DOES VARIABILITY IMPACT INFANTS' SOUND DISCRIMINATION?

By

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A Thesis Submitted to The Honors College

In Partial Fulfillment of the Bachelors degree
With Honors in

Linguistics

THE UNIVERSITY OF ARIZONA

MAY 2015

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Abstract

In the first 12 months of life, infants develop a robust knowledge of the acoustic dimensions in their phonetic inventory (Booth & Waxman, 2002; Kuhl, 2006; Yeung & Werker, 2009). The *associative model* (Apfelbaum & McMurray, 2011) predicts that infants may utilize perceptual cues such as talker variability to help discriminate between sounds. This variability may help infants establish acoustic boundaries of sounds, particularly if those sounds are acoustically similar. We find that 7.5 month old infants accurately discriminate between /p/ and /b/ in syllable onset position regardless of the presence of talker variability. We hypothesize that because /p/ and /b/ occur frequently in syllable onset position, infants may already have robust categorizations of the two sounds. We then examine whether talker variability is useful in discriminating between two more acoustically similar sounds, /n/ and /ŋ/. The sound /ŋ/ does not occur in syllable onset position in English; therefore, infants will likely have less robust acoustic boundaries for /ŋ/ and may have a harder time distinguishing /ŋ/ from /n/. We predict that 7.5 month old infants familiarized in a Multiple Talker condition will more accurately discriminate between /n/ and /ŋ/ than infants in a Single Talker condition.

Introduction

Language development follows a relatively consistent trajectory throughout the first few years of life. Around roughly 9 months of age, infants begin discriminating between native and non-native language sounds, developing a phonetic inventory for their native language. At the same time, infants weaken their ability to discriminate irrelevant non-native contrasts. In our study, we will examine the ability of 7.5 month old infants to discriminate both a native sound contrast (/b/ v. /p/) and non-native sound contrast (/ŋ/ v. /n/) in syllable onset position. The following introductory sections will offer a brief timeline of infant language development. In addition, we will address how talker variability may affect infants' performance on sound discrimination and word learning tasks.

What is the difference between word learning and sound discrimination?

Infants must first learn to discriminate between phonologically relevant sounds in their native language(s) before they can begin the process of word learning. Before infants become adept at sound discrimination tasks, the process of perceptual narrowing occurs around six months of age (Kuhl, 2006). This narrowing of perceptual categories is a pan-sensory developmental process, meaning that the process utilizes speech and auditory stimuli, as well as many other forms of sensory input. By 12 months of age, infants demonstrate noticeable changes in their speech perception abilities (Kuhl, 2006). By this age, there is a rise in infants' performance on native sound discrimination and a decline in performance on non-native sound discrimination as infants begin to learn how the sounds in their native phonetic inventories are categorized. Research in cognitive development has suggested that infants between the ages of 6 and 12 months can draw parallels between speech sounds and conceptual knowledge before they can learn the specific names for objects, suggesting that non-informative perceptual cues may be useful to younger infants (Booth & Waxman, 2002). In their study, researchers contrasted the performance of younger and older infants by testing 14 and 18 month old infants on a word learning task. In the experiment, the infants were given novel category exemplars in one of three conditions with a function, a name, or no cues. Both age groups were more likely to better select category matches with a function than with no cues. However, object names only helped 18 month olds, suggesting that younger infants still rely on other perceptual cues when learning words.

Infants develop a rather robust knowledge of phonologically relevant dimensions in the first year of life and can fairly easily contrast speech sounds and words of their native language (s) (Booth & Waxman, 2002; Kuhl, 2006; Yeung & Werker, 2009). The Switch habituation paradigm (Stager & Werker, 1997) can help demonstrate whether learning is occurring. In the habituation training, infants are familiarized with a set of sound tokens. These sound tokens may be consistently paired with a distinct visual object. During the test phase of an experiment, infants hear a combination of Same trials (in which the infant was exposed to the same auditory stimuli as the familiarization phase) and Switch trials (in which the infant either was exposed to auditory stimuli that differed from that in the familiarization phase or the pairing of the auditory stimuli and visual objects are switched from the familiarization phase) and looking times are compared for each. 14 month old infants show difficulty discriminating between novel, similar sounding words (such as /bih/ and /dih/) in the Switch habituation paradigm even though the infants can distinguish between the individual sounds (/b/ and /d/, Stager & Werker, 1997; Werker, Fennell, Corcoran, & Stager, 2002). There are several theories regarding why infants have difficulty in some aspects of word learning and sound discrimination. The *associative model* (Apfelbaum & McMurray, 2011) states that infants may view word forms as largely uni-dimensionalized acoustic input, therefore they are unaware of which dimensions they should paying attention to. The associative model would predict that infants would use perceptual cues like talker variability to discriminate between sounds and facilitate learning. In our study, the associative model would predict that talker variability will aid in sound discrimination for 7.5 month old infants. We will examine this hypothesis further in the coming sections.

