

THE ROLE OF SEMANTIC PREDICTABILITY IN
ADAPTATION TO NONNATIVE-ACCENTED SPEECH

by

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A THESIS

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Nonnative-accented speech is more difficult for native listeners to understand than native-accented speech. However, listeners can improve their abilities to understand nonnative-accented speech through exposure and training. The goal of this project was to explore whether exposing native listeners to different sentence types affects listeners' adaptation to nonnative-accented speech. Listeners were trained on high predictability sentences (e.g., "The color of a lemon is yellow"), low predictability sentences (e.g., "Mom said that it is yellow"), or semantically anomalous sentences (e.g., "The green week did the page"). Previous research has demonstrated that semantic predictability impacts speech perception, but its influence on adaptation to nonnative-accented speech is unclear. This experiment indicated that there is no generalizable advantage to training on high predictability versus low predictability versus semantically anomalous sentence types.

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Introduction

When a person speaks in a language other than their first language, this is called nonnative-accented speech. Nonnative-accented speech is more difficult for native listeners to understand than native speech due to a combination of unfamiliar acoustics, variability, and shifted expectations (Baese-Berk & Morrill, 2015; Rogers et al., 2004; Romero-Rivas, Martin, & Costa, 2015; Van Engen & Peelle, 2014). Perceiving nonnative accented speech could involve difficulties different from those involved in perceiving other types of unfamiliar speech such as unfamiliar native accents, speech in noise, and speech from individuals with aphasia and other speech or language disorders (Bent & Atagi, 2017). Compared to native-accented speech, native listeners use higher effort to understand nonnative-accented speech, which requires recruitment of different areas of the brain and uses more functional cognitive capacity (Van Engen & Peelle, 2014).

“The communicative burden” is a term used in linguistics to describe the shared effort of carrying out communication. The speaker and listener both have jobs to help carry the communicative burden: the speaker must work to convey meaning, and the listener must work to achieve understanding. When there is a nonnative speaker and a native listener, the communicative burden is often placed largely on the nonnative speaker. However, native listeners can and should do their part to improve communication. Recent research has demonstrated that individuals can improve their ability to comprehend nonnative-accented speech simply through exposure. For example, if a listener practices listening to one talker, they will improve at accurately

comprehending that talker (Bradlow & Bent, 2008). This is good news for listeners—the more they hear a nonnative-accented speaker, the better they understand.

Other studies show the generalizability of these types of trainings. If a listener hears a variety of different speakers with the same accent, it will help them understand a novel speaker with that accent (Bradlow & Bent, 2008). Additionally, when someone spends time listening to multiple different accents, they show improvement with accents they heard, but they also are better at comprehending novel accents with acoustical similarities to the training accents (Baese-Berk, Bradlow, & Wright, 2013; Xie & Myers, 2017).

Generalizable adaptation occurs across speakers and accents due to broader pattern-identification and learning mechanisms. Listeners are quick to adapt to unfamiliar language structures of all types, including phonological and grammatical structures, and to generalize the patterns they find to other unfamiliar structures (Baese-Berk et al., 2013). Additionally, listeners use feedback to inform their adaptation—training with higher intelligibility nonnative-accented speech facilitates learning better than training with lower intelligibility nonnative-accented speech (Bradlow & Bent, 2008).

Adapting to nonnative-accented speech can also be influenced by the content of the speech, or the semantics. When it is available, listeners use lexical information, or their knowledge of the words in their language, to map unfamiliar pronunciations onto familiar ones to adapt to an unfamiliar accent (Romero-Rivas et al., 2015). People also use context clues to identify words when pronunciations are unfamiliar (Bent, Holt, Miller, & Libersky, 2019; Bradlow & Alexander, 2007; Holt & Bent, 2017; Winn,

2016). For example, when presented with a semantically high predictability sentence (e.g., The color of a lemon is yellow), listeners transcribe the final word more accurately than when they are presented with a low-predictability sentence (e.g., Mom thinks that it is yellow) (Bradlow & Alexander, 2007). This is due to the brain's ability to use collocation frequency information to fill in the blank. The word identification advantage provided by high-predictability sentence content also reduces listening effort, as shown by pupillary response experiments with hard of hearing participants (Winn, 2016).

