Infant Attention to Phonetic Detail: Knowledge and Familiarity Effects

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1. Introduction

The growing literature concerning young word learners' attention to phonetic detail is a welcome addition to the field of psycholinguistics. However, a review of the recent research reveals conflicting findings. Some studies indicate that novice word learners cannot access phonetic detail in word forms (e.g., Stager & Werker, 1997; Werker, Fennell, Corcoran & Stager, 2002), whereas, other research has demonstrated that same aged infants can use all the detail found in words (e.g., Swingley & Aslin, 2002). Although these results appear contradictory, we argue that both sets of findings support the position that there is continuity between the representations used in the refined phonetic perception of young infants and the meaningful phonemic representations used in early word learning. A recent study by Fennell and Werker (in press) has helped to resolve the methodological and theoretical debate arising from the above results by demonstrating that novice word learners only attend to detail when words are known. However, the design of that experiment left open the possibility that word/object familiarity, without explicit knowledge, is enough to allow for access to phonetic detail. By investigating this possibility, the current study provides a stricter test of the word knowledge hypothesis.

1.2 Phonetic perception in the first year of life

From the beginning of the first year of life, infants demonstrate fine sensitivities to phonetic contrasts. Eimas, Siqueland, Jusczyk and Vigorito (1971) conducted the classic study in infant phonetic perception. They demonstrated that even 1-month-old infants are capable of categorical–like speech perception. Subsequent studies with other consonant and vowel contrasts indicate that the range of phonetic contrasts that an infant can discriminate is quite broad (for a review see Aslin, Jusczyk & Pisoni, 1998).

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Werker and Tees examined the breadth of infant sensitivities in 1984 by testing infants on native and non-native phonetic contrasts. They discovered that 6-month-old infants discriminated both types of contrasts, yet 12-month-old infants, despite being able to differentiate their native phonetic contrasts, failed to discriminate the non-native contrasts. These results suggest that the narrowing of phonetic sensitivities is due to the language environment in which the infant is maturing. This pattern of moving from more general to language-specific phonetic perception has been replicated using different contrasts (for review see Werker, 1995). This research clearly demonstrates that the perceptual salience of phonetic units becomes language specific during the first year of life. The question naturally arose whether novice word learners were using these phonetic categories to aid in vocabulary acquisition.

1.3 Attention to phonetic detail in word forms

The existing research did not provide a clear answer to the question of whether early word learners applied their phonetic perception abilities to word learning. 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 (1980) reported that 2-year-olds still confuse minimally different words. Others report similar findings of minimal pair confusion (e.g., Brown & Matthews, 1997; Gerken, Murphy & Aslin, 1995), while other research indicated that even 7-month-old infants could attend to detail in words (Jusczyk & Aslin, 1995). This inconsistent pattern of results left the question unresolved of whether young word learners have the ability to use fine phonetic differences in word comprehension.

The picture selection and pointing tasks used in some of the earlier toddler studies could be too difficult for children this age and would be impossible to extend to infant research. Thus, task difficulty alone may have led to the findings that young children do not attend to phonetic detail. Also, previous infant and toddler research included tasks that did not require a link to meaning (e.g., Jusczyk & Aslin, 1995). To address these potential confounds, Stager and Werker (1997) used a word-object associative task called the Switch procedure.

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 links between the specific words and objects, the 'switch' trial, as a violation of those links, should attract greater looking time than the 'same' trial.

Werker et al (1998) demonstrated that 14-month-old infants can learn dissimilar sounding labels (e.g. "lif" vs. "neem") in the Switch procedure; 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")[1]. This was surprising 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-month-old English-learning infant to discriminate, and presumably to use in word learning. Through a set of control studies, Stager and Werker demonstrated that 14-month-old infants still discriminated /b/ from /d/ in a speech discrimination task and only failed to notice the detail when they had to link labels to objects. Thus, it would seem that infants of 14-months only have difficulty accessing phonetic detail when they are placed in a word-learning situation. Why might this occur?