How does talker variability aid in word learning and sound discrimination?

Infants in the early word learning stages often have difficulty discriminating between minimal pairs due to a tendency to overgeneralize the dimensions of phonetic categories, meaning that infants may not view two acoustically similar sounds as separate phonemes (Rost & McMurray, 2009). As infants age, their ability to distinguish these minimal pairs increases as they become more familiar with the phonology of their native language(s). Research by Rost and McMurray (2009) has suggested that increased talker variability may aid in word learning and sound discrimination for infants. In Experiment 1 of the study, infants were exposed to single talker tokens of lexical neighbor stimuli paired randomly between subjects with one of two visual objects. During the test phase, looking times for Same trials and Switch trials were compared. Learning was based on increased looking times in the Switch v. Same trials during the test phase. Infants in Experiment 1 showed no significant difference in looking times, therefore no learning was determined. In Experiment 2, a variety of talkers and speech registers were used to create the sound tokens for the habituation phase. They hypothesized that increased variability would aid the infants in creating more reliable and robust dimensions. Infants familiarized in the multiple exemplar condition appeared to learn two novel words, suggesting that the increase in variability increased learning.

Studies supporting the associative model of learning (Stager & Werker, 1997; Apfelbaum & McMurray, 2011) suggest that variations on irrelevant dimensions of training stimuli may increase learning for older infants. According to Apfelbaum and McMurray (2011), at 14 months of age, infants are still developing their phonological categories. Therefore, noninformative cues, such as talker variability, may aid in overall word learning. These noninformative cues may allow infants to develop a more robust categorization of sounds and word forms by providing a wider depth of acoustic boundaries, which infants can then use to develop phonetic categories. Our study will aim to explore the possible benefits of talker variability on sound discrimination tasks.

Does the benefit of talker variability increase with the difficulty of the sound discrimination task?

It is commonly understood that some sound contrasts are easier than others. Two sounds that vary greatly in place, manner, and voicing will be easier to discriminate than two sounds that vary on only one of those categories. In particular, the contrast between /ŋ/ and /n/ in syllable-onset position is difficult even for native-Filipino speakers for whom that contrast exists in their native language. A study by Narayan (2008) examined English and Filipino speakers ability to discriminate between sounds in two different pairings: /m/-/n/ and /ŋ/-/n/. Narayan studied whether English-speaking adults demonstrated poor perception of the non-native contrast /n/-/ŋ/ because their native phonology does not contrast those two sounds in syllable-onset position (p. 201). While the phoneme /ŋ/ is grammatical in syllable onset position in Filipino, the phoneme does not exist in this position in English, making it a presumably more difficult task for native English speakers. There were two participant groups included in the study, native Filipino speakers and English speakers. Both groups were given two tasks: discriminating /m/-/n/ sound contrast and /ŋ/-/n/ sound contrast. English speakers performed as expected, accurately perceiving the [ma]-[na] contrast at an average rate of 98.8% accuracy. On the non-native [ŋa]-[na] contrast, English speakers performed slightly below chance with an average of 45.9% accuracy and much larger variances. Filipino speakers accurately perceived [ma]-[na] contrast at an average rate of 98.8% and [ŋa]-[na] contrast at 90.8%. Interestingly, while the Filipino speakers' discrimination of [ŋa]-[na] contrast was more accurate, the overall pattern of responses showed that Filipino listeners performed significantly poorer on the [ŋa]-[na] contrast than the [ma]-[na] contrast, likely due to the acoustic similarities between /ŋ/ and /na/.

Werker and Tees (1984) conducted a study measuring native English-learning infants' perceptual awareness of a Hindi phonetic contrast ([d̪a] v. [ɖa]) and found that infant performance declined from 6-8 to 10-12 months of age. At 9 months of age, infants are developing the phonemic categories of their native language. Branching off of Werker and Tees' (1984) research, Yeung and Werker (2009) decided to test the aforementioned Hindi contrast on 9 month old infants to see whether infants' current perceptual reorganization would affect their discrimination performance. They found that infants did not discriminate the non-native Hindi dental-retroflex consonant unless distinct visual objects were paired consistently with tokens from each phonetic category. Their findings suggested a functional mechanism of phonetic reorganization in which categorical cues were used to aid perceptual learning.

