

Running Head: LEARNING PHONEME DISCRIMINATION AT THE

Learning Phoneme Discrimination at the End of Words in Typically Developing Infants

Meagan Yee

Carnegie Mellon University

Abstract

When children learn about minimal-pair phonemes (such as /d/ and /t/) is it specific to word position or does their knowledge of the phoneme generalize to all word-positions? Previous research has shown that 14-month old infants are able to be trained to use phonemic distinctions in the word-initial position. The set of experiments conducted in this study aim to see if 14-month old infants can be taught to use phonetic distinctions in word final-position using similar training used to help them use phonetic distinctions in word-initial position. The results indicate that similar training fails to help them discriminate between /d/ and /t/ at the end of words. However, preliminary results suggest that older infants can effectively learn to use this phonetic distinction word-finally when taught words that have /d/ and /t/ occurring word-finally. One implication from this study is that learning phonemes is specific and not abstract.

Learning Phoneme Discrimination at the End of Words in Typically Developing Infants

Languages are made up of meaningful sounds, called phonemes. These sounds are important because they are the basic units that make up words and indicate a difference in meaning. For example, in English, /r/ and /l/ are different phonemes because words like “rock” and “lock” have different meanings and refer to different objects. However, different languages use different phonemic distinctions: for example, in Japanese there is no meaningful difference between /r/ and /l/. At birth, infants can distinguish between more phonemic differences than adults. Interestingly, they can hear differences in their native language as well as in unfamiliar languages. Japanese babies are able to hear the English distinction between /r/ and /l/ even though there is no meaningful difference between the two sounds in Japanese. However, after their first year of life babies lose their ability to distinguish phonemes in unfamiliar languages and can only discriminate between phonemes that indicate a difference in meaning in their native language (Werker & Lalonde, 1988).

This ability to distinguish sounds in their native language plays an important role in object name learning. Infants have to learn that when two object names differ by only one phoneme, they’re referring to two different objects. Stager and Werker (1997) used a switch task to show that 14-month old infants are unable to associate two phonetically similar labels with two different objects. The switch task consists of the infant being shown two different object-label pairings. One object is called a “bih” and the other is called a “dih”. During the test trials the infants are shown the “bih” object, which is paired with the label “bih” half the time and the label “dih” half the time. The infants accept the object to be called by either label. However, when learning about two different objects called a “lif” and a “neem” infants don’t treat the two labels as interchangeable, demonstrating that they treat phonetically similar labels as being the

same. The nature of the sound doesn't seem to affect whether 14-month old infants use phonetic distinctions when learning the names of novel objects. They fail to discriminate between sounds that differ in place of articulation, such as bin vs. din, voicing contrast, such as bin vs. pin, or a combination of place articulation and voicing contrast, such as din vs. pin (Pater, Stager & Werker, 2004). 14-month old infants continue to fail to discriminate between minimal-pair words even when the objects have different physical shapes and different colors and when exposure time is increased (Werker, Fennell, Corcoran & Stager, 2002). Though the infants don't understand that there is a meaningful difference between two similar phonemes, Stager & Werker (1997) were able to show that 14-month olds could perceive the acoustic differences in the two phonetically similar labels by testing the infants on the same minimal-pair words, but instead of presenting the words with objects they presented them with a checkerboard background (Werker et al., 2002).

One theory behind the reason why 14-month old infants fail to use phonemic distinctions when performing an object-labeling task is that the infants don't have enough attentional resources to be able to attend to fine phonetic details. More attention is required during word learning because the infants have to be able to associate a sound with a specific object. With limited cognitive capacity, younger infants are unable to pay attention to fine phonetic detail while learning objects names. The reason that Werker et al. give for this difference in age group is that 14-month old infants use more of their attentional resources linking word forms to objects and therefore don't pay attention to fine phonetic details. It has been suggested that because 17-month old have larger vocabularies than 14-month olds they have more experience linking words with objects and therefore have more attentional resources available to notice differences in minimal-pair phonemes (Werker et al., 2002).