1.4 Representational discontinuity vs. continuity

The puzzle of the apparent inconsistency between the fine phonetic abilities shown in speech perception studies and the perceptual mistakes made in early word acquisition begs for an explanation. One solution for this riddle involves representational discontinuity. Brown and Matthews (1997) postulate that two separate developmental patterns exist for phonetic vs. 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 (see also Charles-Luce & Luce, 1990; Metsala & Walley, 1998). Therefore, novice word learners do not notice the detail in the word forms because they are switching from a pre-lexical phonetic system to a meaning-based phonological system and have yet to build the relevant phonemic representations involved in the task.

The other class of explanations rejects the notion that the processes of phonetic and phonological development are independent and parsimoniously argues instead for a continuity between phonetic and phonological representations (Werker & Fennell, in press; Werker, et al, 2002). Their

[1] This result has since been replicated in the following ways: using multiple phonetic contrasts, using CVC word forms, using more visually distinct objects, and increasing the length of the habituation trials. In all cases, the 14-month-olds failed to notice the difference in the similar sounding labels. (Pater, Stager & Werker, under review; Werker, et al, 2002).

challenge to discontinuity theorists is: Why would the infant build anew an already existing representation? 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. Thus, the attentional resources available for attending to 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 (e.g., Casasola & Cohen, 2000). 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 attention to fine phonetic detail that the infant sacrifices.

1.5 Attention to phonetic detail in well-known words

In apparent contradiction to the Stager and Werker (1997) results, Swingley and Aslin (2002) found that novice word learners do attend to and use phonetic detail in words forms. This, in turn, challenges both hypotheses discussed in the previous section, as both use the Stager and Werker paper as evidence. Swingley and Aslin used a visual fixation task to determine young word learner's ability to attend to correct and incorrect pronunciations of known word forms. They presented 14-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" (the baby object in both conditions) were significantly delayed in the mispronunciation condition as compared to the correct pronunciation condition. This indicates access to the fine phonetic detail in the word forms. The infants also looked longer to the correct picture after hearing the correct pronunciation than after hearing the mispronunciation[2]. Therefore, the 14-month-old infants in this study appear to attend to all the fine phonetic detail in the word form, unlike the same-aged infants in Stager and Werker and in Werker et al (2002).

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

[2] 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 (longer looks to incorrect).

considered. The first possibility is that the Switch procedure is too difficult for the infants to demonstrate the ability shown in the Swingley and Aslin study. We are currently conducting a study with Daniel Swingley to investigate 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 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. 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 much easier task.

Contrary to the resource limitation explanation, strong representational discontinuity theorists would state that 14-month-old infants would notice phonemic detail in well-known words **only** if they possessed the relevant phonological representations. Considering that previous studies (e.g., Pater et al, under review; Stager & Werker, 1997; Werker et al, 2002) have all demonstrated 14-month-old infants' inability to use the /b/ - /d/ contrast, 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 even if the words were well-known. Therefore, if 14-month-old infants successfully notice the /b/-/d/ contrast in well-known words, it would challenge the representational discontinuity position.

Fennell and Werker (in press) tested this prediction by using two well-known words that formed a minimal pair with a /b/-/d/ contrast. A group of 14-month-old infants were habituated to two word-object pairings – ball and doll[3] – and were then tested in the Switch procedure to see if they accessed the relevant phonemic detail. The infants attended the phonemic difference in the well-known words. In fact, 15 out the 16 infants looked longer to the pairing violation (e.g., object ball paired with "doll"). By using the same contrast and procedure as Stager and Werker (1997), Fennell and Werker provided both a clear demonstration that word knowledge allows access to phonetic detail at 14 months and strong support for the resource limitation hypothesis.

