Infants of 14 Months Use Phonetic Detail in Novel Words Embedded in Naming Phrases

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1. Introduction

By the end of the first year of life, infants have both refined their speech perception skills and established an ability to quickly map words to objects. However, recent research has suggested that these abilities are not yet well-coordinated, and that infants fail to bring their full speech perception abilities to bear in the context of word learning. This paper seeks to address this apparent infant failure of coordination. We will demonstrate that 14-month-olds can in fact use fine phonetic detail in word learning.

1.2 Speech perception and word learning in infancy

Over the past four decades, researchers have shown that infants can discriminate phonetic categories, such as the difference between a [d] and a [b], (for a review, see Aslin, Jusczyk & Pisoni, 1998). By the twelfth month, infants have refined their discrimination, moving beyond universal phonetic categories (discriminating among both native and non-native phones) to establish native language categories (e.g., Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Werker & Tees, 1984; for a review, see Werker, 1995). This developmental pattern of phonetic fine-tuning affords infants a strong platform from which to learn novel words in rich detail.

At the same time, infants are also becoming more adept at mapping novel words to meaning. In striking parallel to phonetic perceptual development, infants' comprehension vocabulary begins to grow in earnest around the end of the first year (Feldman, et al., 2000; Fenson, et al., 1994). By 14 months, infants also begin to use grammatical form to assign meaning to new words, distinguishing novel nouns from adjectives and mapping the former specifically

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to objects and categories of objects (Booth & Waxman, 2003; Waxman, 1999; Waman & Booth, 2001).

Apparently, then, by 14 months, infants possess finely-calibrated phonetic sensitivities and keen word learning skills. However, there is also evidence that they fail to coordinate these abilities. Using the Switch habituation task, Stager and Werker (1997) examined 14-month-old infants' ability to map two distinct novel labels (i.e., "bih" and "dih") to two distinct novel objects. Despite their phonetic perception skills, the infants failed to notice when the labels associated with each object were switched at test. Stager and Werker reasoned that the task may have been too difficult; it is extremely uncommon for infants to learn two similar sounding words simultaneously. They tested another group of 14-month-olds in a simpler version of the task, in which infants were exposed to only one object-label combination (e.g., bin object called "bin") and were then were exposed at test to a switch in label (e.g., bin object called "din"). Surprisingly, infants still failed to notice the change. They did, however, succeed with two phonetically dissimilar novel words (e.g., "lif" and "neem") (Werker, Cohen, Lloyd, Casasola & Stager, 1998). They also successfully discriminated the relevant contrast ("b" versus "d") in a speech discrimination task (Stager & Werker, 1997). Therefore, infants' difficulty using this phonetic detail in the Switch task cannot be attributed to difficulties with either a) learning object-label associations in the task, or b) perceiving the relevant contrast. Nonetheless the effect is robust. Infants' difficulty using phonetic information persists even in the face of very dissimilar looking objects (Werker, Fennell, Corcoran & Stager, 2002) and across a variety of phonetic contrasts (Fennell, 2004; Pater, Stager & Werker, 2004; Werker, 2004).

1.3 Theoretical explanations

Two theoretical explanations have been offered to account for this phenomenon. Some have argued for a *representational discontinuity* in phonetic/phonological development. They hypothesize that, in word-learning tasks, infants abandon the precise perceptual representations that they refined in infancy because this permits them to build abstract phonological representations that can be applied generally. These abstract representations will later become refined as words are added to the lexicon (e.g., Barton, 1980; Brown & Matthews, 1997; Edwards, 1974; Ferguson & Farwell, 1975; Rice & Avery, 1995). On this view, because infants' early word forms do not contain specific phonological representations, phonetically similar words are easily confused.

