back and forth across the screen at a slow and constant velocity ("ball" = 12.1 cm/s; "doll" = 12.6 cm/s). Importantly, change in direction of movement was out of synchrony with presentation of the word, to ensure that the infant had no assistance from modal or causal cues (see Gogate & Bahrick, 1998). The “spinner” object was videotaped against a black background and then transferred to laser disk format. The “spinner” was filmed with the base remaining stationary while the wheel was moved around in a clockwise motion. At the distance tested, the objects take up a 13.50° vertical and 13° horizontal visual angle.

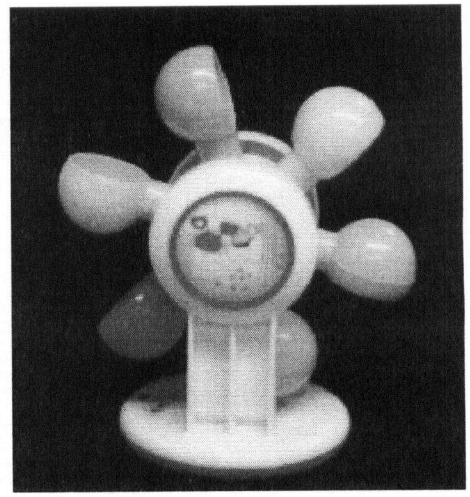
[12] This stimulus can be phonetically transcribed as: [ni:m].



a) Ball



b) Doll



c) Spinner

Figure 1: Objects used during habituation and testing in Experiment One: (a) ball, (b) doll and (c) spinner.

2.2.1.3. Apparatus

Testing took place in an 2.8 m by 2.3 m quiet room, which was dimly lit by a shaded 60W lamp situated 80 cm to the left of the infant at a 45 degree forward angle. The infant sat on the parent's lap facing a 27 inch Mitsubishi CS-27205C video monitor that was approximately 1.2 m from the infant. The audio stimuli were delivered at 65 dB, +/- 5 dB, over a BOSE 101 speaker, located directly above the monitor. The monitor was surrounded by black cloth, which stretched the width and height of the room. The infants were recorded using a Sony DCR-TRV11 digital video camera. The lens of the digital video camera peeked out of a 6.4 cm hole in the black cloth located 21 cm below the monitor. As a masking control during testing, the parent wore Koss TD/65 headphones over which female vocal music was played from a Sony CFD-V17 CD player.

Habit 2000, a computer program produced by the Infant Cognition Laboratory at the University of Texas at Austin, was used to order stimuli presentation and collect looking time data. The program was run on a Macintosh Power PC G4. Both the visual stimuli and audio stimuli played from digitized files on the computer and were sent to the monitor and speaker in the testing room.

The experimenter, who was blind to the audio stimuli being presented and to whether a trial was a habituation or test trial, monitored the infant's looking times via a closed circuit television system from an adjacent testing room. A designated key was pressed on the computer keyboard during infant looks, which the Habit 2000 program recorded. The video record was used for subsequent reliability coding.

2.2.1.4. Procedure

After the procedure was explained to the parent or parents and they had signed a consent form, the experimenter obtained the MacArthur Communicative Development Inventory, a vocabulary checklist, from the parent(s) to ensure that the infant comprehended one or both of the target words. This checklist was completed by the parent(s) prior to visiting the laboratory. The infant and one parent were then taken to the testing room and positioned for the experiment. The experimenter turned on the digital video camera and entered the adjacent observation room to begin testing. The infant was assigned to participate in a pre-selected order, chosen from a randomly sequenced list of possible orders. These orders counterbalanced the order of test trial ('same' before 'switch'/'switch' before 'same') and 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 et al. (2002), but modified for habituation criterion (adjusted from 50% of the highest total looking time - summed across a block of four trials - to 65% in the current study in order to make it comparable to Stager & Werker, 1997)[13]. Each trial began when the infant fixated on a flashing red light. On the first trial, infants were presented with a pre-test stimulus, the label "neem" paired with the spinner. During the habituation phase the infant was shown two word-object pairs (e.g., Pair A: word "ball" and ball object, Pair B: word "doll" and doll object). Every block of four trials contained two instances of each word-object pairing presented in a random order (ABAB, ABBA, etc.). Looking time was calculated on-line, and when the average

[13] The 65% criterion is the standard criterion used for this age group (e.g., Stager & Werker, 1997; Werker, Cohen et al, 1998). The 50% criterion was used in the Werker et al (2002) study in order to make the 14-month-old results comparable to the results of the older infants studied in that article.

looking time across a four-trial block decreased to the pre-set criterion, the habituation phase ended. The infants participated in a minimum of 8 and a maximum of 24 habituation trials.

Following habituation, the test phase began. One test 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, the 'switch' trial, contained a familiar word and familiar object but in a novel pairing (e.g., label from pair A with object from pair B). The order of presentation of the trials was counterbalanced across subjects. It was expected that, if infants had accessed the phonetic detail, they would detect the 'switch' and look longer during the 'switch' than the 'same' trial. In the final, post-test trial the child was again presented with "neem" and the spinner. It was expected that if infants were still engaged in the experiment, looking time would recover to near pretest level during this final trial.

2.2.1.5. Reliability Coding

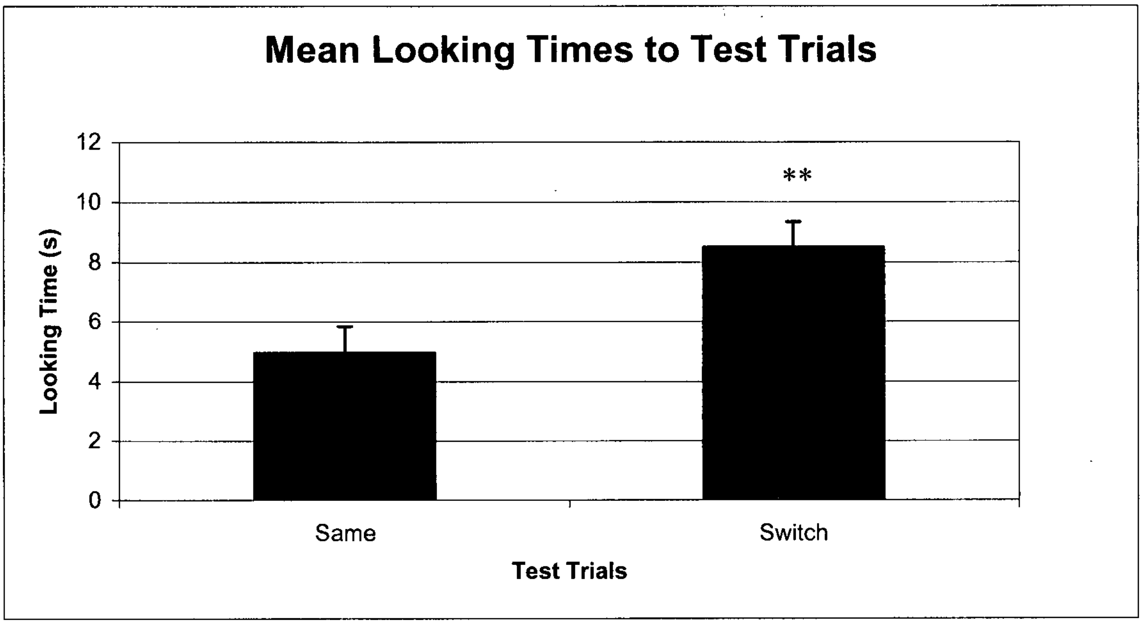
To determine the reliability of the experimenter's coding, a second trained coder scored the looking times of 25% of the usable subjects off-line. On-line scores were rounded to the nearest 0.1 s. Off-line scoring was also done to the nearest 0.1 s. A Pearson product-moment correlation of on- and off-line 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.

2.3 Results

To determine whether infants maintained interest throughout the experiment and recovered from habituation, a series of planned orthogonal comparisons were run to first compare pretest to posttest and, if these two trials were found to be the same, to then compare these trials to the last habituation block. There was no significant difference between the pretest and posttest. The pretest and posttest were significantly different from the last habituation block [$t(2, 39) = 15.61$, $p < 0.001$; $Mean_{PRETEST} = 18.7$, $Mean_{LASTBLOCK} = 6.6$, $Mean_{POSTTEST} = 16.6$][14]. A 2 (sex: female vs. male) X 2 (trial block: first four habituation trials vs. last four habituation trials) mixed ANOVA produced a significant main effect for trial block, with neither a main effect for gender nor an interaction [$F(1, 14) = 538.23$, $p < 0.001$; $Mean_{FIRSTBLOCK} = 14.4$, $Mean_{LASTBLOCK} = 6.6$]. Thus, as expected, there was a significant drop in looking time across the habituation phase.

The main set of analyses addressed infants' performance on the test trials. A 2 (sex: female vs. male) X 2 (test trials: 'same' vs. 'switch') mixed ANOVA revealed a significant main effect for test trials, with the infants looking longer to the switch trial than to the same trial ($F(1, 12) = 22.48$, $p < .001$; $Mean_{SWITCH} = 8.49$, $Mean_{SAME} = 4.95$). Sex was included in the analysis because of the potential effect of better female performance. Many language studies have demonstrated that female participants across all ages have enhanced performance. However, in the current study, there was no main effect for sex and no interaction. All infants habituated to the stimuli and all but one of the sixteen infants looked longer to the 'switch' trial. This shows that infants of 14 months access phonetic detail in well-known word-object pairings (See Figure 2).

[14] The variances of the dependent variables lacked homogeneity. The t-test was corrected to account for this non-homogeneity.



** $p < .001$

Figure 2: Mean looking times to test trials in Experiment One

2.4. Discussion

In comparing the two studies to date that have demonstrated that 14-month-old infants can attend to fine phonetic detail in words paired with objects, the current study and Swingley and Aslin (2002), there is one major commonality. That commonality lies in the use of already known words. In both studies, the infants were tested on highly familiar object-label combinations, rather than the novel object-label combinations used in previous research. Even though different tasks were used in the two studies, the infants showed success in distinguishing phonetically similar words. Importantly, the infants in the current study succeeded in the identical Switch procedure used in previous work. This provides an unequivocal demonstration that lack of attention to fine phonetic detail, a robust finding in word *learning* situations, does not characterize performance in word *recognition* tasks. It is noteworthy that the infants in the current study accurately used to the *exact same* phonetic detail (the place of articulation cues in [b] and in [d]) that infants in previous studies failed to access when the task required word learning (Pater, Stager & Werker, in press; Stager & Werker, 1997; Werker et al., 2002). It would seem that the infants' a priori knowledge of the words and their referents allowed them to access the relevant phonetic detail and thus notice a violation in the object-label pairing[15].

2.4.1. Resource Limitation

This demonstration of novice word learners' success in distinguishing minimal pair words, together with the previous evidence from Swingley and Aslin's (2002)

[15] It is important to note that we use the term knowledge, rather than experience. It is not that the infants have previous experience with the specific object-label combinations presented in our study. None of the infants would have previously heard our speaker, a graduate student in our department, utter "doll" or "ball". Also, it is very doubtful that the participants would have seen the specific object used in the study. Therefore, the infants were applying their generalized knowledge of the objects and labels used in the study.

mispronunciation study and even the older evidence from Barton (1978, 1980) provides compelling evidence that when infants know words well, fully specified representations are available[16]. As outlined in the introduction, a resource limitation hypothesis can account for this intriguing pattern of findings. The use of well-known words reduces the demands placed on the infant, since the basic object-label mappings of these words have been previously established. Without having to devote cognitive resources to forging the object-label link, novice word learners are better able to access the fine phonetic detail present in the words.