1.6 Potential Problems and Remaining Questions

In our previous experiment (Fennell & Werker, in press), the infants were exposed to two well-known members of a familiar minimal pair. The infants'

[3] These stimuli are phonetically transcribed as: [b❷:l] and [d❷: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.

knowledge of **both** words could have greatly facilitated the task. Also, 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 stricter test of the resource limitation hypothesis would involve a switch from a known word to a phonetically similar unknown word.

Although Fennell and Werker (in press) provided evidence that a priori knowledge facilitates attention to phonetic detail, the exact degree of knowledge needed for access to phonetic detail in the word form was still unknown. Is semantic knowledge the necessary component that allows novice word learners to access detail in the word form, or is word/object familiarity without explicit knowledge enough to ease cognitive demands and allow for access? To answer this question we tested two groups of infants: those who explicitly knew the target word and those who did not explicitly know the word, but had experience with the target word and object category.

2. Experiment

The current experiment once again focused on 14-month-old infants. To make the experiment comparable to our previous study, we used one of the words from that study: "doll". We also separated the infants into two groups: those who explicitly knew "doll" and those who did not. Based on the resource limitation hypothesis, we predicted that those infants who knew "doll" would access the detail in this stricter test involving a switch to mispronounced version 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. If this group did not notice the switch, it would indicate that word knowledge is necessary to access phonetic detail. If they noticed the pairing violation, then it would seem that word/object familiarity facilitates the task and allows for access to phonetic detail.

2.1 Method

2.1.1. Participants

Twenty-nine infants completed the study, 15 girls and 14 boys (mean age, 14 m, 15 d; range, 13 m 24 d to 15 m 7 d). 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 12 infants were tested but were not included in the analyses because they were upset (n = 6), too restless during testing (n = 4), were not visible to the coder during at least one trial (n = 1), or were reported to have previously heard "gall" (n = 1).

Approximately half of the infants (6 boys, 8 girls) comprehended the target word ("doll") and half (8 boys, 7 girls) 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 infants' knowledge of that word.

Subjects were recruited through visiting new mothers at BC Women's and Children's Hospital, and through voluntary response to advertisements. Participating infants were given an "Infant Scientist" t-shirt and diploma.

2.1.2. Stimuli

The audio stimuli were two CVC words that formed a minimal pair: "doll" and "goll"[4] recorded in infant-directed speech (IDS). These stimuli differ only in the place of articulation of the initial consonant. IDS is effective in gaining and maintaining infant attention (e.g., Fernald, 1985) and in facilitating word learning in infants (Fernald, McRoberts, & Herrara, 1991). The use of IDS also facilitates infant phonetic discrimination (Karzon, 1985). An additional, highly dissimilar nonsense label, "neem"[5], was used during the pre- and post-test trials.

In a soundproof room, we 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 our previous study (Fennell & Werker, in press) - a doll with light blue clothing and bright yellow hair that is a highly representative instance of its object category. A multicoloured 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). Importantly, 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). The "spinner" was filmed with the base remaining stationary while the wheel was moved around in a clockwise motion.

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

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[4] These stimuli can be phonetically transcribed as: [d➋:l] and [g➋:l]. We acknowledge that "goll" sounds like valid English words ("gall" and "Gaul"). However, these are not words that your average 14-month-old infant knows. Nevertheless, we confirmed with parents post-testing that their infant did not know these words.

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

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 Leslie Cohen 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.

2.1.4. Procedure

Prior to the experiment, parents completed the MacArthur Communicative Development Inventory, a vocabulary checklist. This provided the measure of whether the infant did or did not known the word. 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 8 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 ("goll" – doll). 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.