While we know that native listeners can improve comprehension of nonnative-accented speech through exposure, and listeners use semantic content to process speech, there is not yet research discussing the intersection of these two observations. What is the direct effect of semantic content on adaptation to nonnative-accented speech?

One potential outcome is that that feedback provided by high predictability sentences facilitates learning. In other words, because listeners trained on high predictability sentences can fill in any words they were unable to understand based on context, they have a way to map unfamiliar pronunciations onto familiar pronunciations (Bradlow & Bent, 2008; Romero-Rivas et al., 2015). This would give listeners trained on high predictability sentences an advantage over those trained on lower predictability sentences, which would result in higher accuracy in the post-test.

Another hypothesis is that increase in listener effort necessitated by low predictability sentences challenges listeners and promotes development. Because listeners exposed to low predictability sentences cannot rely on the semantic predictability to predict the upcoming speech, they may learn to rely on acoustic information for accent adaptation rather than on the informational content (Winn,

2016). Thus, the attention required for training with lower predictability sentences could allow for better generalization and lead to higher accuracy in a post-test than training on high predictability sentences (Baese-Berk et al., 2013).

The following experiment was conducted to understand the relationship between training on different levels of semantic predictability and listener adaptation to nonnative-accented speech.

Methodology

Stimuli

The stimuli were English sentences taken from existing lists of high predictability, low predictability, and semantically anomalous sentences (see Appendix A). The lists of high and low predictability sentences were found in Bradlow & Alexander (2007). These sentences were designed with final word collocation frequency specifically in mind, and their level of semantic predictability was determined through pilot studies. The list of semantically anomalous sentences recorded were the Syntactically Normal Sentence Test sentences found in Brouwer, Van Engen, Calandruccio, & Bradlow (2012) and in the OSCAAR SNST corpus.

A female nonnative speaker with a Mandarin L1 was recorded in a sound-attenuated booth reading from these lists of high predictability sentences, low predictability sentences, and semantically anomalous sentences. The speaker read each sentence twice to reduce disfluencies, though only one of the productions was used for the experiment.

The continuous audio file of the speaker reading was divided into individual audio files of each sentence. Then, using existing Praat scripts, 0.5 seconds of silence was added to the beginning and end of each sentence. Sentences were leveled for intensity at 75 dB, and then mixed into speech-shaped noise with a 1:1 signal-to-noise ratio (i.e., 0 dB SNR). This speech-shaped noise was added to prevent participants from performing the task with complete accuracy, which would hinder researcher understanding of listener adaptation (Smiljanić & Bradlow, 2011).

Subjects

Subjects were monolingual native English speakers ages 18-34 with normal hearing and speech drawn from the Psychology and Linguistics Human Subjects Pool at the University of Oregon. Subjects participated in exchange for credit in the human subjects pool. To register for the study, the participant must have identified themselves as monolingual English speakers over the age of 18 with normal hearing and speech. Each participant also completed a language experience questionnaire at the end of the experiment which asked them to self-report age, exposure to languages other than English, and hearing and speech impairments. Of the 65 participants who were recruited for the experiment, 14 were excluded due to noncompliance with the task, a self-reported hearing impairment, or issues with the computer program. Thus, usable data was collected from 51 participants with $n=16$ for the semantically anomalous training condition, $n=17$ for the high predictability training condition, and $n=18$ for the low predictability training condition.

Experimental Procedure

After signing a consent form, subjects completed the test individually on a computer in the Spoken Language Research Laboratory using headphones in a sound-attenuated room. To collect experimental data, a PsychoPy computer program with a training phase and a testing phase was used (See Appendix B).

For the training phase, subjects were assigned randomly to one of three training conditions: semantically anomalous, high predictability, or low predictability. Each subject heard 40 sentences from the condition to which they were assigned. These were 40 unique sentences within each condition, and the presentation order was randomized

for each participant. Subjects were first asked to complete a volume check with no transcription aspect to allow them to adjust volume to a comfortable level. Then, they were told to transcribe each sentence they heard by typing their response, then submitting their response to proceed to the next sentence. The sound file was only presented once, and they received no feedback for their transcriptions. The next sentence played as soon as participants indicated they had finished their previous response, with the exception of a pause between the training and testing phases to give participants a break.