It has been shown that 15-month old infants can be trained to use phonemic differences when they learn about words that use similar phonemes in two distinct environments. In a study conducted by Thiessen (2006), 15- and 16-month old infants were exposed to three novel objects: a dawbow, a tawgoo, and a daw. The “dawbow” and “tawgoo” objects served as two distinct lexical contexts in which the phonemes /d/ and /t/ occur. During the test phase these infants were less likely to accept the “daw” object to be called a “taw”, thus showing that they can be trained to use phonemic contrasts during word-learning. The environments in which /d/ and /t/ occur must be distinct in order for infants to be trained. When learning about two novel objects called a “dawgoo” and a “tawgoo” the infants were unable to use the phonemic distinction between /d/ and /t/ and were more likely to accept the “daw” object to also be called a “taw”. This phenomenon that infants are able to distinguish between two similar phonemes by experiencing them in distinct lexical contexts can be explained the theory of acquired equivalence and distinctiveness.

According to the acquired equivalence theory, people can be trained to make distinctions between things based on different properties (Hall, Mitchell, Graham & Lavis, 2003). The idea behind this theory is that when two things that initially aren't very distinct are paired with two things that have very different properties, the initially similar things become more distinct from each other. When infants are learning about minimal pair phonemes, such as /d/ and /t/, associating them to different words helps make them more distinct from one another. One reason why infants who have larger vocabularies may have an easier time making these phonemic distinctions may be because they have more experience with and know more words in which these minimal-pair phonemes occur and this experience helps them make this distinction.

We know that infants can learn to use phonemic distinctions when the phonemes are at the beginning of a word, but we don't know if this knowledge can be used for phonemes at the end of a word. Some theories suggest that phonemes are abstract, so that when infants have learned to use a phoneme in one word position, they should know how to use it in all word positions. However, there has been little research done on phoneme discrimination at the end of words. One study, which focused on word-final phonotactics, was conducted by Zamuner (2006) and found that during syllable discrimination tasks, 10-month old infants showed no discrimination between phonemes that differed by voicing contrast or place of articulation in word-final position. However, by 16-months old infants were able to discriminate between similar phonemes that differed in place of articulation in word-final position, but not in voicing contrast in word-final position. These findings suggest that being able to detect phonemic distinctions in the word-final position is a harder task than detecting this distinction in the word-initial position. One explanation for this finding is that word onsets are more salient than word-final sounds and word onsets are produced with less variability and in a canonical form. Since it seems to be harder for infants to perceive phonemic differences in word-final position, but that by 16-months they are able to make this perception, it would be interesting to see if children learn to discriminate between phonemes during word-learning tasks regardless of their position within the word or if they have to learn to use discrimination for each position separately.

I'm interested in whether phonemes are abstract or specific. If phonemes are abstract we'd expect that learning would generalize to all positions in a word, whereas if they're specific children would have to learn them based on word position. My first research question is whether 14-month-old infants fail to discriminate between /d/ and /t/ when they occur word-finally as they do when /d/ and /t/ occur at the beginning of words. If 14-month-olds fail to discriminate

between /d/ and /t/ when they occur at the end of a word, then when they learn about an object called a “yat” they should also accept “yad” as a label. However, if they don’t make the same mistake – if they use the distinction between /d/ and /t/ when learning about words that differ in word-ending phonemes – then when 14-month-olds learn about a new object called a “yat,” they shouldn’t accept “yad” as a label for that object. I predict that 14-month-old infants will make the same mistake when words differ by word-ending phonemes as when words differ by word-initial phonemes. I expect the infants to accept the object as either a “yat” or a “yad,” suggesting that the position of the phoneme in the word doesn’t determine whether or not the infant uses phonemic distinctions when learning new words. However, if I find that the infants don’t make the same mistake then this demonstrates that they use phonemic distinctions differently depending on the position of the phoneme in the word.