Stemming from Narayan (2008) and Yeung and Werker (2009)'s previous research, a new study was conducted testing infants' ability to discriminate the aforementioned [ma]-[na] and [ŋa]-[na] contrast (Narayan, Werker, & Beddor, 2010). In Experiment 1, English-learning infants aged 6-8 months and 10-12 months were tested on their ability to discriminate the native [ma]–[na] distinction. As expected, infants demonstrated longer looking times during switch trials, indicating discrimination between the sounds. In Experiment 2, researchers tested infants' abilities to discriminate the less acoustically salient [ŋa]-[na] contrast. They hypothesized that the older infants (10-12 months), due to decrease in ability over time to discriminate non-native sounds, would not discriminate the contrast, while the younger infants (6-8 months) would. Both age groups failed to discriminate the contrast, suggesting that the sounds' acoustic similarities may have led to less accurate discrimination than the more acoustically robust [ma]-[na] contrast.

English does not allow for /ŋ/ in syllable-onset position, and overall, /ŋ/ is rarely allowed in syllable-onset position in any languages, making it a rarely used and difficult contrast for all language-speakers. As suggested in the research above (Rost & McMurray, 2009; Apfelbaum & McMurray, 2011), talker variability may increase the rate of learning during sound discrimination and word learning tasks. Because infants at 14 months are still developing phonological categories, perceptual cues like talker variability may help infants establish acoustic dimensions of different sound tokens. Exemplars from multiple talkers offer a broader range of the phonemic category of a particular sound, helping infants establish the boundaries of a particular phoneme. However, if the sound contrast is more acoustically robust, we hypothesize that infants are less likely to utilize noninformative cues because the acoustic dimensions are already well formed. Because of this hypothesis, talker variability may be increasingly beneficial in relation to the acoustic salience of the sound contrast.

Present Study

Past studies have examined the possible ways that talker variability can impact infants' performance on sound discrimination and word learning tasks (Rost & McMurray, 2009; Afpelbaum & McMurray, 2010; Rost & McMurray, 2010). Our research aims to further explore whether talker variability can lead to an increase in infant performance during sound discrimination in a non-native context. In Experiment 1 of our study, we test English-learning infants on their ability to discriminate between frequently used phonemes /p/ and /b/. Because /p/ v. /b/ is an acoustically robust sound contrast, we hypothesize that infants in both the Multiple Talker and Single Talker condition will accurately discriminate the two sounds. In Experiment 2, we test infants on their ability to discriminate between the phonemes /n/ and /ŋ/. We believe this sound contrast may be more difficult for infants because of the high acoustic similarities between the sounds; therefore, we hypothesize that talker variability will play a larger role in aiding in sound discrimination. We hypothesize that infants who are exposed to multiple talkers in the habituation phase of the experiment will show stronger discrimination, as evidenced by longer looking times in Switch v. Same test trials, than infants exposed to a single talker. In the Single Talker condition, we predict little or no difference in looking times between Switch and Same test trials.

In Experiment 1, we look at native-English speaking infants' ability to discriminate a native sound contrast (/b/ v. /p/). We created two conditions: Multiple Talker and Single Talker. In the Multiple Talker condition, infants are familiarized with multiple talker tokens of either /bɪm/ or /pɪm/. In the Single Talker condition, infants are familiarized with different tokens of either /bɪm/ or /pɪm/ from a single talker. In the test phase, infants in both groups hear two trials each of the word they were familiarized with and the novel contrast for a total of four trials. The last trial is a novel, unrelated word intended to dishabituate the infant. If the infant was attentive during the habituation trials, then it is predicted that the infant will show interest in the novel stimuli. All five test trials are spoken by a novel single talker to minimize any possible effect caused by using a familiar talker. If we had used the talker from the Single Talker condition, the test trials would have been more similar to the Single Talker habituation stimuli than the Multiple Talker habituation stimuli, which could have altered overall looking times due to a familiarity effect.

Upon completion of Experiment 1, we find that infants perform well on the task of discriminating between /p/ and /b/. However, there is not a significant interaction between Multiple v. Single Talker conditions. Infants in our study may have already developed a robust categorization of /p/ and /b/, possibly decreasing the necessity for infants to rely on other perceptual cues, such as talker variability, to discriminate between the sounds. In Experiment 2, we decided to examine another sound contrast with a higher level of difficulty than that of Experiment 1 to determine if talker variability would have a larger impact on discrimination performance. Branching off from Narayan, Werker, & Beddor's (2010) research, we look at native-English speaking infants' ability to discriminate between /ŋ/ and /n/ in syllable-onset position. Using the same Switch habituation paradigm of Experiment 1, infants are placed into either Multiple Talker or Single Talker condition. The only difference between Experiment 1 and Experiment 2 are the sound tokens used in the habituation and test trials.