At the end of training, subjects in all groups were given a post-training test consisting of a novel set of 10 high predictability, 10 low predictability, and 10 semantically anomalous sentences. All participants heard the same 30 sentences with randomized presentation order. Again, they listened to and transcribed the sentences one at a time. At the end, participants were asked to fill out an online language background survey, which required them to self-report prior experience with English, age, experience with other languages, and any speech or hearing impairments. In total, the experiment lasted approximately 20 minutes.

Results

Scoring

Post-test data was scored based on whether a participant transcribed each word correctly. The participant's transcription was compared to the corresponding target sentence, and each word in the target sentence was either scored a 1 or a 0 depending on whether the participant wrote that word in their response. Typos and misspellings resulting in non-words that strongly resembled the target, such as "teh" instead of "the", were counted as correct. If a participant typed a homophone of the target word, that was also counted as correct.

Results Summary

Results of post-test transcription accuracy were grouped into (1) Post-test transcription accuracy by training condition, (2) Post-test transcription accuracy by sentence type and training condition (3) Post-test transcription accuracy by sentence type within training condition and (4) Post-test final word transcription accuracy by training condition. These first three ways of showing the results were chosen in order to show how training conditions impacted outcomes within and across conditions. The fourth, narrowing to sentence-final word transcription accuracy, uses fewer data points but better matches the original stimuli design.

Post-Test Transcription Accuracy by Training Condition

First, for each participant, the proportion of words transcribed correctly in the post-test was determined. Then, the participants were grouped into training types.

Figure 1 below shows proportion of words transcribed correctly in the post test by training condition: anomalous, low predictability, and high predictability.



Figure 1: Post-Test Performance by Training Condition

Although the variation in the low predictability training condition was greater than in the other two conditions, average transcription accuracy was approximately equal across conditions.

Post-Test Transcription Accuracy by Sentence Type and Training Condition

After dividing into training conditions, the data were divided again into post-test sentence type. This method of visualization helps show whether participants in any one training condition show a better ability to generalize adaptation compared to the participants in other training conditions.

Figure 2 below shows proportion of words transcribed correctly for semantically anomalous post-test sentences by training condition: anomalous, low predictability, and

high predictability. Figure 3 shows proportion of words transcribed correctly for low predictability post-test sentences by training condition. Figure 4 shows proportion of words transcribed correctly for high predictability post-test sentences.

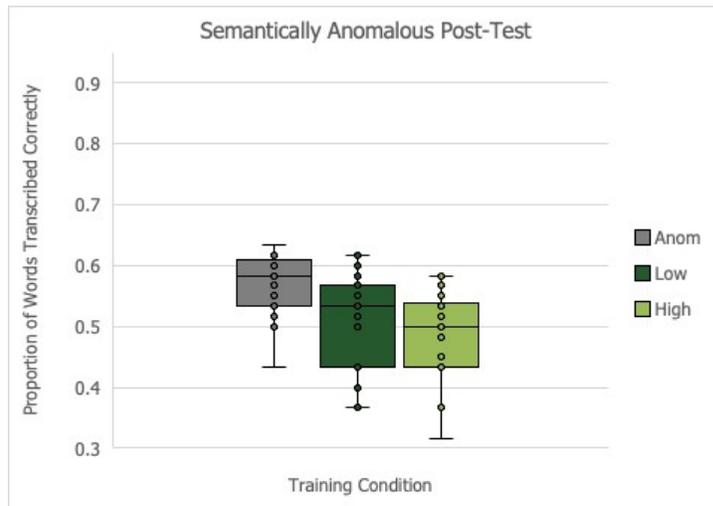


Figure 2: Semantically Anomalous Post-Test Sentences Performance by Training Condition