The limited resource explanation requires consideration of other situations that might make access to the fine phonetic detail possible. One might suggest that more frequent exposure to the word-object link would facilitate access to the criterial information. However, this is unlikely because in previous word-learning studies infants were presented with up to 120 repetitions of each word-object pairing without being able to access the phonetic detail (see also Swingley & Aslin, 2002, for a similar argument). Instead, it is the conditions under which the child learned the word-object pairing that are important. In every situation in which infants at 14-months succeeded, they came into the testing situation already knowing the word-object pairings. In the course of learning these pairings in their home environments, the infants were likely exposed to each word not only a number of times, but across a number of different speakers in a number of different contexts. Similarly, they were likely exposed to multiple instances of the target

[16] It could be argued, based on the data from Experiment One, that perhaps infants only have access to detail in well-known minimal pair words and our claim that infants have access to the representations of all well-known words is too broad. Evidence against this position is provided in a study by Swingley and Aslin (2002). They demonstrated that infants of 14-months accessed phonetic detail in familiar words for which they had close neighbours in their lexicon (e.g., ball) and words for which they had no neighbours (e.g., baby).

objects ball and doll. This variability in exposure may enable the infants to recognize the new instances of the objects as familiar, and may thus facilitate attentional focus to what is constant in the word forms that are linked to these objects.

Table 1: Infants' Access and Use of Fine Phonetic Detail in Laboratory Tasks: A Summary of Relevant Studies

Authors	Age in Months	Procedure	Main Difference, Aside from Age, from Stager & Werker, 1997 (Exp. 1)	Contrast Used	Did the Infants Use Phonetic Detail?
Jusczyk & Aslin, 1995	7.5	Head-turn Preference	Different testing procedure	[c]-[t], [b]-[d]	Yes
Stager & Werker, 1997 (Exp. 2a)	8	Switch	Simplified version of the Switch procedure	[b]-[d]	Yes
Hallé & de Boysson-Bardies, 1996	11	Head-turn Preference	Use of familiar word forms; different testing procedure	Multiple	No
Stager & Werker, 1997 (Exp. 1)	14	Switch	******	[b]-[d]	No
Stager & Werker, 1997 (Exp. 2b)	14	Switch	Simplified version of the Switch procedure	[b]-[d]	No
Pater, Stager & Werker, submitted	14	Switch	Use of more valid word forms (e.g., bin-din).	[b]-[d], [b]-[p], [d]-[p]	No
Werker, Fennell, Corcoran & Stager, 2002 (Exp. 2)	14	Switch	More distinct objects; greater exposure to stimuli	[b]-[d]	No
Stager & Werker, 1997 (Exp. 4)	14	Switch	Labels not associated with objects.	[b]-[d]	Yes
Swingley & Aslin, 2002	14	Visual Fixation	Use of familiar words and objects; different testing procedure	Multiple	Yes
Current Study	14	Switch	Use of familiar words and objects	[b]-[d]	Yes
Werker et al., 2002 (Exp. 1 & 3)	17 & 20	Switch	More distinct objects; greater exposure to stimuli	[b]-[d]	Yes
Swingley & Aslin, 2000	18-24	Visual Fixation	Use of familiar words and objects; different testing procedure	Multiple	Yes

A resource limitation hypothesis that involves a single, detailed representation can account for all the results in Table 1. The younger infants (7.5- and 8-month-old infants) can access the phonetic detail in the representation because they are not trying to connect the word forms to objects or concepts. At the end of the first year of life, infants are beginning to link words with their referents and do not seem to utilize all the detail in the word form representation, due to the cognitive load of the linking process. However, they can access the detail in the word form representation when there is no object present. More importantly, at the same age that infants fail to access detail in new words, they can access the exact same detail when the link between word and object is already in place. At 17-months of age and beyond, having established multiple instances of word-referent combinations, infants can more easily pick out the constant parts of the word representation necessary to make an accurate word-referent link. This allows them to recognize the constancy not only in familiar words, but in new words as well.

2.4.2. An Alternate Explanation?

The resource limitation hypothesis is not the only possible explanation for the data summarized in Table 1. As noted in the Introduction, some researchers have suggested that initial lexical representations are underspecified, and have taken as evidence failures by toddlers and young children to distinguish minimally different words (Brown & Matthews, 1997; Edwards, 1974; Garnica, 1973; Kay-Raining Bird & Chapman, 1998; Merriman & Schuster, 1991; Pollock, 1987; Shvachkin, 1948/1973). It has been argued above and previously (see Werker & Fennell, 2004) that this is unlikely, and that the failures shown at 14 months reflect difficulty in accessing rather than in representing fine phonetic detail. The failures shown by older infants may reflect another level of difficulty in access to already represented phonetic detail in the face of an even more demanding word comprehension task. Thus, the resource limitation hypothesis allows for continuity in the underlying phonetic representation of words, while at the same time acknowledging that different testing situations may facilitate or hinder access to that phonetic detail.

Admittedly, it is still an open question as to whether lexical representations are fully specified at the time of attempting to learn a new word, or only become fully specified after the word is well known. This is a question that will be reintroduced in Chapter 4 of this thesis. However, the most parsimonious explanation is that the word is fully specified from the beginning and that the difficulty lies in access rather than in representation. As outlined in Werker & Curtin (submitted), one way to envision why 14-month-old infants fail to attend to detail in the word learning task is to imagine "bih" and "dih" represented as fully specified word forms that overlap on all dimensions except place of articulation. The task facing the child in the Switch procedure is to take those two fully specified word form representations and attach them to two different objects. Because the two word forms overlap on so many dimensions, considerable attention is required to pull out just that feature – among all the features in the representation – that distinguishes the two words. In the face of the computational difficulty of forging novel word-object links, the cognitive resources are simply not available for such directed attention.

Still, some may reject the parsimony argument as an adequate proof for the resource limitation hypothesis. After all, much of the data in this chapter that has been presented in favour of the resource limitation hypothesis could be equally applied to the representation argument. For example, a major claim shared by the two hypotheses involves the developmental data pattern of phonetic perception (outlined in Table 1). The resource limitation explanation for the data has already been presented. The advocates of the representation-based approach would argue that young infants (8 months) and older infants (14 months) listening to labels not matched with objects would access phonetic detail because they are accessing a low-level *phonetic* representation. The failure of infants aged 14-months to access detail in newly learned words would reflect the inadequate *phonological* representations that these infants possess due to their incomplete phonemic inventory, which needs to be built up over time (e.g, Brown & Matthews, 1997; Shvachkin, 1948/1973). In this approach, the phonemic inventory is only established as required to distinguish words in the lexicon. Infants of 14-months would not yet know many minimally different words, and would thus not have experienced the pressure to represent fine phonetic detail when learning new words.

The data presented above and in Table 1 seem to support both theoretical stances; thus we must turn to possible ways to disambiguate the competing hypotheses. The current study provides a means to do just this. The data from the ball/doll experiment clearly falsify a tenet of the representational discontinuity argument (i.e., that phonemes, once built, are universally available). If 14-month-old infants possess the relevant phonemes, as indicated by Experiment One, why are they not using them in the word learning situation? Representational discontinuity theorists would have great difficulty explaining this situation, while the resource limitation hypothesis encounters no such difficulty.

Another study that is an important test of the representational underspecification hypothesis is the research that the author is currently carrying out with Janet Werker, Daniel Swingley and Katherine Yoshida. In this study, 14-month-old infants are habituated to two novel, nonsense minimal pairs (e.g., bin/din). After habituation, the infants are tested using the Swingley and Aslin (2002) visual fixation task, which may have fewer memory demands than the Switch task since it involves the simultaneous presentation of the habituated object-label pairings at test. If the infants in this study do not access the detail in the habituated words, we would once again have data that supports both hypotheses. However, if the infants of 14-months access the habituated words' phonetic detail in this study, their success can only be accounted for by the resource limitation hypothesis. The representation hypothesis would be challenged in this case since it posits underspecified representations at this stage of development[17] (Brown & Matthews, 1997; Shvachkin, 1948/1973). This latter scenario is what we have found thus far in this study. In this easier procedure, the 14-month-old infants are noticing the phonetic detail in the two new words.

2.5. Known versus unknown foils

The current behavioural results appear to contradict the electrophysiological results outlined in the introduction. Mills et al. (in press) found that the ERP waveforms to known words were the same as waveforms to minimally different foils in 14-month-old infants. However, an important difference between the current experiment and the ERP work is that the foil in the ball/doll experiment was another known word (e.g., "ball"

[17] The representational discontinuity hypothesis does not necessarily propose that the specific phonemes /b/ and /d/ are underspecified at this age. However, the representation theorists would have difficulty explaining why same-aged infants would notice the phonetic detail in this task and not in the Switch procedure.

to "doll"), whereas it was a nonce word in the ERP work (e.g., "cat" to "gat"). Thus, one could argue that infants would only notice differences in phonetic detail between two known words and would not notice a change from a known word to an unknown, minimally different foil. This argument does not map well onto the resource limitation hypothesis. After all, exposure to a well-known word should facilitate access to its phonetic detail, no matter what type of word form (known or unknown) one would use as a foil. This issue is explored in the next experiment.

2.6. Conclusion

The discontinuity hypothesis can be rejected on the basis of this study, and this rejection is further supported by the research currently underway in collaboration with Werker, Swingley, and Yoshida. However, there are lingering questions concerning the resource limitation hypothesis. Although the experiment presented in this chapter provides evidence that a priori knowledge facilitates attention to phonetic detail, the exact nature of the word knowledge that allows novice word learners to access the detail of the word form is not yet determined. The resource limitation hypothesis predicts that any factor that reduces the cognitive demands put on novice word learners could reveal the infants' ability to attend to and utilize phonetic detail. Thus, would simple familiarity with the word/object combination, and not necessarily full referential word knowledge, be enough to allow for access to fine phonetic detail at 14 months of age?

Chapter 3: Knowledge versus familiarity

3.1. Introduction

The results of Experiment One discount the representational discontinuity argument and support the resource limitation hypothesis. Experiment Two further examines the latter hypothesis by unpacking the processing demands that prevent the 14-month-old infant from using phonetic detail. Specifically, the exact degree of knowledge needed for access to phonetic detail in the word form is still unknown. Is full knowledge of word meaning the necessary component that allows novice word learners to access detail in the word form, or is familiarity with the word and/or object without explicit semantic knowledge enough to ease cognitive demands and allow for access? To answer this question, two groups of infants were tested: those who explicitly knew the meaning of the target word and those who did not, but had experience with the target word and object category.