In contrast, others have questioned why infants would refine their phonetic representations in the first year of life, yet fail to recruit them in early word-learning. These researchers have interpreted the results differently, as evidence of a *resource limitation*. On this view, infants *can* use phonetic detail in early word-learning, but are unable to demonstrate this ability in difficult tasks that tax infants' resources (Fennell & Werker, 2003, 2004; Stager & Werker, 1997; Werker & Fennell, 2004). Linking a label to an object requires many cognitive resources: infants must perceive and attend to the details of both the word and object; encode the relevant information; and then retrieve and maintain access to that information, while at the same time establishing a link between the visual and auditory information. Fennell and Werker (2003, 2004) argue that this strain limits the cognitive resources of novice word learners and they lose some information in the process (also see Casasola & Cohen, 2000; Cohen, 1998). Essentially, in a difficult task, something has to give; and, in this case, it is the fine phonetic detail.

If the *resource limitation* hypothesis is correct, infants should use phonetic detail in situations when the word-learning burden is alleviated. In accord with this prediction, in tasks involving familiar words, 14-month-olds successfully use the precise phonetic detail that they failed to use in novel words (Fennell & Werker, 2003; Swingley & Aslin, 2002). Findings like these challenge the *representational discontinuity* view, but are compatible with the *resource limitation* view. In the next section, we consider other key aspects that possibly tax infants' resources when mapping words to objects in the Switch procedure.

1.4 Task difficulty: The problem of isolated words

Recall that in the Switch procedure, the novel objects are paired with novel words that are presented repeatedly but in isolation (e.g., "Bin. Bin. Bin."). This made the design comparable to that in most speech perception work, in which speech stimuli are typically presented in isolation in order to simplify and control the stimuli. However, within the realm of word-learning, this may complicate infants' task, especially because words are not typically presented in isolation, and when they do occur alone, they are likely to be commands or exclamations ("Stop!" "Wow!") and unlikely to be referential or 'names for things'. Namy and Waxman (2000) documented that when novel words are presented in isolation, 17-month-old infants fail to map them to meaning. In their task, an experimenter presented an infant with a novel object in conjunction with a novel word. If the word was presented within a naming phrase (e.g., "Look at the blicket!"), infants successfully established a word-object mapping, and extended the word appropriately to other members of the same object category. In contrast, if the word was presented in isolation (e.g., Look! blicket!), infants failed to establish the mapping. Thus, when novel words were introduced in naming phrases, their referential status was apparent to infants; isolated words afforded no such referential cues.

Following this line of evidence, we propose that infants' difficulty establishing word-object mappings in the now-classic version of the Switch task is related, at least in part, to the manner in which the words were presented. We suggest that if the novel words are presented within naming phrase, their referential status would become clear, and that this clarity would alleviate the difficulty of the task. We therefore expect that infants will successfully use phonetic detail mapping novel words to their referents. On the other hand, it is also possible that infants' difficulty will persist. After all, presenting words in running speech may be computationally or perceptually more demanding than presenting words in isolation, because it requires infants to parse the relevant units (words) from the ongoing speech signal and to then compare phonetic detail. Thus, if infants succeed in using phonetic detail in this more crowded speech space, it is a powerful result.

The designs of Experiments 1 and 2 mirror those of the now-classic Switch task with one crucial exception: we presented the novel words within naming phrases rather than in isolation. Yet the procedural details, visual stimuli, the novel words and phonetic contrasts were identical to those in previous work (e.g., Stager & Werker, 1997; Werker et al. 2002). Therefore, any differences in the current tasks can be attributed to the introduction of the naming phrases.

2. Experiment 1

In Experiment 1, we used the simplest variant of the Switch task. Infants are habituated to one word-object pairing and are then tested on a "switch" in the label. Although 14-month-olds have consistently failed to use phonetic detail in this task (Fennell, 2004; Pater, Stager & Werker, 2005; Stager & Werker, 1997), we predicted that when the novel words are embedded within naming phrases, infants this age would successfully attend to phonetic detail and establish precise word-object mappings.