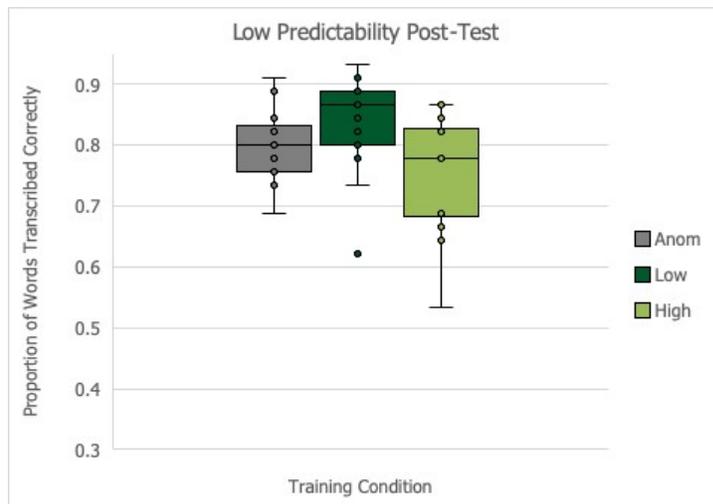


Figure 3: Low Predictability Post-Test Sentence Performance by Training Condition

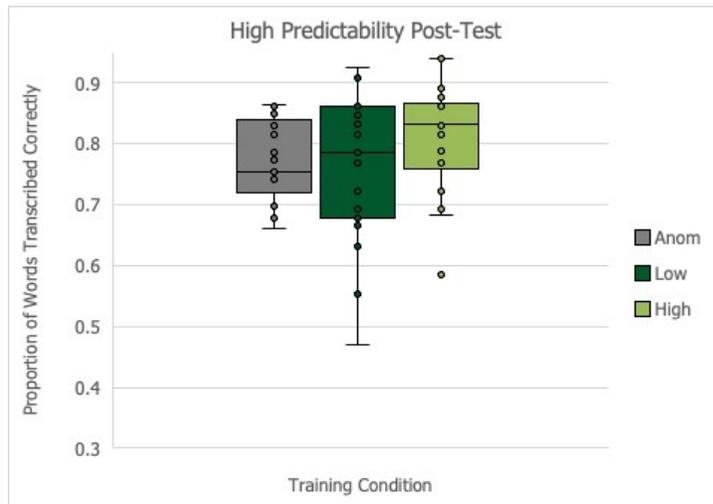


Figure 4: High Predictability Post-Test Sentence Performance by Training Condition

The results indicate that for each type of sentence in the post-test, participants who trained on that type of sentence show an advantage over the participants in other training conditions. This means participants in the low predictability training had on average better transcription accuracy than the other two groups on low predictability sentences in the post-test. Similarly, those in high predictability training on average better transcription accuracy than the other two groups on high predictability post-test sentences, and those in semantically anomalous training on average better transcription accuracy on semantically anomalous post-test sentences than the other two groups.

Post-Test Transcription Accuracy by Sentence Type Within Training Condition

To compare performance within a condition, participant averages were regrouped into anomalous, low, and high training conditions to show performance on different types of post-test sentences. Figure 5 below shows the accuracy of participants

in the semantically anomalous training condition on the three types of post-test sentences: semantically anomalous, low predictability, and high predictability. Similarly, Figure 6 shows the accuracy of participants in the low predictability training condition on the three types of post-test sentences. Figure 7 shows the accuracy of participants in the high predictability training condition on the three types of post-test sentences.