If the infants don’t use the distinction between /d/ and /t/ when learning about a novel object called a “yat” and also accept “yad” as a label, then my second research question asks whether we can teach infants to begin to use the difference. One thing that helps infants between 14 and 17 months is learning that meaningfully different sounds (like /d/ and /t/) occur in different words. For example, /d/ occurs in “diaper” and “doggy”, while /t/ occurs in “tiger” and “teddy.” Previous research indicates that teaching infants about different words with /d/ and /t/ (like “dawbow” and “tawgoo”) helps 14-month-old infants use the difference between /d/ and /t/. This previous research has only examined the difference between /d/ and /t/ in word-initial position. My question is whether the training that helps infants use the distinction in word initial position also helps infants use the difference between /d/ and /t/ when those phonemes occur at the end of a word.

I predict that the training will help infants learn to use the distinction between /d/ and /t/ when learning about new words that only differ by their word-ending phonemes. This finding would demonstrate that learning about different words in which phonemes such as /d/ and /t/ are meaningfully different helps infants learn to use phonemic distinctions when learning new words that only differ by their word-ending phonemes. This would also suggest that this type of training helps infants regardless of what position in the word the phoneme occurs. These experiments are important because they will provide us with insight into whether infants' learning is very specific, and bound to particular contexts, or whether infants' learning is flexible, and infants are capable of generalizing rapidly to new contexts.

Experiment 1

The purpose of this experiment was to see whether 14- and 15-month old infants are able to use the phonetic distinction at the end of words during a word-learning task. We hypothesize that since children don't use phonetic distinctions in word-initial position during word-learning tasks, they won't use phonetic distinctions in word-final position during a word-learning task.

Method

Participants

Participants were 8 babies, from the Pittsburgh area, between the ages of 14 and 15 months ($M = 14.8$). In order to obtain data from 8 babies, it was necessary to test 10. The other two babies were excluded for crying.

Stimuli

This experiment was run on an Apple G5 PowerPC, using the computer program HabitX. The object labels "yad" and "yat" were created using the SoftVoice text-to-speech synthesizer. We used the female voice set to a monotone, with a pitch of 190 Hz. Each syllable had a duration

time of 500 ms, and was repeated with pauses of 1.4 s between syllables during habituation and test trials. The sounds, which were played from loudspeakers, were equivalently loud and reached the infants' ears at about 60 dB. Both labels were paired with the same object, a crown-shaped object that moved horizontally back and forth across the screen. A clip of Winnie-the-Pooh was used as the attention-getter between trials.

Procedure

Upon arrival at the lab, the parents were given a consent form to read and sign and were given a description of what would be happening during the study. The infants were with at least one parent during the entire experiment. Each parent and child was taken to the sound proof testing room, where a computer monitor, speakers, and video camera are connected to the main computer in the control room. The parents were given instructions to keep their child seated on their lap and to refrain from any interaction with the child while the study was being conducted. The parents were also given a set of headphones to wear that played classical music while the experiment was being conducted. This part of the procedure is to ensure that the parents have minimal influence of what the baby does during the study. The experimenter controlled the experiment from the adjacent control room, coding the baby's looking time through a video camera connected to the testing room.

During the habituation phase, the infants were shown the crown-shaped object paired with the label "yad". When the infant looked away from the screen for more than 2 seconds the attention-getter started playing. Once the infants reached the habituation criterion, which was set to a looking time less than 50% of the average of the first three trials, the test trials began. Three of the test trials consisted of the same object-label pairing as the habituation phase and three of the test trials showed the same crown-shaped object paired but with the label "yat". The stimulus

was presented until the infant looked away for more than 1 s or until the infant had looked at the monitor for 20 s (the maximum time allowed per trial). The order of the test trials was randomized before the experiment began so that the coder was blinded to the conditions. After each stimulus presentation the attention-getter was played before moving on to the next test trial. Looking times for each test trial was measured and recorded on the computer

At the end of the experiment session the parent and child were debriefed, in which the experimenter explained the question that the study is aiming to answer and the hypotheses that have been made. They were then offered either a book or a t-shirt as a thank-you gift for participating in the study.