2.2 Methods

2.2.1. Participants

Sixteen infants (mean = 14.7 months, range = 13.5 – 15.5 months) from the greater Chicago area participated. All were exposed primarily to English (at least 80% exposure) and had no apparent or reported health problems. An additional 11 infants were excluded due to: restlessness (6), becoming upset (4), or parental interference (1).

2.2.2. Stimuli

The audio stimuli consisted of three novel CVC words presented in the context of seven different naming phrases, produced by an English-speaking female in infant-directed speech (IDS) and recorded in a soundproof booth. The naming phrases were: Look, it's the __. There's the __. Do you see the __? I like the __. Where is the __? Here's the __. Look at the __! Two of the novel words formed a minimal pair that differed only in the place of articulation of the initial consonant: "bin" and "din". The third word, "neem", was highly dissimilar from the other words and was used during the pre- and post-test trials. The final stimuli were created using the PRAAT computer program. The first author spliced the naming phrases from the neem stimuli before the determiner (e.g., "Look at | the neem."), copied the splices (e.g., "Look at"), and spliced the endings from the bin and din lists on to the copies. This resulted in sentences where the introductory parts of the naming phrases were identical, as indicated in italics: “*Look at* the neem!”; “*Look at* the bin!”; and “*Look at* the din!”. This was done to ensure that infants would not able to use any subtle sound differences in the naming phrases to succeed in discriminating the two target words. One exemplar of the novel word in isolation was placed before the first naming phrase so that the infant would hear the relevant contrasting phonetic information at the beginning of each trial. An isolated exemplar was also placed after the final naming phrase, resulting in a total of nine instances of the target word, similar to the ten novel words found in each trial of Werker et al. (2002).

One object was used for the habituation and test trials (see Figure 1a). The object was fashioned out of red, yellow, and blue clay. A store-bought, multicoloured toy water wheel (“spinner”) was used for both the pre- and post-tests (see Figure 1c). The objects were videotaped against a black background and then transferred to digital format. The clay object was taped moving back and forth across the screen at a slow and constant velocity. The “spinner” was filmed with the base remaining stationary while the wheel was moved around in a clockwise motion.

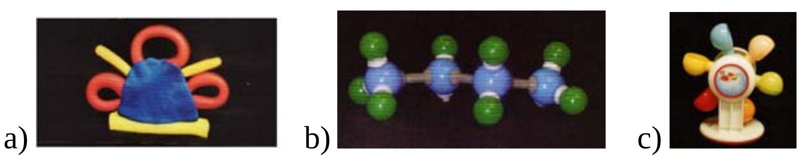

Figure 1: Visual stimuli for Experiments 1 and 2

2.2.3. Apparatus

The experiment took place in a 3.12 m by 3.89 m quiet room, which was dimly lit by a shaded 60W lamp situated 60 cm to the left and slightly behind the infant. The infant sat on the parent’s lap facing a projection screen that was approximately 1.93 m from the infant. The visual stimuli were projected onto the screen using an InFocus projector. The audio stimuli were delivered at 65 dB, +/- 5 dB, over two Altec Lansing speakers, located directly below the screen. The monitor was surrounded by black cloth, which stretched the width and height of the room. The infants were recorded using a Sony 8mm digital video camera connected directly to a Macintosh G7 laptop computer. The image from the camera was captured using the iMovie program. The lens of the video camera peeked out of a hole in the black cloth located 1.27 cm below the screen. As a masking control during testing, the parent wore Peltor headphones over which female vocal music was played from an Audiophase portable CD player.

The experiment was controlled by a version of the Habit program and run on a Macintosh G7 laptop. The visual and audio stimuli, played from digitized files on the computer, were synchronized and sent to the monitor and speaker. The experimenter monitored infants’ looking times via a closed circuit system from behind the projection screen and black cloth curtains. A designated key was pressed on the computer keyboard during infant looks, which the Habit program recorded. The video record was used for subsequent reliability coding.