The design of the first experiment generated another important issue. In the ball/doll experiment, the infants of 14 months were successful in noticing a switch in two well-known members of a familiar minimal pair. The infants' knowledge of *both* words could have greatly facilitated performance in the task. This design is not directly comparable to Swingley and Aslin (2002), where the known word was compared to a mispronounced nonce version of that word. Therefore, a more refined exploration of what facilitates access to phonetic detail would involve testing infants on a switch from a known word to a phonetically similar unknown word, as the infants would have to detect a "mispronunciation" in this test, rather than detecting an object-word mismatch as in the ball-doll study. Also, by switching to a nonce word rather to a known word, the word that provides the test loses its semantic support. If the 14-month-old infants notice the switch (as in Swingley & Aslin), this would further support the resource limitation hypothesis. If the infants do not notice the switch to the phonetically similar unknown word (as in the ERP study by Mills et al., in press), it would indicate that knowledge of both the target word and the 'switch' word is necessary for novice word learners to access phonetic detail.

The current experiment once again focused on 14-month-old infants. To make the experiment comparable to the previous study, one of the words from that study was used: "doll". Also, the infants were separated into two groups: those who explicitly knew "doll" and those who did not. Based on the resource limitation hypothesis, the prediction is that those infants who knew "doll" would access the detail in this test involving a switch to a mispronounced version of the word rather to another known word. The group of infants who did not explicitly know "doll" provide the crucial test of the knowledge/familiarity question. Although they do not know the word, "doll" is a very common word and object in the infant environment, thus making it familiar. In fact, some of the infants in this group were reported to explicitly know the object category of dolls, without knowledge of the word (e.g., "She has a doll, but we call it 'baby'".). If this group did not notice the switch, it would indicate that knowledge of word meaning is necessary to access phonetic detail. If they noticed the pairing violation, then it would seem that word/object familiarity without explicit knowledge of word meaning is sufficient to facilitate the task and allow for access to phonetic detail.

This chapter is adapted from Fennell and Werker (2004), *Infant attention to phonetic detail: Knowledge and familiarity effects*, published in the Proceedings of the 28th Annual Boston University Conference on Language Development, Cascadilla Press.

3.2. Experiment Two

3.2.1. Method

3.2.1.1. Participants

Thirty-two infants completed the study, 16 girls and 16 boys (mean age, 14 months, 14 days; range, 13 months 24 days to 15 months 7 days). All subjects were without apparent health problems, were at least 37 weeks gestation, and were exposed to English at least 80% of the time. An additional 11 infants were tested but were not included in the analyses because they were upset (n = 7), too restless during testing (n = 2), were not visible to the coder during at least one trial (n = 1), or were reported to have previously heard "gall" (n = 1).

Half of the infants (8 boys, 8 girls) comprehended the target word ("doll") and half did not, according to a vocabulary checklist filled out by the parents in advance of the study. The parents were not informed of the target word until after the experiment to ensure more accurate reporting of their infant's knowledge of that word.

3.2.1.2. Stimuli

The audio stimuli were two CVC words that formed a minimal pair: "doll" and "goll"[18] recorded in infant-directed speech (IDS). These stimuli differ only in the place

[18] These stimuli can be phonetically transcribed as: [dɔ:l] and [gɔ:l]. "Goll" does sound like valid English words ("gall" and "Gaul"). However, these are not words that the average 14-month-old infant knows. Nevertheless, the experimenter confirmed with parents post-testing that their infant did not know these words.

of articulation of the initial consonant. As in Experiment One, the highly dissimilar nonsense label, "neem", was used during the pre- and post-test trials.

In a soundproof room, the experimenter recorded an English-speaking female producing several exemplars of each word in an infant-directed, rise-fall intonational phrase. Final stimuli comprised ten exemplars of approximately 0.6 s in duration each, with a 1.5 s silent interval between exemplars, resulting in two audio files of 20 s in duration, one for each word.

The object presented during the habituation and test phases was the same doll as used in the previous experiment - a doll with light blue clothing and bright yellow hair that is a highly representative instance of its object category (See Figure 1b). Again, a multi-coloured toy water wheel ("spinner") was used for both the pre- and post-tests. A digital picture of the doll object on a black background was animated using the computer program Final Cut Pro to move back and forth across the screen at a slow and constant velocity (12.6 cm/s). As before, change in direction was not synchronous with presentation of the word, to ensure that the infant had no assistance from modal or causal cues (see Gogate & Bahrick, 1998).

3.2.1.3. Apparatus

Same as Experiment One.

3.2.1.4. Procedure

Prior to the experiment, parents completed the MacArthur Communicative Development Inventory (CDI), a vocabulary checklist. If the parent had not completed the full CDI before coming to the lab, they were asked to fill out the relevant section of the CDI (i.e., "Toys") immediately prior to testing. Parents were not told which word would be the stimulus for the experiment prior to testing. The CDI provided the measure of whether the infant did or did not know the word. (After testing, the experimenter confirmed the CDI information by explicitly asking the parent whether the infant knew the word "doll".) The infant and one parent were then taken to the testing room and positioned for the experiment. The experimenter turned on the digital video camera and entered the adjacent observation room to begin testing. The infant was assigned to participate in a pre-selected order, chosen from a randomly sequenced list of possible orders. These orders counterbalanced the order of test trial ('same' before 'switch'/'switch' before 'same').

The infants were tested using a modified habituation paradigm, with a habituation criterion of 65% of the highest total looking time - summed across a block of two trials. Each trial began when the infant fixated on a flashing red light. On the first trial, infants were presented with a pre-test stimulus, the label "neem" paired with the spinner. During the habituation phase the infant was shown one word-object pair (word "doll" and doll object). Looking time was calculated on-line, and when the average looking time across a two-trial block decreased to the pre-set criterion, the habituation phase ended. The infants participated in a minimum of 4 and a maximum of 24 habituation trials. Following habituation, the test phase began. One test trial was a 'same' trial in which the pairing presented in the habituation phase was presented again (doll – "doll"). The other trial, the 'switch' trial, contained the familiar object but in a novel pairing with the nonce word (doll – "goll"). It was expected that, if infants had accessed the phonetic detail, they would detect the 'switch' and look longer during the 'switch' than the 'same' trial. In the final, post-test trial the child was again presented with "neem" and the spinner. It was expected that if infants were still involved in the experiment, looking time would recover to near pretest level during this final trial.

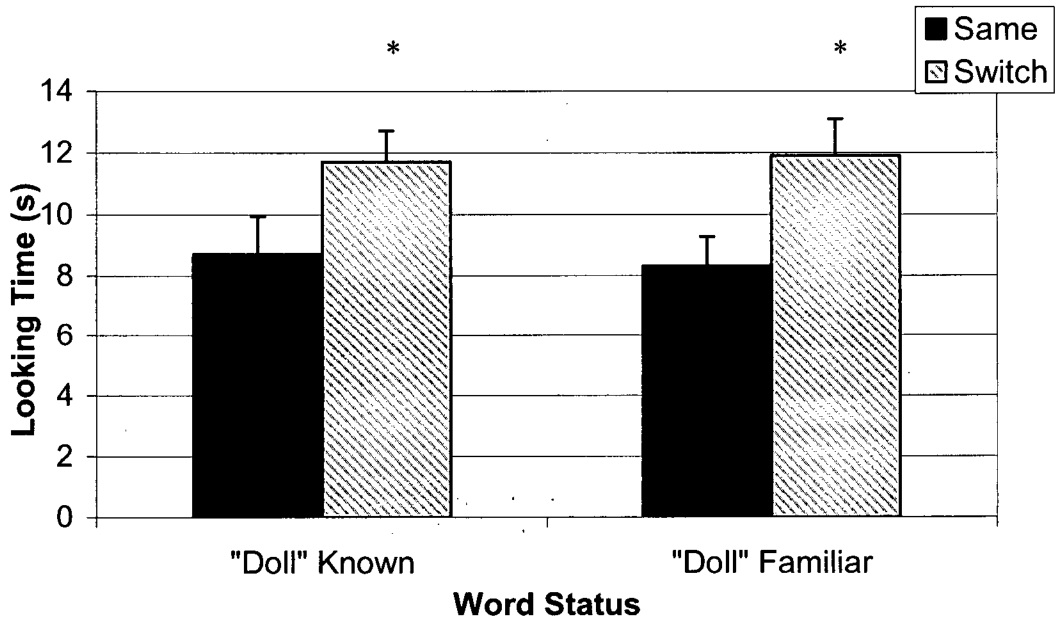
3.2.1.5. Coding

Infants' looking times were analyzed using a frame-by-frame analysis. Many infant researchers have begun to use this analysis due to its precision and accuracy. The coding process involves transferring the visual record of the infant from a digital tape to a computer hard drive. The coder then moves through key trials (e.g., pre- and post-test, as well as the two test trials) frame-by-frame and codes whether the infant is looking to the screen or not. In this coding procedure, there are 30 frames per second (1 frame = 33.33 msec).

3.3. Results

To determine whether infants maintained interest throughout the experiment and recovered from habituation, a series of planned orthogonal comparisons were run to first compare pretest to posttest and, if these two trials were found to be the same, to then compare these trials to the last habituation block. There was no significant difference between the pretest and posttest. The pretest and posttest were significantly different from the last habituation block [$t(2, 95) = -14.36$, $p < 0.001$; $Mean_{PRETEST} = 18.0$, $Mean_{LASTBLOCK} = 8.4$, $Mean_{POSTTEST} = 17.5$]. This analysis showed that the infants recovered to the posttest. Therefore, they maintained interest throughout the experiment. A 2 (sex: female vs. male) X 2 (trial block: first two habituation trials vs. last two habituation trials) mixed ANOVA produced a significant main effect for trial block [$F(1, 30) = 340.57$, $p < 0.001$; $Mean_{FIRSTBLOCK} = 16.9$, $Mean_{LASTBLOCK} = 8.4$]. There was no main effect for gender, but there was an interaction [F1, 30) = 13.24, $p = .001$], with female infants showing a greater drop in looking time ($Mean_{FIRSTBLOCK} = 17.8$, $Mean_{LASTBLOCK} = 7.6$) than male infants ($Mean_{FIRSTBLOCK} = 16.0$, $Mean_{LASTBLOCK} = 9.1$). However, subsequent paired-sample t-tests revealed that the looking time reduction from first habituation block to last habituation block was significant for both sexes [Females: $t(15) = 17.357$, $p < .001$. Males: $t(15) = 9.604$, $p < .001$]. Thus, as expected, there was a significant drop in looking time across the habituation phase for all infants.

The main analysis involved testing infants' performance on the test trials according to their knowledge of the word form. A 2 (explicit knowledge of "doll": yes or no) X 2 (test: 'same' and 'switch') X 2 (sex: male or female) mixed ANOVA showed a significant main effect for test with the infants looking longer to the 'switch' trial than to the 'same' trials [$F(1, 28) = 24.4$, $p < .001$; $Mean_{SWITCH} = 11.8$, $Mean_{SAME} = 8.5$]. There was neither a main effect for knowledge of "doll" nor a main effect for sex. There were no interactions. Subsequent paired-sample t-tests demonstrated that both groups of infants looked significantly longer to the 'switch' trial ["Doll" Known: $t(15) = 3.913$, $p = .001$. "Doll" Familiar: $t(15) = 3.449$, $p = .004$]. Thus, the infants successfully noticed the phonetic detail in the words, even if their parents reported that they did not yet explicitly know the word "doll".



* p < .01

Figure 3: Mean looking times to test trials in Experiment Two.