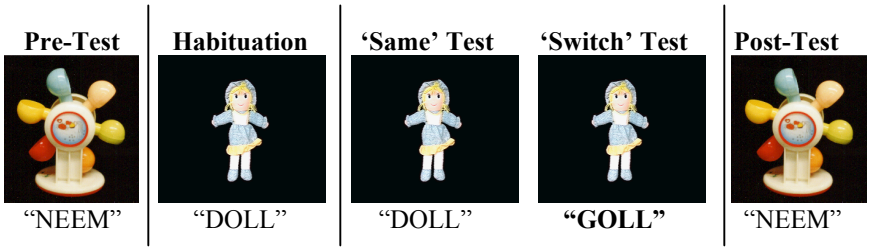
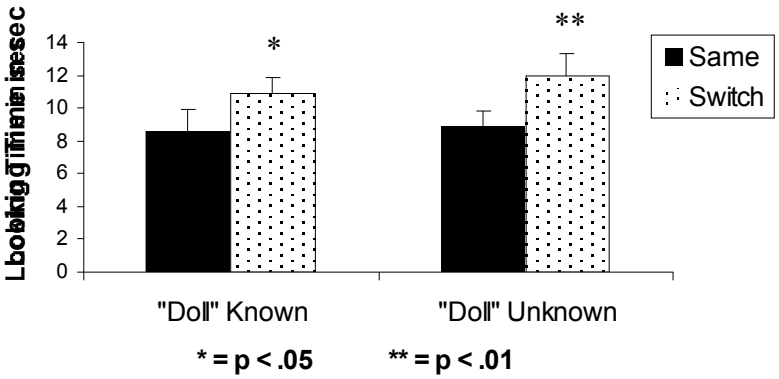


Figure 1: Experimental Procedure

We performed a frame-by-frame analysis of the infants' looking times. 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. Results

We ran a series of planned orthogonal comparisons using the pretest, posttest and last habituation block data. This analysis showed that the infants recovered to the posttest. Therefore, they maintained interest throughout the experiment. The main analysis involved testing infants' performance on the test trials according to their knowledge of the word form. A 2 (knowledge of "doll": yes or no) X 2 (test: 'same' and 'switch') mixed ANOVA showed a significant main effect for test with the infants looking longer to the 'switch' trial than to the 'same' trials [$F(1, 27) = 14.98$, $p = .001$; $Mean_{SWITCH} = 11.5$, $Mean_{SAME} = 8.7$]. There was no main effect for knowledge of "doll" and no interactions. Subsequent paired-sample t-tests demonstrated that both groups of infants looked significantly longer to the 'switch' trial. Thus, the infants successfully noticed the phonetic detail in the words, even if their parents reported that they did not yet know the word "doll".



4. Discussion

The success of infants who knew the target word supports the conclusion from the previous experiment that a priori word knowledge facilitates 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. This fits well with the resource limitation hypothesis. The infants who did not explicitly know "doll" would still have in all probability encountered the word form "doll" and/or doll objects previous 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 quicker acquisition of the word-object combination in the experiment, thus allowing that group of infants to access the 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 three less interesting possibilities for the above results. The first is that the parental report (MacArthur CDI) was not a fine enough measure of word knowledge and the infant in the familiar group actually knew the word, thus succeeding in the task. We doubt this is the case for two reasons: this measure is both reliable and valid (Fenson et al., 1993); and we confirmed infants' knowledge or lack of knowledge of the word post-testing. Nevertheless, we are currently running a training study that will control for object familiarity in order to more strictly test the familiarity explanation.

The second 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, Stager & Werker, under review; Swingley & Aslin, 2002). Therefore, this /d/-/g/ facilitation possibility is improbable.

The other 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 is easier for the infant. This is unlikely since the single object version has been used before to test 14-month-old infants' attention to phonetic detail (Pater, Stager & Werker, under review; Stager & Werker, 1997). In these studies, infants have repeatedly failed to attend to detail even in the one-object version when novel words and objects are used.

5. Conclusion

Using a strictly controlled laboratory procedure, we have demonstrated that familiarity with a word/object combination, without explicit knowledge of the word, allows novice word learners to access phonetic detail. The experiment presented in this paper adds to the limited literature on this topic and clarifies the tenability of two theories of phonetic perception in early word learning.

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