Experiment 1

Methods

Participants

33 children (17 boys, 16 girls) between the ages of 7 and 8 months were included in the data analysis of this experiment. 12 participants were excluded from data analysis due to fussiness or failure to habituate (7), significant foreign-language exposure(1), or looking times above or below 2 standard deviations from the mean (computed across both conditions; 4).

Auditory and Visual Stimuli

Both Experiment 1 and Experiment 2 involved a sound discrimination task, and the individual sound targets were embedded into the beginnings of novel one syllable words. In Experiment 1, the infants were tested on their ability to distinguish between the sounds /p/ and /b/, embedded in the words "bim" and "pim." A total of 16 different sound tokens were used for the habituation trials. Each infant heard a total of 8 different sound tokens.

For the habituation stimuli, /bɪm/ and /pɪm/ were recorded by 5 female speakers in an infant directed register. We selected 5 female talkers from a previous set of 13 (Quam, Knight, & Gerken, under revision). We first selected the test talker, and then selected the other 4 talkers to be as evenly distributed as possible around the mean pitch of the test talker (see Table 1). For the Single Talker condition, the same test talker was used, but a single, different talker was used during habituation. This was the talker from the set of 4 (from the Multiple Talker habituation) who had the closest mean pitch to the test talker. The auditory stimulus was a red and black checkerboard in all trials (see Figure 1).

	Talker	Pitch Mean (Hz)	Pitch Max (Hz)	SD of Pitch Samples (Hz)	F1 (Hz)	F2 (Hz)
Single Talker Training (Exp. 1)	1	249.51787	34.088626	304.961483	703.661502	2111.521312
	2	245.16721	33.959844	293.336419	621.841498	2108.798571
	3	262.11317	37.877802	313.868551	927.957439	2193.672001
	4	237.30065	24.537765	271.67309	713.233129	2184.857026
	5	240.6518	31.562389	296.117384	650.838873	2124.375547
	6	251.57691	37.24317	303.939877	640.140261	2178.460949
	7	277.23694	50.969443	348.014344	648.896988	2014.774649
	8	239.74859	33.004217	290.582066	620.237396	2012.598104
Multi Talker Training (Exp. 1)	1	277.23757	71.346457	369.822461	789.95326	2033.681045
	2	291.95279	72.566458	396.16685	731.417307	2044.646884
	3	192.05326	13.260001	221.690271	1013.55571	2248.513118
	4	283.68077	94.008717	410.208587	1029.19279	2301.4705
	5	207.79702	18.335346	239.037695	964.446987	2151.958273
	6	250.13066	60.358534	348.236542	1076.84454	2206.180083

	7	249.51787	34.088626	304.961483	703.661502	2111.521312
	8	245.16721	33.959844	293.336419	621.841498	2108.798571
Test (Exp. 1)	1	222.36657	17.663447	247.840451	871.412378	2177.634428
	2	205.62769	24.801567	240.576559	783.944156	2168.009892
	3	212.08375	33.711695	262.76429	475.178432	2022.929767
	4	214.45756	29.171782	254.808145	781.422963	2143.155125
	5	210.85672	27.230089	267.170775	724.570924	2103.490361
	6	217.88236	36.292876	271.843483	667.803336	2112.702428
	7	211.67836	29.85816	269.305195	584.69154	2112.866954
	8	216.72382	41.200648	286.520062	894.146731	2130.360894
Single Talker Training (Exp. 2)	1	207.13367	34.258234	264.644274	456.766159	1777.242674
	2	197.22178	34.278118	257.769894	510.011706	1716.358305
	3	200.63273	26.03632	243.219889	484.945539	1780.927443
	4	198.73669	24.232902	238.366659	546.310808	1825.25706
	5	199.15446	32.819465	246.217819	445.184399	1834.083263
	6	199.39179	32.722767	255.36946	470.499142	1731.974705
	7	196.8931	34.592802	258.74678	485.697972	1771.594953
	8	210.27078	48.384562	294.389843	517.34529	1840.008922
Multi Talker Training (Exp. 2)	1	293.7597	66.015383	387.818189	733.645557	1846.135613
	2	230.99899	21.568055	273.183656	563.698436	1963.708228
	3	206.2322	27.76246	250.953098	610.401134	1739.535331
	4	214.94211	34.708146	269.186023	507.325995	1574.329876
	5	224.80482	68.099137	362.089282	523.051486	1793.099487
	6	209.29003	48.196252	301.939471	520.535206	1882.479225
	7	207.13367	34.258234	264.644274	456.766159	1777.242674
	8	197.22178	34.278118	257.769894	510.011706	1716.358305
Test (Exp. 2)	1	217.15698	59.613491	325.049014	516.733995	1765.853399
	2	201.28353	31.457905	259.261582	652.912907	1869.183048
	3	209.18524	45.645143	297.622931	616.049331	1847.033528
	4	194.97801	28.697955	246.929218	512.454533	1697.853387
	5	189.29533	37.084221	269.967387	564.893254	1800.185633
	6	194.22222	33.003745	255.950566	550.344862	1759.062228
	7	201.5581	49.499372	304.713555	527.488562	1812.964841
	8	187.69207	36.8132	260.551744	563.039708	1823.632006