Results and Discussion

We calculated each infant's mean looking time to both Same and Switch trials. Four out of the eight infants had longer average listening times for the Switch trials. Across all subjects the average listening time was 5.4 s ($SE = 1.1$) for the Switch trials and 4.5 s ($SE = 0.6$) for the Same trials. A paired t-test indicated that this difference in average listening times were not significant: $t(7) = 0.954$, $p = 0.372$. This finding is consistent with my hypothesis that infants at 14- and 15-months old are unable to use phonetic distinctions in word-final position during a word-learning task.

Experiment 2

Thiessen (2007) showed that 15- and 16-month old infants can be taught to use the phonetic distinction between /d/ and /t/ at the beginning of words by exposing them to words that provide distributional information it would be interesting because if learning is abstract then the training should work for discriminating between the two phonemes in any word position. Experiment 1 showed that 14- and 15-month old infants aren't using the phonetic distinction

between /d/ and /t/ when they're in the word-final position. So the purpose of this experiment is to see if similar training with words where /d/ and /t/ are in two completely different environments will help infants use the phonetic distinction between /d/ and /t/ at the end of words.

Method

Participants

Participants were 8 more babies, from the Pittsburgh area, between the ages of 14- and 15-months of age ($M = 14.7$). In order to obtain data from 8 babies, it was necessary to test 15. Five of the babies were excluded for crying, 1 was excluded for being premature, and 1 was excluded because of a computer problem during the experiment.

Stimuli

This experiment used four object labels that were created using synthesized speech: “yad”, “yat”, “dawbow”, and “tawgoo”. Yad was paired with the crown-shaped object, dawbow was paired with an object with spinning spoons, and tawgoo was paired with a molecule. The crown-shaped object and the molecule moved back and forth across the screen, while the object with the spinning spoons was stationary in the middle of the screen. The Winnie-the-Pooh clip was used as the attention-getter between trials.

Procedure

The procedure for this experiment was similar to the one used for Experiment 1, except that during the habituation phase the infants were shown three different object-label pairings instead of only one. The habituation trials were randomized so that the infants saw the three different object-label pairings in a random order that the experimenter was blind to. During the test trials, the infants saw the crown-shaped object paired with “yad” for the three of the trials

and the crown-shaped object paired with “yat” for the other three trials. The order of the test trials was also randomized.

Results and Discussion

We calculated each infant’s mean looking time to both Same and Switch trials. Five out of the 8 infants had longer average looking times for the Same trials. Across all subjects the average looking time for the Switch trials was 5.5 s ($SE = 0.99$) and for the Same trials was 6.8 s ($SE = 0.81$). A paired t-test indicated that this difference was not significant: $t(7) = -1.196$, $p = 0.271$. This finding suggests that the type of exposure to words that have /d/ and /t/ in them, which helps infants learn to use the phonetic distinction between the two phonemes when they appear in word-initial position doesn’t help them learn to use the distinction between the two phonemes when they appear in word-final position. This suggests that learning about phonemes in one position of a word doesn’t generalize to all positions in a word.

Experiment 3

Work done by Stager and Werker (1997) suggests that when a word-learning task is too difficult for infants they fail to discriminate between two syllables, even though they can hear the difference between them. The purpose of this study was to verify that the infants perceive the sound differences between /d/ and /t/ when they’re in the word-final position. Instead of pairing “yad” with an object, we played “yad” while showing the infants a black and white checkerboard. By showing the infants a black and white checkerboard instead of pairing the labels with objects we change the task from a word-learning task to a speech-perception task. The speech perception task is less taxing on the child because it doesn’t require associating a word with an object and allows the child to pay attention to fine phonetic differences. We expect that the infants will be able to detect the difference in /d/ and /t/.

Method

Participants

Participants for this study were 6 babies, from the Pittsburgh area, between the ages of 14- and 15-months ($M = 14.5$). In order to obtain data from 6 babies we tested 9. The first infant to participate in this experiment was excluded for piloting reason. The other two babies were excluded because they were born more than 3 weeks before their due date.