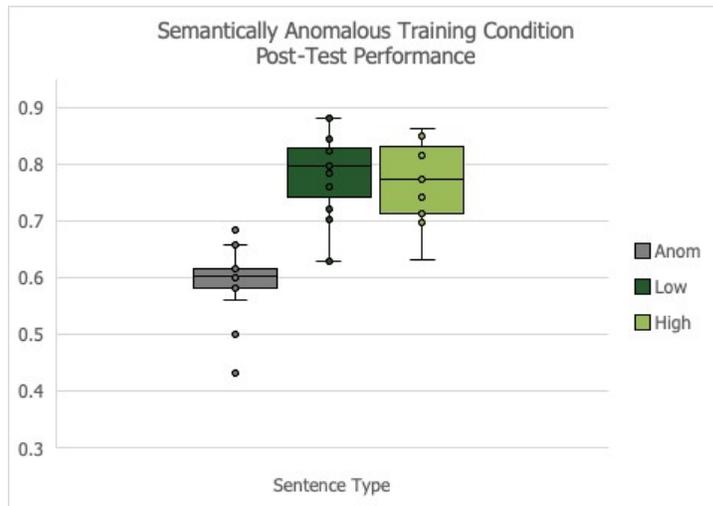


Figure 5: Semantically Anomalous Training Condition: Post-Test Performance

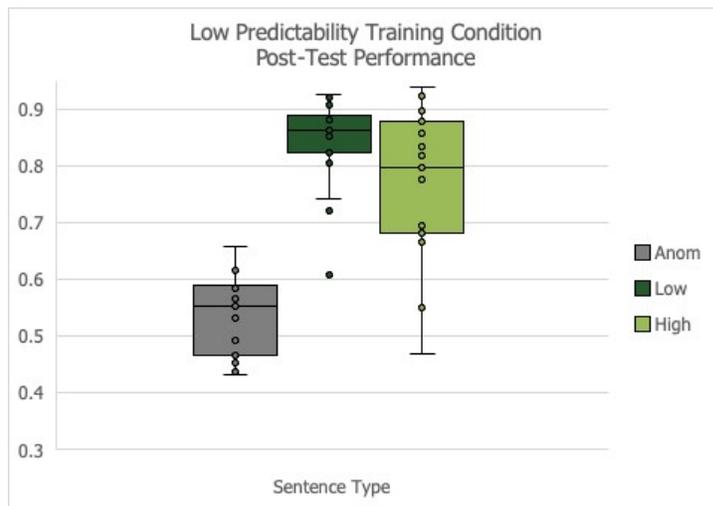


Figure 6: Low Predictability Training Condition: Post-Test Performance

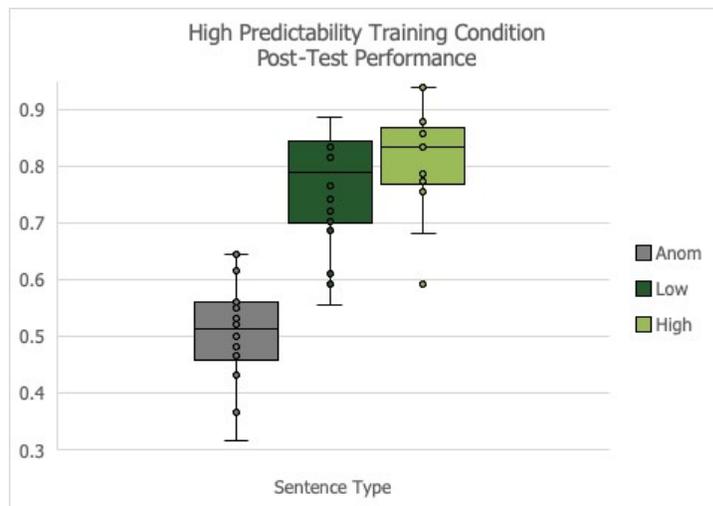


Figure 7: High Predictability Training Condition: Post-Test Performance

Participants in all three conditions transcribed with similar accuracy on high and low predictability sentences, but they had much lower accuracy when transcribing semantically anomalous sentences.

Post-Test Final Word Transcription Accuracy by Training Condition

Because the high and low predictability stimuli were originally designed to control for final word collocation frequency, singling out participant transcriptions of final words for these two sentence types in the post-test could be a better indicator of post-test performance. This provides far fewer data points but removes factors which may skew results. For example, this method controls for the number of words per sentence. It also controls for sentences which may have a greater number of function words, because these can tend to be phonologically reduced and similar to one another,

potentially causing a disproportionate number of transcription errors, especially when hearing pronouns and articles out of context (Baker et al., 2011).