2.2.4 Procedure

After the parent(s) arrived at Dr. Waxman's laboratory, the experimenter explained the procedure to them and gathered a signed consent form. The infant and one parent were then taken to the testing room and positioned for the experiment. The experimenter went to the observation area and began the procedure. Infants were assigned to one of four possible orders. These insured that order of test trial ("same"-"switch"/"switch"- same") and the novel word presented during habituation ("bin"/"din") were counterbalanced.

We used a modified habituation paradigm with a habituation criterion of 65% (like Stager & Werker, 1997), and each fixed trial was 20 seconds long (like Werker et al., 2002). Each trial began when the infant fixated on a dynamic stimulus (an oval shape that changed size and colour). On the first trial, infants heard a pre-test stimulus (the label "neem)" presented in naming phrases and paired with the spinner object. During habituation, infants were familiarized to one object-label pair (e.g., the clay object and "bin" presented in naming phrases). Looking time was calculated on-line; when the average looking time across a two-trial block decreased to 65%, the habituation phase ended. Infants participated in a minimum of four 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 (e.g., clay object – "bin"). The other trial, the 'switch' trial, presented the same visual object, paired with a (minimally) different word (e.g., "din") in naming phrases. Test trial order was counterbalanced across participants. If infants had learned the pairing, then they should detect the 'switch' and look longer on 'switch' than on 'same' trials. Finally, in a post-test trial, infants were again presented with the spinner-"neem" pairing. If infants were still involved in the task, their looking time should recover, approaching the pre-test level.

2.2.5 Coding

For key trials (i.e., pretest, posttest, two test trials), infants' looking times to the object were analyzed in a frame-by-frame (1 frame = 33.33 msec) analysis.

2.3 Results

A series of planned orthogonal comparisons confirmed that infants maintained interest throughout the experiment and recovered from habituation. There was no significant difference between the pretest ($M = 18.5$ s) and posttest ($M = 16.88$ s), and the pretest and posttest were significantly different from the last habituation block ($M = 9.01$ s) [$t(1, 46) = 9.670$, $p < .001$]. 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 [$F(1, 14) = 75.377$, $p < .001$; First Block = 15.83 s, Last Block = 9.01 s]. Thus, as expected, there was a significant drop in looking time across the habituation phase.

The main set of analyses addressed infants' performance at test. See Figure 2. A 2 (sex: female vs. male) X 2 (test trials: same vs. switch) mixed ANOVA revealed a significant main effect for test trials [$F (1, 14) = 5.216$, $p = .039$]. As predicted, infants looked reliably longer on switch ($M = 11.67$ s) than on same ($M = 9.46$ s) trials. There were no other main effects or interactions. Thus, when novel words are presented within the context of naming phrases, 14-month-old infants use fine phonetic detail in establishing word-object mappings.

2.4 Discussion

The results of Experiment 1 demonstrate that naming phrases clarified the referential context of novel words and allowed novice word learners to utilize their phonetic sensitivities when acquiring the label. This is consistent with the resource limitation position; the phonetic representations refined in infancy were recruited successfully in word-learning once the referential nature of the task became clear. Thus, there is continuity between the phonetic representations formed during the first year and those that are recruited in early word-learning.

3. Experiment 2

Based on the success of the infants in Experiment 1, we asked whether infants are able to use detail in the two object-label version of the Switch task when the words are presented in naming phrases. This is a more challenging task because learning two phonetically-similar words in a single testing session is quite demanding for novice word-learners, and rather rare in natural word-learning situations. Our question was whether the facilitative effect of naming phrases would help infants to overcome these difficulties, permitting them to use phonetic detail in the task.

3.1 Methods

3.1.2 Participants

Sixteen infants (mean = 15.1 months, range = 14.6 – 15.5 months) from the greater Chicago area participated. All had at least 80% exposure to English and had no apparent or reported health problems. An additional 13 infants were excluded due to: becoming upset (5), technical error (3), restlessness (2), parental interference (2), or were off-camera during the test trials (1).