Stimuli

For this experiment we used synthesized versions of “yad” and “yat”, which were played while a black and white checkerboard was shown on the computer monitor. The clip of Winnie-the-Pooh was used as the attention-getter between trials.

Procedure

Half of the infants were habituated to “yad” and the other half were habituated to “yat”. This was done to eliminate the possibility that the infants are showing an object preference. During the habituation trials the words were played while a black and white checkerboard was shown on the computer screen. There were 6 test trials, where infants heard “yad” for the 3 trials and “yat” for the 3 trials. The order of when they heard “yad” or “yat” was randomized.

Results and Discussion

We calculated each infant’s mean looking time to both Same and Switch trials. Five out of the 6 babies showed a longer looking time during the Same trials. Across all subjects the average looking time for Switch trials was 2.4 s ($SE = 0.21$) and the average looking time for Same trials was 3.7 s ($SE = 0.58$). A paired t-test indicated that this difference in looking time is significant: $t(5) = -2.736$, $p = 0.041$. These results indicate that the infants are able to hear the

difference between /d/ and /t/ when they're in the word-final position, they're just not using this distinction during word-learning tasks.

This finding that infants prefer the Same trials to the Switch trials is unusual because we expect them to have a novelty preference after being habituated to a stimulus. We expected that the infants who were habituated to “yad” would prefer to listen to “yat” during the test trials and that infants who were habituated to “yat” would prefer to listen to “yad” during the test trials. However, we found that the infants preferred to listen to the sound that they were habituated to. Though this is an unusual finding, we are able to confidently conclude from it that since infants are showing a preference to one sound, they are able to hear the difference between /d/ and /t/ when they come at the end of words.

Experiment 4

In Experiment 2 we showed that exposing infants to “dawbow” and “tawgoo” don't help them learn to use the phonetic distinction between /d/ and /t/ at the end of words. This may indicate that when infants learn phonemic distinctions they need to learn them separately for different positions within words. Since “dawbow” and “tawgoo” begin with /d/ and /t/, respectively, they might not have been effective when infants are learning about words that differ by only word-final positioned phonemes. The purpose of this study is to see if exposing infants to words that provide distributional information about the occurrence of /d/ and /t/ in word-final position, rather than word-initial position, will help them learn to use the phonetic distinction between the two phonemes when they occur in the word-final position.

Method

Participants

Participants were 13 more babies, from the Pittsburgh area, between the ages of 14- and 15-months of age ($M = 14.3$). In order to obtain data from 13 babies, it was necessary to test 18. Three of the babies were excluded for crying, 1 was excluded for not habituating, and 1 was excluded because of parent interference.

Stimuli

For this experiment we used four different object names using natural speech. The four different labels were “yad”, “yat”, “boeyad”, and “gooyat”. We used natural speech because it yielded better sound quality for “boeyad” and “gooyat” than synthesized speech. “Yad” was paired with the crown-shaped object, “boeyad” was paired with the object with the spinning spoons, and “gooyat” was paired with the molecule. The crown-shaped object and the molecule moved back and forth across the screen, while the object with the spinning spoons was stationary in the middle of the screen.

Procedure

The procedure for this experiment was identical to the procedure for Experiment 2. However, instead of using “dawbow” and “tawgoo” during the habituation phase, we used “boeyad” and “gooyat”.

Results and Discussion

We calculated each infant’s mean looking time to both Same and Switch trials. Six of the 13 infants had longer average looking times for the Switch trials. Across all subjects, the average looking time for the Switch trials was 5.4 s (SE = 0.99) and for the Same trials the average looking time was 5.2 s (SE = 0.65). A paired t-test indicated that this difference in looking time was not significant: $t(12) = 0.150$, $p = 0.884$. These results suggest that even when exposed to

different words that end in /d/ and /t/ infants don't learn to use the phonetic distinction between the two phonemes in word-final position.