3.4. Discussion

The success of infants who explicitly knew the target word supports the conclusion from the previous experiment that *a priori* word knowledge facilitates performance in the task. The finding that infants who did not explicitly know the word "doll" also successfully accessed the phonetic detail indicates that word/object familiarity is enough to alleviate task demands and allow for access. The infants who did not explicitly know "doll" would still have, in all probability, encountered the word form "doll" and/or doll objects prior to the experiment. It is likely that this previous experience, even without explicit knowledge of the word-object combination, was enough to simplify the task for these infants. The previous experience combined with the massed exposure to the doll-"doll" combination during the habituation phase could have led to an efficient acquisition of the word-object combination in the experiment, thus freeing processing resources to allow attention to the phonetic detail. This hypothesis is also consistent with the classic notion from Macnamara (1982) that knowledge of a concept or object drives the search for a label and with Jusczyk's (1997) notion that knowledge of a word form drives the search for a referent.

There are less interesting possible explanations for the above results. The parental report (MacArthur CDI) may not be a fine enough measure of word knowledge and the infant in the familiar group actually knew the word, thus succeeding in the task. This possibility is doubtful for two reasons: this measure is both reliable and valid (Fenson et al., 1993); and the experimenter confirmed, by explicitly asking the parents, the infants' knowledge or lack of knowledge of the word's meaning following testing.

Another possibility is that the [d] – [g] contrast is easier for 14-month-olds to access than the [b] – [d] contrast used in our earlier work. This would explain why those infants for whom "doll" was a new word still accessed the detail. However, previous work has demonstrated that 14-month-old infants fail to access phonetic detail in novel word forms across many contrasts, even those involving two-feature changes (Pater et al., in press; Swingley & Aslin, 2002). Therefore, the conjecture that the [d] – [g] contrast is easier is improbable.

Yet another possible explanation relates to the use of the one-object version of the Switch procedure, which was required due to the nature of the experiment (i.e., noticing changes in detail in one known word). Perhaps the one-object version of the Switch procedure facilitated the task for those infants for whom "doll" was a new word, and that is what allowed for access to the phonetic detail in the task. However, previous research does not appear to support this supposition. The second experiment in Stager and Werker (1997) involved a single, novel word-object association during the habituation phase. The 14-month-old infants who were tested in this version of the Switch procedure failed to notice the switch from "bih" to "dih". Also, the 14-month-old infants in the last two experiments of Pater et al. (in press) failed to notice fine phonetic detail in the one-object Switch procedure, including a switch from [d] to [p] - a two feature difference in phonemes (place + voicing). The weight of the evidence indicates that the one-object Switch procedure does *not* simplify the procedure to the point that 14-month-old infants can notice changes in detail in novel words. Therefore, it is quite unlikely that the use of the one-object procedure explains why the 14-month-olds who did not explicitly know "doll" accessed the detail in the previous study.

This experiment provides an interesting challenge to the ERP findings with novice word learners. In the current study (and in Swingley & Aslin, 2002), the infants accessed the detail in the word forms, even when unknown foils were used as test items, unlike the same-aged infants in Mills et al. (in press). The difference between the ERP results and this behavioural study may seem hard to explain, as Mills et al. also used well-known words and their respective mispronunciations in the ERP task. There is, however, one key difference between the recent behavioural work and the ERP task. In the behavioural studies, both in the Switch and visual fixation procedures, the target object was always present. However, in the ERP task, the words were aurally presented with no accompanying object. One could argue that this lack of visual information made the ERP task harder by requiring that the infant evoke an image of the object, or have a mature enough representation of the word meaning to be able to fully understand it without the object present. These increased task demands may interfere with the 14-month-old infants' ability to demonstrate their attention to phonetic detail in known word forms. A new ERP study that includes a visual presentation of corresponding objects in both the correct pronunciation and mispronunciation conditions is required to determine if the presence of an object facilitates attention to phonetic detail.

3.5. Conclusion

The study outlined in this chapter indicates that familiarity with the word/object combination reduces the cognitive demands placed on infants to the point where they can access the fine phonetic detail present in the word forms. However, other possible, though improbable, explanations for the results still remain. The contrast used in the present study may have been more salient than contrasts used in past research; and, the one-object Switch procedure may have been easier than the two-object procedure. These concerns must be addressed before directly attributing infants' success in this experiment to familiarity.

Chapter 4: Narrowing the Possibilities

As discussed in the last chapter, the infants' previous experience with the word form and object may have facilitated the task in the previous experiment and allowed them to access phonetic detail even though they were reported to have *no* explicit knowledge of the word prior to testing. This suggests that familiarity with the word and/or object is enough to reduce the cognitive demands placed on the novice word learner. However, there are alternative possibilities that could explain why the 14-month-old infants for whom "doll" was a novel word accessed the fine phonetic detail. The possibilities, raised in the discussion of the last chapter, must be addressed before this explanation can be completely accepted. This chapter will critically examine and methodically test the possibility that the [d] – [g] contrast is more perceptually salient[19] than the phonetic contrasts used in previous research. The first experiment in this chapter will test this possible alternative explanation, as well as the possibility that the one-object version of the Switch procedure is easier than the two-object version. The second experiment will directly test the hypothesis that object knowledge, with no previous word exposure, is enough to allow for access to phonetic detail in a novel word. The results of the second experiment will also indicate whether new words can be fully realized phonetically from the beginning of the learning process or only become phonetically realized after they are well-known.

4.1. Salience of the [d] – [g] contrast

4.1.1. Phonological hierarchies

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[19] Please note that this is an explicit reference to perceptual salience, not acoustic salience. Two phones could have a large acoustic difference, but may not be as perceptually salient as two other phones that have a smaller acoustic difference (e.g., Best & MacRoberts, 2003). Since these experiment involve speech perception, an exploration of the literature on perceptual salience is much more important than looking at acoustic differences (e.g., spectrographs, fundamental frequencies).

One claim made by developmental underspecification theorists is that not all phonemic contrasts are created equal (see discussion in Brown & Matthews, 1997). Phonemic representations are elaborated based on pressure from the linguistic input. Therefore, the infant would begin with no phonemic contrasts and then proceed in a step-wise fashion in establishing a phonemic inventory. Some models predict a fixed order to this progression. For example, Jacobson (1941/1968) derived a universal phonological hierarchy based on the order of acquisition of phonemic contrasts across languages. Other hierarchies are based on phonological rules derived from a specific linguistic theory. Rice and Avery (1995) based their phonological hierarchy on the theory of Feature Geometry. The phonemic features (e.g., sonorant voice, dorsal, velar) in the geometry are universal. No one language makes use of all the features, but there is a universal set of features from which all languages draw their phonemic representations. In this sense, Feature Geometry is related to Universal Grammar. These phonological hierarchies can be seen as proof for a discontinuity argument. If native contrasts are refined and perceptually available by the end of the first year of life, then all phonemes should be available to the novice word learner. Yet, if phonemes emerge in a step-wise fashion (e.g., labial-dental contrasts before velar-dental contrasts), as seen in hierarchies, then it would appear that phonemic acquisition differs from phonetic acquisition.

Support for phonological hierarchies comes from studies with older children that have demonstrated a stage-like progression in the comprehension of phonemic contrasts (Barton, 1978, 1980; Brown & Matthews, 1997; Edwards, 1974; Garnica, 1973; Shvachkin, 1948/1973). However, there are major methodological and theoretical problems with this research, as mentioned in the introductory chapter. In reminder, these studies involved demanding tasks, such as picture selection and explicit pointing. The demanding nature of the task could be falsely illustrating a hierarchy in terms of order or imposing a performance hierarchy when no such hierarchy is present in the toddler's phonemic representations. Brown and Matthews (1997), whose own study falls prey to these criticisms, even point to this problem:

> "Although these studies do assess the child's phonological knowledge – selection of the correct items requires that the child rely on adequate internal phonemic representation to accurately perform the task – their results (in particular, the orders of acquisition they report) have been undermined by methodological, statistical and experimental design problems." p. 79

The major theoretical problem with the hierarchy studies is that researchers usually assume a universal hierarchy or a set hierarchy for a specific language. However, most of the hierarchies proposed are different from one another, thus potentially refuting a universal order of acquisition. There is virtually no empirical support for Jakobson's (1941/1968) universal order of acquisition (e.g., Ferguson & Farwell, 1975). In Brown and Matthew's (1997) study, some children showed an order of acquisition consistent with the hierarchy proposed by Rice and Avery (1995), while other children showed different patterns. It is difficult to argue for a universal or set order of acquisition when children in the same study differ in their order of acquisition.

Although phonological hierarchies have major weaknesses, it is important to note that *none* of the phonological hierarchies reviewed above predicts that the /d/-/g/ contrast comes online before the /b/-/d/ contrast (e.g., Brown & Matthews, 1997; Jakobson, 1941/1968; Rice & Avery, 1995). Indeed, all predict either simultaneous or later emergence of /d/-/g/. The /b/-/d/ contrast has been intensely studied and there is no evidence that its perceptual salience is so great that infants access the detail in a word learning task (Pater et al., in press; Stager & Werker, 1997; Werker et al., 2002). If one accepts a hierarchy approach (which the author does not), the /d/-/g/ contrast is predicted to be built after the /b/-/d/ contrast; thus, there is no reason to expect that the infants can access the detail in the /d/-/g/ contrast in novel words when it has been shown that the detail differentiating the /b/-/d/ contrast is not used.

4.1.2. Perceptual Salience

One interpretation of the resource limitation hypothesis is that if the cognitive load preventing access to phonetic detail in the completely specified representation is eased, then all phonemes should be equally accessible. However, a viable position that allows for an apparent order of acquisition can be generated from the resource limitation hypothesis proposed in Stager and Werker (1997) – and further elucidated in Werker et al. (2002) and Fennell and Werker (2004). The hypothesis is based on the premise that the infant is picking up all the detail in the word form, but just failing to access some of the information. One factor that could increase processing load is acoustic/phonetic similarity. This allows for the possibility of differential access that varies according to the perceptual salience of phonetic detail, with more salient acoustic/phonetic differences being accessed more easily than less salient differences. This could account for better performance on a demanding task for contrasts that are more perceptually salient.

Brown and Matthews (1997) argue against the possibility that acoustic/phonetic detail can explain the order seen in phonological hierarchies. Spectrographic analyses of the stimuli used in their study failed to support a relation between order of acquisition and acoustic differences. Perceptually distinct contrasts, determined by perceptual confusion in differing noise conditions (Miller & Nicely, 1955), were also not necessarily acquired first by the participants. However, the methodological problems with this study call this argument against acoustic/perceptual saliency into question.

If perceptual distinctiveness plays a role, would the [d] – [g] contrast be considered more distinct than the [b] – [d] contrast used in previous research (e.g., Stager & Werker, 1997)? Miller and Nicely's (1955) classic confusion matrix, which measured the perceptual confusion of phoneme pairs in various noise situations, indicates that the [b] – [d] contrast is much more stable than the [d] – [g] contrast. Thus, it does not appear that perceptual distinctiveness of the contrast can account for the increased performance in the doll-goll experiment, although it should be pointed out that the Miller and Nicely data were obtained from adults. It is possible, though unlikely, that infants this age listen to different acoustic/phonetic cues than adults and therefore perceptually confuse different items. Only this possibility could account for perceptual access to [d] – [g] by infants when [b] – [d] is not accessed in the same task.