3.1.2 Stimuli

The audio and visual stimuli were identical to those in Experiment 1. There was an additional object for this experiment: a molecule model from a chemistry set (see Figure 1b).

3.1.3 Apparatus

The apparatus was identical to Experiment 1.

3.1.4 Procedure

The procedure was identical to that of Experiment 1 with one exception: we included two, rather than one, object-word associations during habituation, which necessitated slight changes to the procedure. Only the changes will be highlighted in this section.

There were eight possible orders, which counterbalanced test trials ("same" before "switch"/"switch" before "same") and the type of switch between the test trials (switch in object/switch in word). During the habituation phase the infant was shown two object-label pairs, with the labels presented in naming phrases (e.g., Pair A: clay object paired with “bin”; Pair B: molecule object paired with “din”). The block size was increased to four trials so that every block would contain two instances of each word-object pairing presented in a random order (ABAB, ABBA, etc.). 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).

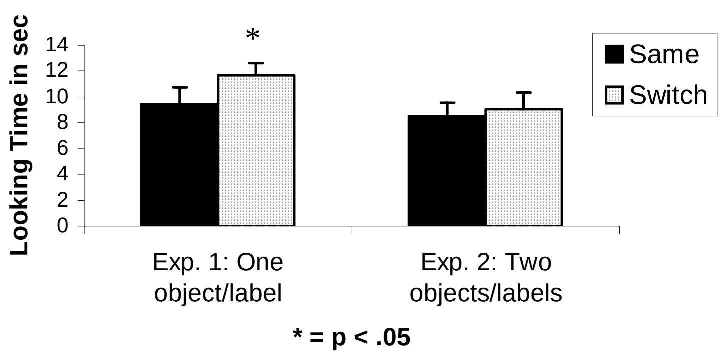

Figure 2: Results from Experiments 1 and 2

3.1.5 Coding

The coding was identical to Experiment 1.

3.2 Results

Planned orthogonal contrasts revealed that infants looked reliably longer during the pre-test (M = 19.0 s) than the post-test (M = 17.03 s), [$t(1, 30) = 2.058$, $p = .048$], suggesting that they became slightly fatigued over the course of the experiment. This is understandable, given the greater difficulty of the task. We next compared looking time on the last block of the habituation phase to the posttest. If the infants did not recover to the posttest, this would be quite problematic; as it would suggest that they had lost interest during the experiment and therefore did not attend to the large visual and audio changes. Fortunately, infants looked longer during the posttest (M = 17.03 s) than the last habituation block (M = 8.44 s), [$t(1, 30) = 8.55$, $p < .001$]. 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 no main effect for gender and no interaction [$F(1, 14) = 102.59$, $p < .001$; First Block = 15.41 s, Last Block = 8.44 s]. Thus, as expected, there was a significant drop in looking time across the habituation phase.

The main set of analyses addressed performance on the test trials. A 2 (sex: female vs. male) X 2 (test trials: same vs. switch) mixed ANOVA revealed no significant main effect for test trials [$F (1, 14) = .110$, $p = .745$; Switch = 9.05 s, Same = 8.53 s). There was no main effect for gender and no interaction. Thus, in contrast to the one object-label version of the task (Experiment 1), in this more demanding task, presenting the minimally contrastive novel words within naming phrases did not provide 14-month-olds sufficient support to establish the two unique object-word mappings (Figure 2).

4. General Discussion

The results of the two experiments presented in this paper demonstrate two important points. First, the success of the 14-month-old infants in Experiment 1 indicates that the use of naming phrases made the word learning situation clearly a referential act, inviting infants to make a mapping between word and object, and demonstrating the continuity between phonetic representations formed in the first year of life and those used in early word learning. Second, the loss of that facilitative effect in the more difficult two object-label task (Experiment 2) shows that task difficulty is the primary means by which infants' use of phonetic detail is masked, as predicted by the resource limitation hypothesis. These results, considered together, demonstrate the rich interplay between speech perception and word learning in the novice word learner.