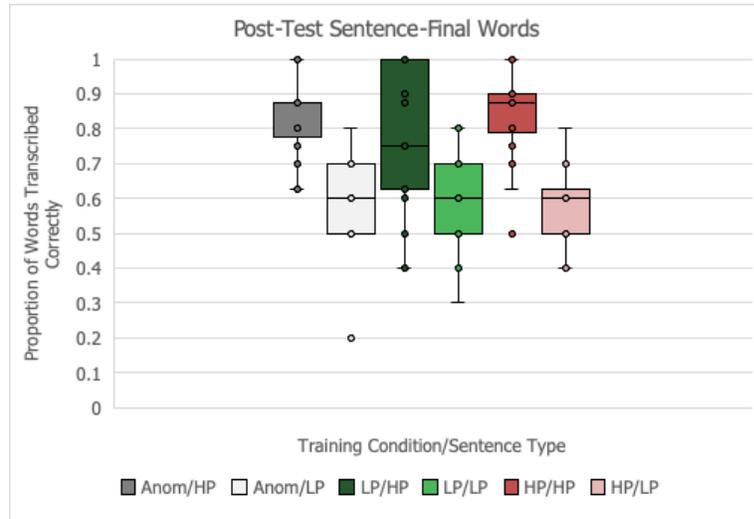


Figure 8: Post-Test Sentence-Final Word Performance

This figure shows final word scores divided into Training Condition / Post-Test Sentence Type for high predictability (HP) and low predictability (LP) post-sentence types.

While no condition shows an advantage for final word transcription accuracy, low predictability training shows a much larger distribution of performance, especially for final words in the high predictability condition.

Discussion

Listeners show an advantage on the type of post-test sentences they heard in training, which is a predictable outcome based on previous understandings of how participants in studies adapt to tasks. When a participant practices a particular type of task, they are better at that task than a novel task (Cole, Patrick, Meiran, & Braver, 2018).

The current study sought to test whether the type of training materials would impact the generalization of nonnative-accented speech adaptation. Specifically, one hypothesis was that the high predictability training condition would show more generalizable adaptation than the other two conditions based on findings that feedback from high predictability sentences helps listeners map unfamiliar pronunciations to their existing representations (Bradlow & Bent, 2008; Romero-Rivas, Martin, & Costa, 2015).

Alternatively, we hypothesized that high predictability training sentences would provide less generalizable adaptation because training with sentences that require more effort helps listeners improve, so the lower predictability conditions provide participants with better tools to understand the listener (Winn, 2016). In this case, listeners who heard high predictability sentences during training might ignore pronunciations to some extent and rely heavily on sentence context to transcribe.

The current results were not in line with either of these expected outcomes. That is, no training group had an adaptation advantage in this experiment (Figure 1). This contradicts both hypotheses. If the first hypothesis were true, we would expect to see participants in the high predictability condition outperforming participants in the low

predictability condition in the semantically anomalous post-test (Figure 2). If the second hypothesis were true, we would expect participants in the low predictability training condition to outperform participants in the high predictability training condition for semantically anomalous post-test sentences (Figure 2). We might also expect participants in the semantically anomalous training condition to outperform participants with high predictability training on low predictability post-test sentences (Figure 3) and to outperform participants with low predictability training on high predictability post-test sentences (Figure 4).

Comparing within conditions is indicative of the difficulty of transcribing semantically anomalous sentences. For instance, while the semantically anomalous training group performed better on semantically anomalous sentences than the other two groups (Figure 2), these participants still only transcribed about half the words correctly per sentence on average and were much more accurate while transcribing high and low predictability sentences (Figure 5).

A notable result for the low predictability training condition was the variation in transcription accuracy for high predictability sentences (Figure 6). For the sentence-final word scores (Figure 8), there is the same large variation for participants in the low predictability condition transcribing high predictability sentences. This outcome was unexpected. It is possible that something about low predictability sentences leads to less consistency in adaptation, but the mechanisms behind this result are unclear.

One potential limitation of this study is the variation in stimuli. Pulling sentences from two different studies means there was no control over what words were in each sentence, whether a participant heard any given word more than once, and the

number of words per sentence. For example, in the high predictability training condition, words per sentence ranged from 4 to 12, while semantically anomalous sentences all had 6 words. Furthermore, low predictability sentences were created with a low collocation frequency for the final word, but they repeated the same structures and words for the beginnings of sentences (Bradlow & Alexander, 2007). This means participants training on low predictability sentences heard things like "mom," "dad," "talked about," and "read about" multiple times in training. It is possible these repetitions helped participants map pronunciations, or that the reduced variation in training words hindered adaptation, creating a confounding factor in the post-test. These sentences were chosen because there was precedence in the literature for their use, but they may have skewed results in specific experiment. To control for this, new sentences would need to be created specifically for this study.