Table 1: Acoustic measurements for each talker exemplar.

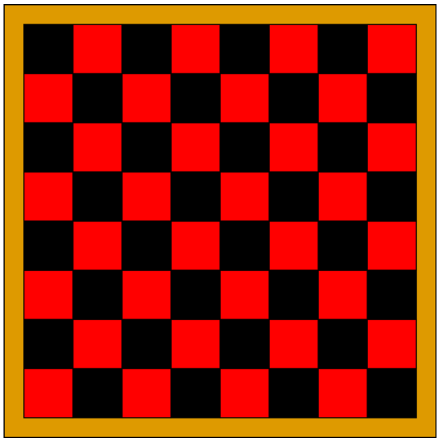

Figure 1: Visual Stimulus used in Experiments 1 and 2.

Apparatus and Procedure

The entire experiment took place in a sound-proof booth. Within the booth, there was a large projector screen in the front of the room with a speaker on each side of the projector. The projector screen showed the visual stimulus, and the speakers projected the auditory stimuli. Each habituation trial length was set at 16 seconds, 2 seconds for each of the 8 sound tokens the infants heard during each trial. After each habituation trial, a visual attention getter appeared on the screen to regain the infant's attention. The infant stayed on the parent or guardian's lap for the duration of the study, and the parent or guardian wore headphones during the entire study and was instructed to not direct the infant's attention to the screen or anywhere else within the room.

In the first phase of the experiment, the infant listened to a maximum of 24 habituation trials. The habituation criterion was based on the infant's overall looking times for the first 3 habituation trials. Once the infant's looking time in a trial was 50% shorter than the mean looking time of the first 3 initial trials, the infant was considered to have habituated and would automatically move on to the test phase. The number of trials was dependent on the rate of the infant's habituation (ie. the faster the child habituated to the stimuli presented, the less habituation trials they listened to).

In the habituation phase, half of the infants heard the words spoken by multiple talkers and half of the infants heard the words spoken by a single talker. All of the sound tokens in the 5 test trials were spoken by a single novel talker. Infants heard only one of the words (either /pɪm/ or /bɪm/) for the entirety of the habituation trials; half of the infants from each condition (Multiple Talkers vs. Single Talker) were habituated to /bɪm/, and half were habituated to /pɪm/. In the test trials, the infants heard both /pɪm/ and /bɪm/ for an equal amount of time (2 total trials for each word).

In the last phase of the experiment, the infant listened to a total of 5 test trials. Two of the five trials were same trials and played the same stimuli the infants were habituated to. In addition, another two of the five trials were switch trials and played stimuli different from what the infants were habituated to. The final trial played stimuli unrelated to the original stimuli and was used in the data analysis to help determine the infant's level of attention during the experiment. If the infant was paying attention during the habituation trials, then it was predicted that the infant would perk up to the novel stimuli and exhibit a longer looking time in comparison to the other test trials.

Results

As mentioned in the Present Study, we hypothesized that infants in the Multiple Talker condition would demonstrate more robust sound discrimination (measured by infants' looking times) than infants in the Single Talker condition. Overall, infants discriminated in both conditions, and we did not find a significant effect of condition type. We did, however, find slightly longer looking times in Multiple Talker (7.38 seconds) v. Single Talker conditions (6.28 seconds) which may be due to the increased complexity of the dimensions of the tokens caused by the variance of speakers.

An analysis of variance (ANOVA) considered the impact of within subjects factor Trial Type (Same v. Switch) and between subjects factor Condition (Multiple Talkers v. Single Talker) on looking times. The ANOVA demonstrated a significant effect of Trial Type on looking times ($F(1,34) = 5.7$, $p = .023$). Overall, infants had longer looking times in Switch v. Same Trials (see Figure 2 and Table 2 for means).