4.1.3. Contrast salience and the Switch procedure

It is still an unanswered question whether or not there is any evidence of an order of phonemic acquisition in more implicit tasks, such as the Switch procedure, because of the small number of contrasts tested. Indeed, the only study to date comparing different phonetic contrasts showed infants aged 14-months to fail at place, voicing, and place-plus-voicing contrasts (Pater et al., in press). This would indicate that consonant contrasts are equally difficult to attend to in a word learning task, thus giving no contrast the upper hand. Yet, the possibility cannot be completely discounted that the [d] – [g] contrast was somehow more salient to the infants in this explicit task, as it has not been tested before in such a task.

4.2. Experiment 3 (Part A)

4.2.1. Hypothesis

Based on the evidence reviewed the last two sections, the prediction is that 14-month-old infants will *not* notice the switch from [d] to [g] in the one-object Switch procedure when novel words are used. If this hypothesis is supported by the data, this would demonstrate that the success of the infants for whom "doll" was a new word in Experiment Two was not due to contrast salience. However, if the infants in the current experiment do notice the [d] – [g] contrast with novel words, the more likely of the two possibilities outlined earlier – contrast salience or the ease of one-object version – is the salience of the [d] – [g] contrast. There is mixed evidence for phonological hierarchies, and the Miller and Nicely (1955) perceptual confusion data comes from adult data; infants may find different phonemes more perceptually confusing.

The following experiment resembles the single object experiment from Stager and Werker (Exp. 2, 1997) in that the 14-month-old infants experience a *novel* object-label pairing and are tested on a switch to a minimally different word.

4.2.2. Method

4.2.2.1. Participants

Fourteen infants completed the study, 6 girls and 8 boys (mean age, 14 months, 18 days; range, 13 months 28 days to 15 months 1 day). All subjects were without apparent health problems, were at least 37 weeks gestation, and were exposed to English at least 80% of the time. An additional five infants were tested but were not included in the analyses because they were upset (n = 1), too restless during testing (n = 3) or were not visible to the coder during at least one test trial (n = 1).

4.2.2.2. Stimuli

The audio stimuli were the CVC word, "din", and a phonetically similar word, "gin"[20] recorded in infant-directed speech (IDS). "Din" is an English word, but it is not in the vocabularies of 14-month-old infants. "Gin" is a nonsense word. These stimuli differ only in the place of articulation of the initial consonant. Once again, a highly dissimilar nonsense label, "neem", was used during the pre- and post-test trials.

In a soundproof room, the experimenter recorded an English-speaking female producing several exemplars of each word in an infant-directed, rise-fall intonational phrase. Final stimuli comprised ten exemplars of approximately 1.1 s in duration each, with a .9 s silent interval between exemplars, resulting in two audio files of 20 s in duration, one for each word.

The object presented during the habituation and test phases was a multi-coloured toy object (see Figure 4). A video file of the object was created using the same procedure as outlined in Experiment One. A digital picture of the toy object on a black background was animated using the computer program Final Cut Pro to move back and forth across the screen at a slow and constant velocity (10.45 cm/s). As before, change in direction was not synchronous with presentation of the word, to ensure that the infant had no assistance from modal or causal cues (see Gogate & Bahrick, 1998). Again, a multicoloured toy water wheel ("spinner") was used for both the pre- and post-tests (see Figure 1c).

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[20] These stimuli can be phonetically transcribed as: [dIn] and [gIn]. Despite the author's predilection for that wonderful tonic additive, please notice that this is a hard g, comparable to the /g/ in "goat", and the 14-month-old infants are not learning a barroom vocabulary.

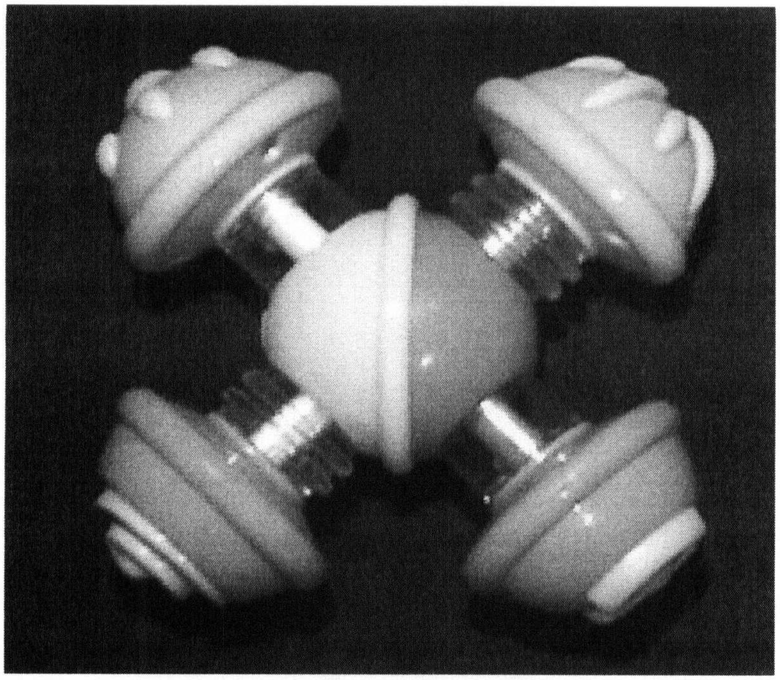

Figure 4: Object used in Experiment Three.

4.2.2.3. Apparatus

Remains the same as Experiment One.

4.2.2.4. Procedure and Coding

The procedure remains the same as Experiment Two, with the exception of the changes to the stimuli. The coding procedure remains the same as Experiment Two.

4.2.3. Results

To determine whether infants maintained interest throughout the experiment and recovered from habituation, a series of planned orthogonal comparisons were run to first compare pretest to posttest and, if these two trials were found to be the same, to then compare these trials to the last habituation block. There was no significant difference between the pretest and posttest. The pretest and posttest were significantly different from the last habituation block [$t(1, 39) = 9.682$, $p < .001$; $Mean_{PRETEST} = 17.2$, $Mean_{LASTBLOCK} = 9.0$, $Mean_{POSTTEST} = 18.7$]. A 2 (sex: female vs. male) X 2 (trial block: first two habituation trials vs. last two habituation trials) mixed ANOVA produced a significant main effect for trial block, with neither a main effect for gender nor an interaction [$F(1, 12) = 92.727$, $p < .001$; $Mean_{FIRSTBLOCK} = 16.1$, $Mean_{LASTBLOCK} = 8.7$]. Thus, as expected, there was a significant drop in looking time across the habituation phase.

The main set of analyses addressed infants' performance on the test trials. A 2 (sex: female vs. male) X 2 (test trials: same vs. switch) mixed ANOVA revealed neither a significant main effect for test trials ($F (1, 12) = .492$, $p = .497$; $Mean_{SWITCH} = 9.1$, $Mean_{SAME} = 8.3$) nor sex. There was no interaction. This shows that infants of 14-

months do not notice a switch from [d] to [g] in the one-object version of the Switch procedure when novel word-object pairings are used (see Figure 6).

4.2.4. Discussion

It does not appear that the perceptual salience of the [d] – [g] contrast is greater than the other contrasts used in previous work (Pater et al., in press; Stager & Werker, 1997; Werker et al., 2002), as the infants failed to notice this phonetic detail in an experiment that involved a novel word-object combination. This finding reaffirms the resource limitation hypothesis. When unknown words and objects are used, infants fail to notice the exact same detail ([d] versus [g]) in novel words that they attended to in Experiment Two, which used a known or familiar word-object combination. In other words, these results replicated the difference seen in the "bih"-"dih" (i.e., Stager & Werker, 1997) versus "ball"-"doll" (i.e., Experiment One) results. Therefore, it is not that the infants lack the relevant representations of [d] and [g], as argued by representational discontinuity theorists. Instead, the findings indicate that word learning is a cognitively demanding task that masks the infants' underlying ability to notice detail. The generalization of these results across phonetic contrasts demonstrates that the effect of word knowledge was not spurious. Finally, the preceding results also confirm that the one-object version of the Switch procedure does not ease the task enough to notice detail, a possibility raised in the previous chapter. With the rejection of the alternative possibilities raised in the last chapter and further support gained for the resource limitation hypothesis, one can turn to refining the explanation given for the results of Experiment Two, specifically that familiarity with the word and/or object without explicit word knowledge allows for access to the phonetic detail.

4.3. Returning to the familiarity question

4.3.1. Familiarity with the word form

Both the first experiment of this thesis ("ball" – "doll") and the results from those children who explicitly know "doll" in the second experiment clearly demonstrate that word knowledge facilitates access to fine phonetic detail. However, the results from the group of infants who did not explicitly know "doll" in Experiment Two indicate that familiarity with the word-object combination, without full semantic knowledge, is also sufficient to reduce the cognitive demands of the task and allow for access to detail. Previous research has demonstrated that word form familiarity positively impacts language learning in infancy, such as aiding in word segmentation (e.g., Bortfeld, Rathbun, Morgan & Golinkoff, 2003; Shi, Werker & Cutler, 2003). Therefore, it is probable that, especially in light of the findings from Experiment Two, familiarity with the word form helps the novice word learner access phonetic detail in the Switch procedure. However, it is unknown whether object knowledge would perform the same role in easing the attentional demands of the task. Researchers have not explicitly looked at how object knowledge influences speech perception during the infancy period.

4.3.2. Object Knowledge

As was mentioned in the last experiment, the parents of some of the infants in the "doll" familiar group reported that their infant knew the object category doll, but used another label for those objects (e.g., "baby"). The success of the infants in the "doll" familiar group has been attributed to familiarity with the word and/or -object; however, object knowledge on its own, without word familiarity, may be enough to reduce cognitive demands and allow for infant access to phonetic detail in novel words. To date, no study has examined if object knowledge alone affects the infant's use of phonetic detail. Therefore, one must turn to other aspects of language to examine the role of object knowledge.

4.3.2.1. Object-related Biases and Constraints in Language Acquisition

Object knowledge has been repeatedly shown to impact other areas of language acquisition, such as semantics and syntax. Infants appear to have a word learning bias that favours objects (e.g, Gentner, 1982; Macnamara, 1972, 1982). Also, caregivers use their knowledge of objects and object categories to teach infants and children new words (Manders & Hall, 2002). As a result, object words are predominant in the early vocabularies of children, denoting their special status in semantic development.

Knowledge of objects and object categories is central to the lexical constraints present in early (and perhaps even late) word learning. The constraints of lexical contrast (e.g., Clark, 1987) and mutual exclusivity (e.g., Markman, 1992) explain why an infant or toddler will not accept a new name for an already known named object, or when faced with two objects, one known and one unknown, the infant/toddler will assume that a novel name belongs to the unknown object. This constraint has been shown in multiple settings and situations (e.g., Hall, 1991; Markman & Wachtel, 1988; Merriman & Bowman, 1989). The whole object bias is another lexical constraint that relates to the special status of objects in early semantic development. An infant or a toddler will assume that the name for an object refers to the whole object, not a constituent part or property of that object or the action of the object (e.g., Baldwin, 1989; Hall, Waxman & Hurwitz, 1993; Macnamara, 1972; Soja, Carey & Spelke, 1991; Waxman & Markow, 1995). The noun bias, which refers to the tendency of infants to acquire more nouns than verbs in early word learning, can also be seen to reflect the importance of object knowledge, as nouns generally refer to objects or object categories (e.g., Gillette, Gleitman, Gleitman & Lederer, 1999). These object-related constraints help the infant to deal with complexities of learning the arbitrary link between words and their referents.