Work done by Werker et al. (2002), suggests that older infants are able to use phonetic distinctions during word-learning tasks. As such, older infants might be more susceptible to training. Similarly, Zamuner (2006) suggests that only older infants are sensitive to word-final phonetic differences. So we ran an exploratory analysis, focusing only on infants in our sample over 15 months of age. When looking at data from the babies who are 15-months or older ($n = 5$), we see that their average looking time for the Switch trial is 5.3 s ($SE = 1.6$) and for the Same trial their average looking time is 3.7 s ($SE = 1.5$). A paired t-test indicates that this difference in looking time is not significant: $t(4) = 0.773$, $p = 0.483$. More research is needed, but this preliminary finding is consistent with the hypothesis that by 15-months infants may be able to learn to use the phonetic distinction between /d/ and /t/ in word-final position after learning about different words that end in /d/ and /t/ because they appear to be looking longer at the Switch trials.

General Discussion

In this study I was interested in seeing if children's knowledge about phonemes is abstract or specific. I hypothesized that learning would be specific and that training children would help them learn to use phonemic distinctions. The results from these experiments demonstrate that learning about phonemes isn't abstract, but is specific depends on the position of the phoneme in the word. Learning phonemic distinctions doesn't generalize to different environments. We found in Experiment 2 that training infants to use phonemic distinctions in word-final position with words that effectively train them to use the same phonemic distinction in word-initial position isn't helpful. The implications from these results are that not only do

children fail to use phonemic distinctions at the end of words, even though they use the same distinctions as the beginning of words, but that learning to use these distinctions at the end of words requires a different type of training.

My next hypothesis was that training children with words that use /d/ and /t/ in word-final position would help them learn to use this distinction more successfully than using words that use /d/ and /t/ in word-initial position. My results showed that younger infants still failed to use the distinction after training, but the results from 15-month old infants suggest that this type of training is effective for older infants. One implication from this finding is that around the age of 15-months children are beginning to be able to learn to use phonemic distinctions in word-final position. However, more research on older infants is necessary to strengthen the conclusion that infants need specific training in order to learn phonemic distinctions in different word positions. Preliminary results from 21-month old infants, who were habituated to “yad” and then tested on the object being called a “yad” or a “yat”, demonstrate that by 21-months children are able to easily use phonemic distinctions in word-final position. More research on this age group is needed to support this finding. Overall, the results I found suggest that the learning mechanism used to distinguish minimal-pair phonemes is specific to the position of the phoneme within the word and that children must learn phonemic distinctions one position at a time.

References

- Hall, G., Mitchell, C., Graham, S., & Lavis, Y. (2003). Acquired equivalence and distinctiveness in human discrimination learning: evidence for associate mediation. *Journal of Experimental Psychology: General*, *132*, 266-276.
- Pater, J., Stager, C., & Werker, J. (2004). The perceptual acquisition of phonological contrasts. *Language*, *80*, 384-402.
- Stager, C. L., & Werker, J. F. (1997). Infants listen for more phonetic detail in speech than in word-learning tasks. *Nature*, *388*, 381-382.
- Thiessen, E. D. (2006). The effect of distributional information on children's use of phonemic contrasts. *Journal of Memory and Language*.
- Werker, J. F., & Curtin, S. (2005). PRIMIR: a developmental framework of infant speech processing. *Language Learning and Development*, *1*, 197-234.
- Werker, J. F., Fennell, C. T., Corcoran, K. M., & Stager, C. L. (2002). Infants' ability to learn phonetically similar words: effects of age and vocabulary size. *Infancy*, *3*, 1-30.
- Werker, J. F., & Lalonde, C. E. (1998). Cross-language speech perception: initial capabilities and developmental change. *Developmental Psychology*, *24*, 672-683.
- Zamuner, T. S. (2006). Sensitivity to word-final phonotactics in 9- to 16-month old infants. *Infancy*, *10*, 77-95.

Acknowledgement

This project was funded by Carnegie Mellon's Undergraduate Research Office. These results represent the views of the author and not those of Carnegie Mellon University.