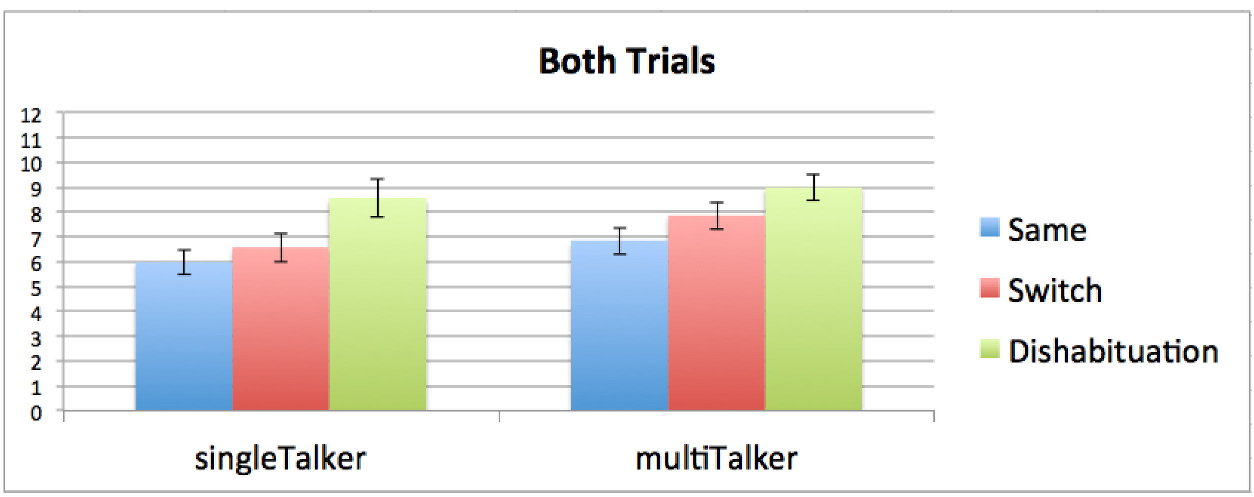

Figure 2: Mean looking times in seconds of the two Same trials and two Switch trials in Single Talker and Multiple Talker conditions

Trial Type	Experiment 1	Experiment 2
Same	6.39 (2.29)	7.34 (2.15)

Switch	7.27 (2.48)	6.36 (2.52)

Table 2: Mean looking times in seconds (with standard deviations) in each trial type across experiments.

While the main effect of Trial Type was significant, we did not find a significant main effect of Talker Condition, nor an interaction between Trial Type and Talker Condition. There is a tendency for greater overall looking in the Multiple Talker condition, and the effect narrowly misses the threshold to be considered a marginal effect ($F(1,34) = 2.5$, $p = .123$). The difference in the mean looking times for Multiple v. Single Talker Conditions was comparable to the difference in the mean looking times of Switch v. Same Trials (see Table 3). The Switch v. Same Trials are a within subject comparison, and the Multiple v. Single Talker Conditions are a between subjects comparison. Because the Multiple v. Single Talker Conditions comparison is between subjects, it holds less statistical power. This overall greater looking time for the Multiple Talker condition may be related to the complexity of the stimulus (ie. more sound tokens for the infant to listen to and process). We will examine the possible effects of Talker Condition and stimulus complexity in Experiment 2.

Talker Condition	Experiment 1	Experiment 2
Single	6.28 (2.27)	6.77
Multiple	7.38 (2.45)	6.93

Table 3: Mean looking times in seconds (with standard deviations for Exp. 1) in each talker condition across experiments

Discussion

We found that infants did show an overall learning effect. Infants looked longer during Switch Trials (where the sound target presented was different from the habituation stimuli) than during Same Trials (where the sound target presented was the same as the habituation stimuli). However, there was not a significant effect of whether the infants were familiarized in the Multiple Talker or Single Talker condition. It is possible that it is relatively easy for English-learning infants to discriminate between /b/ v. /p/; therefore, infants did not need to rely on perceptual cues such as talker variability. English-learning infants may have already constructed robust dimensions of /p/ and /b/ in their phonological inventory, making it an easy contrast for them. To test this possible explanation, we created a more difficult phonological task in Experiment 2. In Experiment 2, infants are given the task of discriminating between two very acoustically similar sounds, /n/ and /ŋ/ in syllable onset position. As discussed in the Introduction, previous research (Rost & McMurray, 2009; Afpelbaum & McMurray, 2010; Rost & McMurray, 2010) suggests perceptual cues such as speaker variation may aid in sound discrimination tasks. In addition, the infants do not have phonological information regarding the relevant dimensions of /ŋ/ because the phoneme does not occur in syllable onset positions in English, therefore making it difficult for infants to find the boundaries. We hypothesize that as the difficulty of the sound discrimination task increases, infants will rely more heavily on talker variability to discriminate this non-native contrast.