Object knowledge also alters how we treat the names for things. Hall (1996) demonstrated that we call solids (e.g., wood) the name of their shape (e.g., square), but substances (e.g., peanut butter) are called the substance name, rather than the shape name (see also Soja, Carey & Spelke, 1991). The animacy or inanimacy of objects allows children to choose whether the object has a proper name or count noun, respectively (Gelman & Taylor, 1984; for a review, see Hall, 1999). Children know that count nouns belong to object categories, not just single objects, and that object shape is used as a cue for inclusion in those kinds (e.g., Bloom, 1996). The object bias even overrides syntax in the early stages of language acquisition, with children treating novel adjectives as object names and ignoring syntactic count versus mass noun distinctions (Hall, Waxman & Hurwitz, 1993; Soja, Carey & Spelke, 1991). Based on the above evidence, objects and object knowledge have a special status in the process of word learning.

4.3.2.2. The Impact of Object Familiarity on Early Language

The preceding studies demonstrate that general object knowledge affects areas of language development, such as semantics and syntax. However, does familiarity with a specific object or object class alter language use? Taylor and Gelman (1988) found that 2-year-old children treat novel count nouns differently depending on whether they are familiar with the named object. For pairs of familiar objects (e.g., dogs), the children restricted the novel noun to the named member of the pair (i.e., treated it as the name for the dog, like "Fido", or the type of dog, like "terrier"). When hearing a novel count noun for a pair of unfamiliar objects (e.g., monsters), the children extended the label to both members of the pair, thus treating the novel noun as the label for the object kind.

Hall (1991) examined whether this familiarity effect extends to proper nouns. He found that 2-year-old children interpreted novel proper nouns (as indicated by syntax) correctly only when they were familiar with objects. When they were unfamiliar with the labeled objects, the children interpreted the novel noun as a count noun, thus ignoring the syntactic cues. These results indicate that familiarity with an object directly affects language use at young ages (see also Hall & Waxman, 1993). Of course, it should be noted that the children in these studies were not only familiar with the object, but were also familiar with the label for the object.

4.3.2.3. Words Facilitating Object Knowledge

In an important study, Balaban and Waxman (1997) demonstrated the flip side of object knowledge helping word learning. They found that labeling objects with words, but not tones, facilitated object categorization in 9-month-old infants. Even low pass filtered words, a process by which words are made harder to comprehend due to the reduction in segmental information while their prosodic qualities are retained, aided the infants in categorizing novel objects. Thus, it appears that language aids in gaining object knowledge. The present experiment was designed to see if the reverse was true as well; would object knowledge aid in word acquisition, specifically the acquisition of phonetically detailed words?

4.4. Experiment Three (Part B)

The prediction generated from the resource limitation hypothesis is that any factor that eases the forging of the object-label link should free cognitive resources and allow 14-month-old infants to access fine phonetic detail in new words. Object familiarity is a candidate for one such facilitating factor. As mentioned in the previous chapter, some parents of infants in the "doll" familiar group stated that their child knew the object doll, but had a different label for it (e.g., "baby"). This indicates that object familiarity, without explicit word knowledge, could have been enough to free cognitive resources and allow these infants to notice the switch from "doll" to "goll". However, since this is the first study that directly tests the impact of object familiarity on access to phonetic detail, there is no previous research which necessarily indicates that object knowledge is a suitable candidate for facilitating the task enough to access detail.

The current experiment explicitly tests, in the form of an exposure study, the possibility that object familiarity allows for access to phonetic detail. A group of infants was exposed to the toy object from Experiment Three (Part A) in the two months prior to the experiment. The object was never labeled in this time period. The first time the infants heard the label for the object was when they began the habituation phase of the Switch procedure. The actual experiment was identical to Experiment Three (Part B). The only difference in procedure was the previous exposure to the object. If infants succeed in this experiment, it would indicate that object familiarity alone, and not full referential knowledge of the word-object association or familiarity with both the word and object, is all that is needed to succeed in the task. It would also indicate that words can fully realized phonetically in the initial stages of learning.

4.4.1. Method

4.4.1.1. Participants

Fourteen infants completed the study, 7 girls and 7 boys (mean age, 14 months, 14 days; range, 14 months 1 day to 15 months 4 days). All subjects were without apparent health problems, were at least 37 weeks gestation, and were exposed to English at least 80% of the time. One infant was tested but was not included in the analyses because of restlessness and one other infant was tested and not included because his/her parent called the object "twisty rattle" in the two months prior to testing.

4.4.1.2. Stimuli

The stimuli were the same as those used in Experiment Three (Part A).

4.4.1.3. Apparatus

All materials and equipment remained the same as those used in Experiment Three (Part A).

4.4.1.4. Procedure and coding

The only difference in procedure from Experiment Three (Part A) was the inclusion of an exposure phase for approximately two months prior to testing. Six to eight weeks before the testing date, parents came into the lab and were given the toy to take home. They were instructed to include the toy in their infant's natural playtime for approximately two hours per week. They were also instructed to never give the toy a label. The parents received a diary in which to record the amount of time their infant played with the toy and to confirm that the parent did not accidentally label the object during one of the playtimes (see Appendix A). The diary was returned when the parent(s) came back for testing. The Switch task remained the same as in Experiment

Three (Part A), with infants being habituated to the toy object (Figure 5) paired with the auditory label "din". The label was changed to "gin" in the 'switch' test trial.

The coding procedure remained the same as in Experiment Two.

4.4.2. Results

To determine whether infants maintained interest throughout the experiment and recovered from habituation, a series of planned orthogonal comparisons were run to first compare pretest to posttest and, if these two trials were found to be the same, to then compare these trials to the last habituation block. There was no significant difference between the pretest and posttest. The pretest and posttest were significantly different from the last habituation block [$t(1, 39) = 9.943$, $p < .001$; $Mean_{PRETEST} = 18.8$, $Mean_{LASTBLOCK} = 9.8$, $Mean_{POSTTEST} = 17.3$]. A 2 (sex: female vs. male) X 2 (trial block: first two habituation trials vs. last two habituation trials) mixed ANOVA produced a significant main effect for trial block, with no main effect for gender [$F(1, 12) = 445.6$, $p < .001$; $Mean_{FIRSTBLOCK} = 17.8$, $Mean_{LASTBLOCK} = 9.8$]. There was a gender by trial block interaction [F1, 12) = 5.487, $p = .037$], with males having a slightly larger drop in looking time ($Mean_{FIRSTBLOCK} = 18.9$, $Mean_{LASTBLOCK} = 10.1$) than females ($Mean_{FIRSTBLOCK} = 16.7$, $Mean_{LASTBLOCK} = 9.6$). Subsequent paired sample t-tests revealed that both sexes had significant drops in looking time ($p < .001$). Thus, as expected, there was a significant drop in looking time across the habituation phase.

The main set of analyses addressed infants' performance on the test trials. A 2 (sex: female vs. male) X 2 (test trials: same vs. switch) mixed ANOVA revealed no significant main effects or interactions [$F (1, 12) = .846$, $p = .376$; $Mean_{SWITCH} = 12.1$,

$Mean_{SAME} = 10.4$). Thus, it appears that object familiarity does not allow infants of 14-months to notice a switch from [d] to [g] in the Switch procedure (see Figure 5).

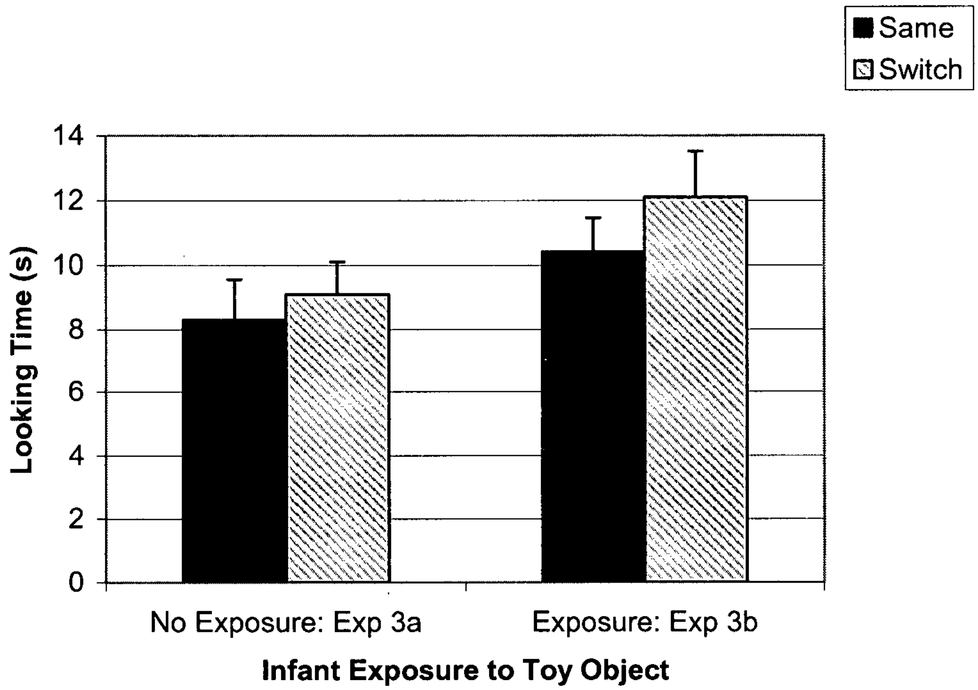

Figure 5: Mean looking times to test trials in Experiment Three.

4.4.3. Discussion

The above results indicate that object knowledge alone is not enough to reduce attentional demands and allow novice word learners to access phonetic detail in a novel word. It appears that infants of 14 months need to be familiar with the word-object combination, or have full referential knowledge of the word form in order to notice phonetic detail.

4.5. Combined Analysis

Before discussing the ramifications of Experiments 3 (Part A) and 3 (Part B), the two sets of results should be compared in order to examine if object had any effect on infants' reaction to the task. A between-within 2 (Object exposure: yes or no) X 2 (Sex: male or female) X 2 (Test Trial: Same versus Switch) ANOVA that includes the data from the two experiments revealed a potential impact of previous exposure to the object. There was not a main effect for test trial or sex. However, there was a main effect for object exposure [$F(1, 24) = 5.28$, $p = .031$]. Infants who had exposure to the object had longer overall looking times to the test trials than infants for whom the object was novel (see Table 2). One possible explanation for this looking time difference is that the infants with pre-exposure to the object are generally more interested in the toy. This increased interest could be manifesting itself as higher looking times overall. At the very least, this significant difference in looking times demonstrates that previous exposure to the object had an impact on the task. Thus, infants are necessarily remembering something about the object when they are performing the task.