The finding that naming phrases facilitate novice word learners' use of phonetic detail challenges the discontinuity proposition outlined in the introduction. In reminder, discontinuity theorists argue that infants have two representations: low-level perceptual representations refined in the first year and only used in basic perception; and more abstract phonemic representations for use of words. For the novice word learner, these latter representations are not yet fully specified. In essence, these theorists argue that the invocation of word learning leads to incomplete detail. Yet, the infants in the current study succeeded when the learning situation, through the use of naming phrases, was made to be *more* referential than the earlier work that used words in isolation. It is our argument that the invocation of word learning (i.e., a clear referential context) is what allowed for the use of phonetic detail; this is precisely the opposite of what discontinuity theorists would predict.

Support for our position would be strengthened if we could identify other cues that clarify the referential status of novel words and in so doing facilitate infants' use of fine phonetic detail. One such cue is object knowledge. Based on Macnamara's (1982) classic notion that knowledge of a concept or object drives the search for a label, Fennell (2004, in prep) investigated the effect of object knowledge on infants' use of phonetic detail. Two groups of 14-month-olds were tested in the one object-label version of the Switch task, with the label presented in isolation. However, before coming to the lab for testing, parents of the infants in the experimental group were given the toy object that would subsequently be used in the experiment proper, and were instructed to expose their infants to that object for approximately two hours per week for 6 to 8 weeks. Importantly, the toy object was *never* labelled during this training period, and the infants had no similar objects in their environment. The control group never saw the object prior to coming into the lab. So, the word presented in the Switch task was novel for both groups, but the experimental group had object knowledge that the control group lacked. The results from the control group mirrored previous studies that used isolated labels; the infants did not notice the 'switch' from the novel word to a minimal pair foil (e.g., switching from "din" to "gin"). However, the group of infants who knew the object did look longer when its name changed to a minimally different label, thus succeeding in using phonetic detail. The infants' in this group had been awaiting a label for the referent for two months, thus priming them for an object-label mapping for this particular object. These findings demonstrate that infants can even use phonetic detail in *isolated* words if there is sufficient referential context.

However, referential context is not the only factor influencing infants' use of phonetic detail. The 14-month-old infants' inability to notice the switch in labels in Experiment 2 supports the proposition, from the resource limitation hypothesis, that difficult tasks inhibit use of phonetic detail by placing heavy cognitive demands on the novice word learner. In its original form, this hypothesis stated that the act of word learning itself placed heavy cognitive demands on the novice word learner. The success of infants in Experiment 1, where novel words were placed in the clear referential context of naming phrases, showed that the cognitive demands did not arise from a general difficulty with word learning. Yet, the infants' ability to use phonetic detail was masked in the more complex two object-label task presented in Experiment 2, even though the infants had the benefit of naming phrases. Thus, based on the facilitation seen in Experiment 1 and the inhibition seen in Experiment 2, we reach the same general conclusion as the resource limitation hypothesis: infants' finely tuned phonetic representations *are* used in word learning and level of task difficulty influences their ability to use said representations.

5. Conclusions

When provided with sufficient referential cues, 14-month-old infants are able to use fine phonetic detail in mapping novel words to novel objects. This demonstrates that there is continuity between the phonetic representations refined over the first year and those recruited in early word-learning. It is only in the context of a difficult task that the novice word learner is unable to demonstrate her underlying ability to use detail. Importantly, it is not a general difficulty with word learning that prevents infants from using detail, as previously proposed. Instead, we suggest that the earlier work inadvertently made word learning difficult by presenting the target words in isolation, an impoverished referential context. However, as evidenced by the infants' failure in the more complex two object-label study, a heavy cognitive load prevents use of phonetic detail even when strong referential cues are provided. This outcome is consistent with the resource limitation hypothesis.

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