Experiment 2

Methods

Participants

14 children (6 boys, 8 girls) between the ages of 7 and 8 months were included in this experiment. 3 participants were excluded from data analysis due to fussiness or failure to habituate.

Auditory and Visual Stimuli

In Experiment 2, infants were tested in a paradigm very similar to that of Experiment 1. The infants were tasked with distinguishing between the sounds /n/ and /ŋ/. As with Experiment 1, the individual sound targets /n/ and /ŋ/ were embedded into the beginning of novel minimal pair words, /nɪm/ and /ŋɪm/. Each infant habituated under the multiple talker condition heard a total of 8 different sound tokens which varied in type and sequence depending on the condition they were in.

In Experiment 2, a total of 16 different sound tokens were used for the habituation trials. For the habituation stimuli, the words /nɪm/ and /ŋɪm/ were recorded by four female native-English speakers, all phoneticians or phonologists, in an infant directed register. A fifth female native-English speaker was recorded for the test trials in both the Multiple and Single Talker conditions. In order to ensure reliable pronunciation of /ŋ/, a phonetician (Natasha Warner) reviewed all pronunciations to help select the most accurate tokens. The variations of the word /ŋɪm/ spoken by talkers were chosen on the basis of their phonetic accuracy. The experimental design was equivalent to Experiment 1; the test trials consisted of 2 same trials, 2 switch trials, and 1 dishabituation trial.

Apparatus and Procedure

The apparatus and procedure for Experiment 2 closely mirrored that of Experiment 1, with the single exception of the sound tokens used. Similar to Experiment 1, in Experiment 2, infants heard only one of the words (either /nɪm/ or /ŋɪm/) for the entirety of the habituation trials. In the test trials, the infants heard both /nɪm/ and /ŋɪm/ for an equal amount of time (2 test trials for each word).

Results

As with Experiment 1, we used an ANOVA, analysis of variance, to examine the impact of within subjects factor Trial Type (Same v. Switch) and between subjects factor Condition (Multiple Talkers v. Single Talker), and their interaction, on infants' looking times. In a test of between subject effects of Multiple Talker v. Single Talker conditions, we did not find any significant relationship (F(1,11) = .016, p = .901). The mean looking time in Same trial type in Multiple Talker condition (7.49 seconds) was slightly higher than Same trial type in Single Talker condition (7.18 seconds). Mean looking times in Switch trials were exactly the same (6.36 seconds) in both Multiple and Single Talker conditions. We also did not find a significant interaction between condition and trial type ((F(1, 11) = .145, p = .701). In our data analysis, we found a main effect of Trial Type (F(1,11) = 5.56, p = .036). In a habituation paradigm, if there is demonstrated learning, then we expect to see longer looking times in Switch v. Same trials. However, infants in Experiment 2 had typically longer looking times in the Same v. Switch trials, meaning that they generally preferred to look longer for the word they heard during the habituation trials (see Figure 3).

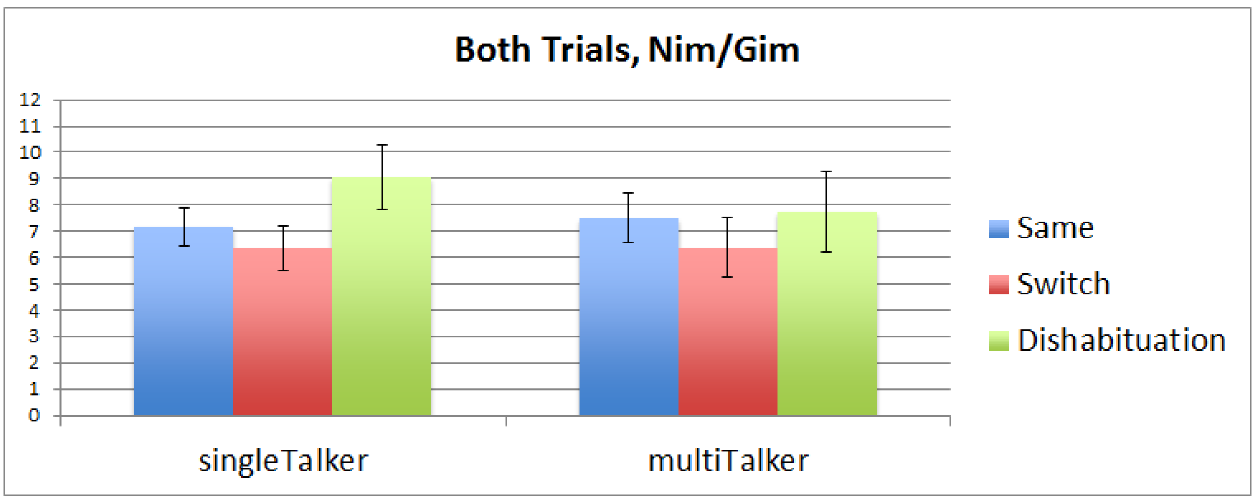

Figure 3: Mean looking times in seconds of the two Same trials and two Switch trials in Single Talker and Multiple Talker conditions