Table 2: Mean Total Looking Times in Seconds to Test Trials: Experiment 3 (Parts A & B)

	'Same' Test Trial	'Switch' Test Trial	Test Trial Average
Infants not exposed to the object (Exp. 3 - A)	8.3	9.1	8.7
Infants exposed to the object (Exp. 3 – B)	10.4	12.1	11.3

If infants are remembering something about the object, one can reject the possibility that infants performed similarly across the two experiments in this chapter because the object was not memorable enough for the infants who had two months pre-exposure to the toy. However, the above analysis does not allow a conclusion regarding the amount of exposure required to access phonetic detail. The infants could be remembering little about the object, just enough to trigger greater attention in the test trials. Perhaps those infants with greater exposure would remember more object details, which would in turn facilitate the task to a greater degree. To help answer this question, an analysis of the parental diaries was needed. Parents had recorded the amount of time the infants played with the toy object in the two months prior to testing using the diaries provided (see Appendix A). Would those infants who had the most exposure to the toy have more access to phonetic detail and thus notice the switch from "din" to "gin"? A correlation of total exposure time in minutes with the difference score ('switch' minus 'same') was not significant ($p = .599$). This suggests that increased exposure did not aid the infants in accessing phonetic detail. Length of exposure to the object did not impact infants' performance in the word-learning task. All of the data presented so far indicate that object familiarity did not aid the infants in accessing detail in the word form. However, alternative analyses could reveal a different picture.

4.6. A revealing exploratory analysis of the data

Researchers using the Switch procedure have only examined total looking time to the 'same' trial as compared to total looking time to the 'switch' trial (e.g., Stager & Werker, 1997; Werker, Cohen et al., 1998; Werker et al., 2002). It is important to note that, while this is the standard measure, it is not the only measure that can be generated from the large amount of looking-time data gathered during the task. Other infant researchers, namely Plunkett, use infants' longest look as an indicator of success in preferential-looking word-learning tasks (e.g., Schafer & Plunkett, 1998). Another potential measure is duration of the infants' first looks (e.g., Naigles & Gelman, 1995). This can be seen as a correlate of the measure used in the visual fixation studies (e.g., Swingley & Aslin, 2002). In these studies, the latency of the shift from distractor to target is the primary measure. Logically, as only direct shifts from distractor to target are included in the analysis, this measure is an inverse of first look. For example, if an infant has a two second latency to the target object, then she had a first look of two seconds to the distractor object. So, while a *shorter* latency to target measure indicates success, a *longer* first look to target would demonstrate detection of a change. Of course, the methodological differences between preferential looking/visual fixations tasks and the Switch procedure may mean that these measures are not useful in the current experimental context. However, as an exploratory analysis, the impact of object knowledge on both the longest look and length of first look during the test trials was investigated.

4.6.1. Duration of longest look

Schafer and Plunkett (1998) argue that duration of longest look to a match as compared to a mismatch is the most sensitive measure of novel word learning in 12 to 17-month-olds. They found no difference in overall looking time to match and mismatch, but did find a significant difference in duration of longest look. Of course, the procedure used in the Schafer and Plunkett study (i.e., preferential looking) differed from the Switch procedure in important ways. There were two objects present in their test trials, while only one object is present during a test trial in the Switch task. Also, there was a training phase in Schafer and Plunkett, but the infants were not required to reach a habituation criterion, unlike the Switch task. Finally, the words used in the Schafer and Plunkett experiment were phonetically dissimilar in multiple ways. Based on the above evidence, this measure may not have the same sensitivity in the Switch procedure that it demonstrates in the preferential looking task.

A 2 (Object Exposure: yes or no) by 2 (sex: male or female) by 2 (Test Trial: 'same' versus 'switch') mixed ANOVA was run including all infants from Experiment Three (Parts A &B). Longest look was the dependent variable. There was no main effect for test trial and no interactions. However, the main effect for object exposure was again significant [$F(1, 24) = 5.0$, $p = .035$]. The infants who were exposed to the object had longer looks overall than those infants with no exposure to the object (See Table 3). This is similar to the finding in the combined analysis that used total looking time as the dependent variable. Once again, this result could indicate that the infants who had experience with the object were more interested in it than those with no experience. As one can see from the data presented in Table 3, object knowledge does not appear to have a differential effect across test trials. Both groups have slightly longer looks to 'switch'. Unlike the Schafer and Plunkett (1998) study, the duration of longest look was not a more sensitive measure than total looking time in the current study.

Table 3: Mean Longest Look in Seconds During Test Trials: Experiment 3 (Parts A & B)

	'Same' Test Trial	'Switch' Test Trial	Test Trial Average
Infants not exposed to the object (Exp. 3 - A)	4.6	5.1	4.8
Infants exposed to the object (Exp. 3 - B)	7.2	8.7	8.0

4.6.2. First look to object

The analyses of total looking time and duration of longest look yielded no strong evidence that object knowledge eases cognitive demands and allows for access to phonetic detail. However, both of these measures can extend over the entire test trial, allowing for the possibility that infants lost attentional focus across the 20 seconds of the test trial. Infants could initially notice the phonetic detail and then "lose" it as the trial progresses. Fernald and Swingley have both consistently argued that such a loss of attentional focus occurs over the duration of test trials in the visual fixation task (e.g., Fernald, Pinto, Swingley, Weinberg & McRoberts, 1998; Fernald, Swingley & Pinto, 2001; Swingley & Aslin, 2002; Swingley, Pinto & Fernald, 1999). In their procedure, visual latency is only measured in a time window extending over a small time period after the beginning of word presentation (367-2000 msec post word onset). After this time, the data indicate that infants randomly look at target and distractor. Infants continue this random pattern even after the word is repeated later in the trial. If the Fernald and Swingley findings extend to the Switch procedure, it could be that the duration of first look would capture the time period when infants are best attending to the object-word combination. It should be noted that the disparate methodologies problem mentioned in the discussion of the longest look literature is applicable in this case as well. The Switch and visual fixation procedures are quite different (e.g., one versus two objects, no habituation phase in the latter). Thus, both the sensitivity of the first look measure and the window of attentional focus concept may not extend to the current study.

A 2 (Object Exposure: yes or no) by 2 (sex: male or female) by 2 (Test Trial: 'same' versus 'switch') mixed ANOVA was run including all the infants from Experiment Three (Parts A & B). Duration of first look was the dependent variable.

There was no main effect for test trial and no sex by test trial interaction. However, the main effect for object exposure was again significant [$F(1, 24) = 4.836$, $p = .038$]. The infants who were exposed to the object had longer first looks than those infants with no exposure to the object (See Table 4). There was a significant interaction between the object exposure and test trial factors at the .10 level, and very nearly at the .05 level [$F(1, 24) = 4.097$, $p = .054$]. One can see from the data presented in Table 4 and Figure 6 that, in the object exposure experiment (Experiment Three: Part B), infants' mean first look to the 'switch' trial (mean = 8.4) was greater than their mean first look to the 'same' trial (mean = 5.1). This did not hold true for those infants with no previous exposure to the object (Experiment Three: Part A). These infants had a longer mean first look to 'same' than to 'switch'. The lack of a significant object exposure by test trial interaction at the .05 level may slightly hinder these first look findings, but the interaction is significant at the .1 level ($p = .054$), unlike the interaction found in the previous ANOVA using duration of longest look ($p = .535$). .

Table 4: Mean First Look in Seconds During Test Trials: Experiment 3 (Parts A & B)

	'Same' Test Trial	'Switch' Test Trial	Test Trial Average
Infants not exposed to the object (Exp. 3 - A)	3.8	3.0	3.4
Infants exposed to the object (Exp. 3 - B)	5.1	8.4	6.7

4.6.3. Further analysis of first looks across experiments

Based on the above analysis, a decision was made to explore the "duration of first look" measure in further detail across analogous experiments. As can be seen in Figure 6, duration of first look can be seen as a potential indicator of attention to and use of phonetic detail in the task. The infants in Experiment Two, who succeeded in noticing the detail, as indexed by the standard measure of total looking time, also succeeded in noticing the detail when indexed by duration of first look ($p < .001$). The infants in Experiment Three (Part B), who were exposed to the object, appear to follow a similar pattern, while those infants with no exposure (Experiment Three: Part A) show a reversal of the pattern (see Figure 6). It could be that the current study lacks the power to reveal a significant difference in Experiment Three (Part B). After all, Experiment Two had 32 participants (16 infants per condition), while Experiment Three (Part B) had 14. However, the standard number of participants in Switch studies is about 16 infants and this sample size has revealed significant differences in other experiments (e.g., Experiment One of this thesis; Stager & Werker, 1997; Werker et al., 2002). It was thought that a sample size of 14 infants, a comparable N to these past studies, would also reveal any effects. Nevertheless, the addition of more infants to the analysis may clarify the pattern.

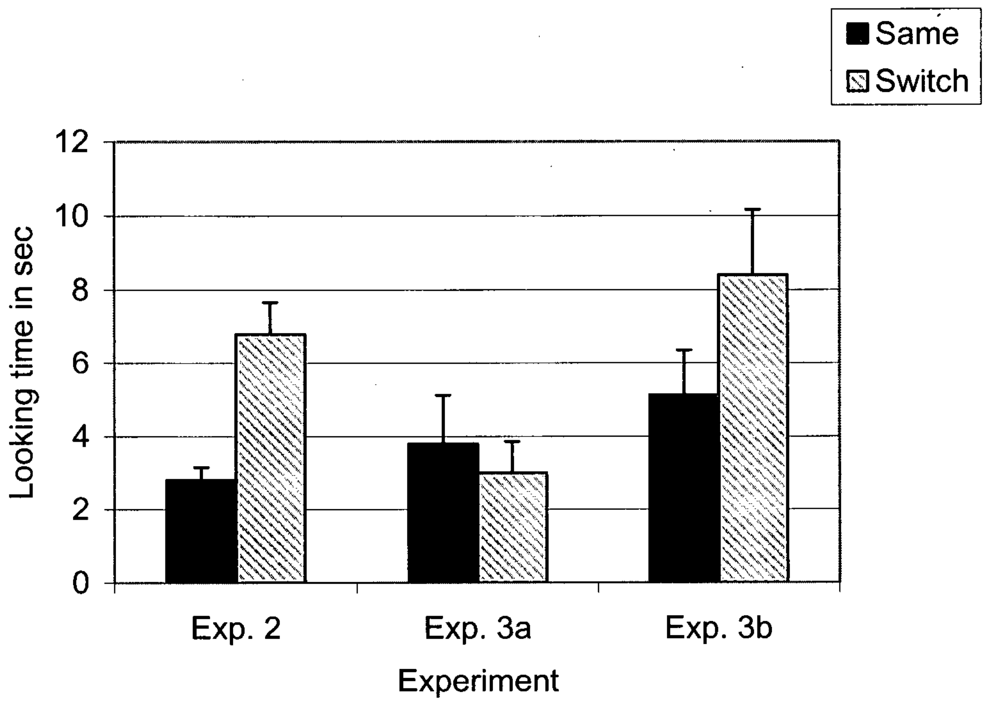

Figure 6: Duration of first look to test trials across Experiments Two and Three.

4.7. General discussion

Based on the findings in Experiment Three (Part A), one can reject the possibilities that 14-month-old infants accessed the phonetic detail in Experiment Two, the "doll" – "goll" experiment, because of contrast salience or due to the simpler structure of the one-object Switch task. The [d] – [g] contrast is as hard as the [b] – [d] contrast; and, as in previous studies using the Switch task, infants of 14 months fail to distinguish novel, minimally different words even when only one object-label combination is present in the habituation phase. Experiment Three (Part B) demonstrated that object knowledge alone was not enough to facilitate the task to the point where novice word learners could access detail in newly learned words. However, the subsequent analyses hinted that alternative measures, such as duration of first look, may reveal that object knowledge has an impact on access to phonetic detail.