Trial Type	Experiment 1	Experiment 2
Same	6.39 (2.29)	7.34 (2.15)
Switch	7.27 (2.48)	6.36 (2.52)

Table 2: Mean looking times in seconds (with standard deviations) in each trial type across experiments.

Infants demonstrated learning in both experiments. As Table 2 depicts, Experiment 1 followed the normal trajectory of what we would expect if the infants learned, with overall longer mean looking times in Switch v. Same trials. Experiment 2, however, shows us the opposite pattern which is uncommon for habituation paradigms. We will discuss this interesting finding further in the General Discussion.

Discussion

In Experiment 1, we found that infants easily discriminated /p/ v. /b/ in the Single Talker and Multiple Talker conditions; therefore, talker variability did not appear to impact infants' looking times. We hypothesized that infants would have greater difficulty discriminating between /ŋ/-/n/ in syllable-onset position because the pair represents a non-native sound contrast. In addition, we hypothesized that the acoustic similarity of the sounds makes it difficult for infants to establish reliable category boundaries. If infants demonstrated learning, we hypothesized that they would look longer during Switch v. Same trials during the test phase. Interestingly, we found the opposite pattern in our data. Instead of looking longer while listening to the novel auditory stimuli, infants had significantly longer looking times during the Same trials. Currently, we are in the process of recruiting more participants for Experiment 2. We hope that a larger sample size will help shed light on our results. In the General Discussion, we will further discuss possible reasons for longer looking times in the Same trials.

General Discussion

Infants showed an overall learning effect in both Experiment 1 and 2. In Experiment 1, infants accurately discriminated the similar sounding phonemes /p/ and /b/ when placed in syllable onset position. We found a significant effect of Same v. Switch trial type, with overall longer looking times during Switch trials ($F(1,34) = 5.7$, $p = .023$). Overall, infants in Experiment 1 accurately discriminated in both Single Talker and Multiple Talker condition. We hypothesize that because /p/ and /b/ are frequently found in minimal pairs in English, English-learning infants have already constructed reliable acoustic dimensions for the two phonemic categories, making perceptual cues like speaker variability less helpful.

In Experiment 2, infants were given a more difficult sound discrimination task for the acoustically similar phonemes /n/ and /ŋ/. As with Experiment 1, infants appeared to discriminate between the two sounds. However, infants showed longer looking times in Same v. Switch trials, with looking times in the opposite direction of what we would normally expect to see if infants are demonstrating learning in a habituation paradigm.

In Experiment 1, we recruited a total of 33 participants. We plan on recruiting 32 infants (16 males and 16 females) for Experiment 2 so that our analysis can better compare the results of Experiment 1 and Experiment 2. Our current sample size for Experiment 2 is relatively small at

14 participants, and we plan on expanding that number in the coming months, potentially giving us a clearer picture of the aforementioned interesting phenomenon. We hypothesize that longer Same Trial looking times could be due to the increased complexity of the stimuli. In addition, the looking times could also be attributed to the number of sound tokens infants heard in the habituation phase.

The Multiple Talker condition of our study contained sound tokens from 5 different speakers. One of those speakers recorded all sound tokens for the Multiple and Single Talker condition test trials. The other 4 talkers recorded 4 exemplars the habituation stimuli, for a total of 16 different sound tokens. Other researchers (Rost & McMurray, 2009) used 18 speakers for a total of 54 exemplars, creating more variability in their stimuli. For future study, it might be worthwhile to examine the effect of increasing the number of speakers and sound tokens during the habituation phase.

Acknowledgments

I would like to thank Dr. LouAnn Gerken and Dr. Carolyn Quam for their guidance and support on my thesis project. The two of them, along with the rest of the Tweety Language Development Lab, have been a great source of encouragement over the past 3 years, and I am incredibly thankful for the amazing research experience and knowledge I have gained. I would like to give a special thank you to Dr. Quam for providing indispensable help during the thesis writing process. Thanks to all of you, I feel much more prepared to tackle the world of academia.

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