Chapter 5: Wrapping Up and Looking Ahead

5.1. General discussion

The data in this thesis provide evidence for the resource limitation hypothesis originally formulated by Stager and Werker (1997) and elucidated by Werker and Fennell (2004). Theorists saw two explanations for the results of the Stager and Werker study, which demonstrated that, although 14-month-old infants could discriminate fine phonetic detail in speech discrimination tasks, they could not use the same detail when learning new words. The resource limitation hypothesis stated that word learning placed heavy cognitive demands on the novice word learner; thus they did not attend to and use all the detail in the word form in order to free resources and link word to object. Other theorists postulated a representational discontinuity between the phonetic categories refined in the first year of life and the phonological categories built up in year two via vocabulary acquisition. Infants were using phonetic categories when performing the simple speech discrimination task in Stager and Werker. Discontinuity theorists would suggest that, when placed in a word learning situation, the infants could not use this detail because the relevant phonological categories had yet to be built. The first experiment explicitly tested the viability of the representational discontinuity hypothesis and found it to be untenable.

In Experiment One, 14-month-old infants demonstrated that they could attend to fine phonetic detail when dealing with well-known words. At first, this result could be seen as supporting both hypotheses outlined above. The resource limitation theorist would state that the demands of word learning were removed from the task, as the word was already known. Cognitive resources would be freed, and detail would be picked up and used. The representational discontinuity theorist would point to the phonemes as being fully realized, thus allowing for their use in the task. Importantly, the first experiment used the exact same phonetic contrast, specifically [b] and [d], that 14-month-old infants have repeatedly failed to use in previous word-learning research. The infants' use of these phonemes refuted the representational discontinuity argument by demonstrating that infants of 14 months have access to [b] and [d] in words. In other words, these phonemes have already been "built", to use the discontinuity term. The argument presented in this thesis is that the phonetic representations used in these word tasks are actually the same representations that have been refined over the first year of life – no discontinuity exists. The apparent discontinuity seen in the data is an artifact of the demands of the task itself. For a 14-month-old infant, the demands of word learning masks use of phonetic detail due to the complexity of matching word to object.

The second experiment was designed to push the limits of the resource limitation hypothesis. The nature of the 'switch' in Experiment One may have oversimplified the task. The word switched from one well-known word to another well-known word (i.e., "ball" to "doll"). Also, the stimuli of Experiment One were incompatible with the other study that demonstrated attention to phonetic detail in well-known words, namely Swingley and Aslin (2002). In their study, Swingley and Aslin contrasted a well-known word with a nonce word that was minimally different from the known word. This can be seen as a stricter test of the resource limitation hypothesis. If infants have access to all the detail in the target word, they should notice any violation of that detail, not just a violation that corresponds to another entry in their lexicon. Furthermore, Experiment Two tested the possibility that familiarity with the word-object combination (or familiarity with one part of that combination – i.e., word or object) facilitated access to detail by reducing the demands of the task. The familiarity test was accomplished by splitting the infants into two groups: infants who had explicit knowledge of the word "doll" prior to the experiment and those who did not have explicit knowledge, but were exposed to the word or members of the doll object category.

The success of the "doll" known group of infants in noticing the 'switch' to a minimally different nonce word confirmed the major finding from Experiment One, specifically that 14-month-old infants can attend to detail in well-known words, in a stricter test. These results also extended the well-known word finding to another phonetic contrast, [d] versus [g]. By also noticing the 'switch' from "doll" to "goll", the group of infants who did not explicitly know the word "doll" demonstrated that familiarity with the object-label combination, or potentially a part of that combination, also facilitates the task to the point where phonetic detail can be used.

Importantly, the Switch procedure was a word-learning task for the group of infants who did not know "doll", yet they accessed the detail. For the infants in Experiment One and the "doll" known group in Experiment Two, the task would be better classified as a word recognition task. All previous attempts to make the word learning task easier for 14-month-old infants have failed to produce significant results (e.g., more presentations during habituation in Werker et al., 2002; use of the one-object version in Stager & Werker, 1997; use of valid English word forms in Pater et al., in press). The results of Experiment Two suggest that familiarity with a word-object combination, or with the word form or object, gives infants a "leg up" in a word learning task. The demands placed on the infants are reduced, as compared to learning a novel word-novel object pairing, because the infants do not have to learn about the word form and about the object concurrently with their attempt to link the word and object. This finding fits well into the resource limitation hypothesis.

Yet, there were alternative, low level explanations for why the infants who did not explicitly know "doll" succeeded in noticing the phonetic detail. Potentially, the [d] – [g] contrast could have greater perceptual salience than the contrasts used in previous work. A literature review of phonological hierarchies (problematic as they are) and perceptual confusion matrices revealed that this possibility was unlikely. The results of Experiment Three (Part A) confirmed that the [d] – [g] contrast was not perceptually distinct enough to trigger access to its phonetic detail in a word learning task involving a novel word-novel object pairing. This experiment also discounted the possibility that it was the one-object version of the Switch procedure that facilitated performance in the task in Experiment Two. Experiment Three (Part A) completed the picture of the [d] – [g] contrast, revealing that it matched the existing picture for the [b] – [d] contrast developed in Experiment One and in previous research (e.g., Stager & Werker, 1997). For both contrasts, phonetic detail was not accessed in a novel word-learning situation, but was present in a known-word recognition task. Thus, one can point to another contrast that appears, on the basis of the recognition task, to have been "built" as a phonological representation, yet is not used in word learning. This provides more ammunition to argue against the representational discontinuity argument and further supports the hypothesis that the phonetic detail is present, but is masked by the demands of the task.

Experiment Three (Part B) once again pushed the limits of the resource limitation hypothesis. By exposing 14-month-old infants to the object used in Experiment Three (Part A) for two months, Part B of Experiment Three tested the possibility that object knowledge, with no previous exposure to the word form, would be enough to facilitate the task and allow for access to phonetic detail. The results from this manipulation demonstrated that object knowledge did not appear to be enough of a facilitator in this task. Infants did not notice the 'switch' when examining their total looking times to the object in the test trials. Also, a combined analysis looking at effect of object knowledge (infants from Part A compared to those infants in Part B) revealed no significant interaction between test trial and exposure. However, a subsequent analysis of the data revealed trends that indicated that infants may have noticed the change in phonetic detail. The mean duration of the first look in the 'switch' trial was greater than the duration of this measure in the 'same' trial. These results did not achieve significance at the .05 level, but were quite close ($p = .054$). This could be due to the smaller sample size in these experiments and consequent lower power. These trends are interesting and deserve further study.

The experiments contained in this thesis have clarified the theoretical assumptions underlying the resource limitation hypothesis and have provided greater evidence for the presence of phonetic detail in known words. Moreover, the data from the three experiments have lead to a stronger refutation of the representational discontinuity explanation. The designs and methodologies used have answered questions, such as the aspects of the procedure that allow for access to fine phonetic detail at 14 months, and have raised others, such as looking to alternative measures derived from other procedures. Obviously, the data and conclusions present in this thesis regarding novice word learners' use of phonetic detail will require further elaboration in future work. Nonetheless, this thesis strengthens the foundation upon which the resource limitation hypothesis has been built.

5.2. Looking Ahead

There are two major extensions of the research presented in this thesis that will help to complete the story. First, the relation between word form familiarity and access to phonetic detail needs to be explored. Word form familiarity refers to the situation where an infant has experienced a word, but has yet to attach any meaning to the sequence of phonemes. As mentioned in Chapter Four, one would predict, based on the facilitative effects of word form familiarity on other areas of speech perception, that familiarity with a word form would facilitate access to phonetic detail when that word form is initially linked to a novel object. The major problem with designing a study to test this prediction of facilitation is how does one familiarize an infant to a word form without the infant searching for a corresponding meaning? This dilemma relates to Jusczyk's (1997) idea that the word form can drive infants' search for meaning (as opposed to Macnamara's (1982) notion that knowledge of an object drives the search for a label). Unlike the object exposure condition, where it was quite easy to prevent the parents from ever attaching a word to the object, a word form exposure condition would be quite difficult to carry out in the home, as there may be a commonality in the contexts in which the parent says the word form (e.g., a specific toy always present). The infant could then attach the word form to this common feature. One potential method of testing the impact of word form familiarity would be familiarizing the infants to passages that contain the word form and then testing them in a version of the Switch procedure similar to Experiment Three. However, a familiarization phase preceding the habituation phase may be too demanding for the infants and may thus mask any effects.

A second mode of inquiry involves the use of neurophysiological techniques. The neurophysiological results of Mill et al. (in press) appear to be in direct conflict with the behavioural results found in Experiment Two of this thesis. Mills et al. (in press) found that nonce words that are phonetically similar to known words show no pattern difference in the ERP signals of 14-month-old infants. However, the same-aged infants in Experiment Two of this thesis did discriminate phonetically similar nonce words from known words. A behavioural difference where no apparent brain response difference occurs is quite hard to explain. Thus, one needs to turn to the nature of the experiment as a potential explanation for the difference in results. In the Mills et al. work, the infant was simply presented with the word and a response was recorded. The infants in Experiment Two were also presented with the well-known word, but saw the matching object paired with that word many times in the habituation phase as well. Also, at test, they experienced an object-label mismatch (object doll matched with nonce word "goll"), something that never occurred in the Mills et al. study. In accordance with the resource limitation hypothesis, the presence of a well-known word-object pairing during habituation would facilitate the task and ease processing demands, thus freeing cognitive resources to be devoted to phonetic detail. The presence of a well-known object mismatch on the 'switch' trial would also make the task easier. The prediction is that in an ERP study, 14-month-old infants would show the ERP signature typically seen to unknown words if the phonetically similar nonce words were presented in the presence of a mismatched object target (e.g., hear "goll", see doll). As some may argue that the similarity in the known and phonetically similar nonce word ERP responses reflect similar representations of the word form (i.e., "doll" and "goll" have the same underspecified representation), differing ERP patterns across these two classes of words in the presence of an object would be an important finding in support of fully realized representations of these phonemes from the beginnings of word learning.

5.3. The end?

The link between speech perception and word learning has proven to be more complicated than first expected. Still, it would seem that the emerging organization in speech perception seen at the end of the first year does prepare the child for word learning by determining the detail that is available in word forms. Along these lines, the reader has been presented an account that focuses on continuity in the representation and on differential access to phonetic detail as a function of processing load. A competing hypothesis that involves a discontinuity in the underlying representations was also presented. The data presented in this thesis support the former account. The debate between adherents of different models is central to clarifying the link between pre-lexical perception and post-lexical phonology. Unpacking this link through additional tightly controlled, linguistically motivated laboratory studies holds promise for a fuller understanding of phonological development.

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Appendix A: Parental Diary from Experiment Three (Part B)

Dr. Janet Werker's Infants Studies Centre
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Phone: 604-822-6408

Instructions: Please fill out this diary after playtimes during which the target toy has been used. Please remember that you can give an approximate length of time. If you have any questions, please feel free to call us at 604-822-6408.

Week 1: ________________________________

Day	Approximately how long did your infant play with the toy during playtime today?	Did you label the toy during playtime? If so, with what label?
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		