Another potential limitation of the stimuli is that the speaker who produced the sentences is accustomed to speaking semantically normal sentences. Therefore, reading the semantically anomalous sentences may have interrupted prosody, speaking rate, or otherwise led to disfluencies in ways that the high predictability sentences did not, meaning speech fluency was not well controlled. However, this is difficult to test because research shows listeners rate nonnative-accented speech as "more accented" when the sentences are low predictability, even when the target word is from the same recording. This means participants are inclined to misattribute the extra effort required by semantic abnormalities to the fluency of the speech (Incera, Shah, McLennan, & Wetzel, 2017).

In order to better understand listener adaptation to nonnative-accented speech in the context of this experiment, it is necessary to collect more information. Currently, participants are being run in a control group who are only given the post-test from this study. With this additional data, it will be possible gain better insight into the impacts of training in any group on post-test accuracy. Furthermore, statistical analyses will be applied to the existing data and future data to ensure results are significant.

Conclusion

Although there is much to be learned about the mechanisms behind adaptation, this experiment shows there is no generalizable benefit for training on semantically anomalous, high predictability, or low predictability sentences alone. However, training on the types of sentences a listener expects to encounter would improve accuracy in understanding those types of sentences, and practically speaking, this would likely be a variety of both high and low predictability sentences.

Beyond this study, there are many paths of inquiry to pursue. How would the results of this experiment look with multiple speakers? Do these results generalize for nonnative-accented speech from speakers with different first languages? Are these differences in adaptation across conditions temporally valid? What if the training was longer or the post-test was administered the next day?

The results of these types of experiments are valuable to help listeners become stronger conversation partners for people speaking their second language. In the meantime, listeners should do their best to support their end of the communicative burden with tools that have already proven effective—effort and a positive attitude.

Appendix A: Stimuli

Semantically Anomalous Training Sentences

1. The last fire tried the nose.
2. The young voice saw the rose.
3. The chance sun laid the year.
4. The white bow had the bed.
5. The near stone thought the ear.
6. The end home held the press.
7. The deep head cut the cent.
8. The full leg set the shore.
9. The safe meat caught the shade.
10. The fine lip tired the earth.
11. The plain can lost the men.
12. The dead hand armed the bird.
13. The fast point laid the word.
14. The mean wave made the game.
15. The clean book reached the ship.
16. The red shop said the yard.
17. The late girl aged the boat.
18. The large group passed the judge.
19. The past knee got the shout.
20. The least boy caught the dance.
21. The green week did the page.
22. The live cold stood the plant.

23. The third air heard the field.
24. The far man tried the wood.
25. The high sea burned the box.
26. The blue bill broke the branch.
27. The game feet asked the egg.
28. The ill horse brought the hill.
29. The strong rock built the ball.
30. The dear neck ran the wife.
31. The dry door paid the race.
32. The child share spread the school.
33. The brown post bit the ring.
34. The clear back hurt the fish.
35. The round work came the well.
36. The good tree set the hair.
37. The hot nest gave the street.
38. The new wife left the heart.
39. The mean shade broke the week.
40. The hard blow built the truth.

Low Predictability Training Sentences

1. Mom thinks that it is yellow.
2. He thinks that it is late.
3. Dad talked about the sheets.
4. He looked at the sleeves.
5. We talked about the water.

6. We heard that it broke.
7. Dad pointed at the wheat.
8. She thinks that it is cold.
9. Dad talked about the bomb.
10. Mom read about the knife.
11. She looked at her legs.
12. We read about the coach.
13. Mom looked at her feet.
14. Dad pointed at the grass.
15. She read about the flower.
16. This is her favorite sport.
17. He read about the flood.
18. He looked at her wrist.
19. This is her favorite week.
20. Mom thinks that it is hot.
21. Dad read about the sky.
22. Dad thinks that it is funny.
23. He pointed at the cents.
24. He pointed at the fruit.
25. She talked about their necks.
26. We talked about the paper.
27. This is her favorite cake.
28. He read about the trees.
29. We read about the family.
30. Mom pointed at his father.

31. She looked at her hands.
32. We looked at the story.
33. We pointed at the bird.
34. Mom talked about the doctor.
35. He pointed at his hair.
36. Mom looked at the juice.
37. He talked about the dinner.
38. She thinks that it is fast.
39. Mom pointed at the coffee.
40. She pointed at the home.

High Predictability Training Sentences

1. The color of a lemon is yellow.
2. My clock was wrong so I got to school late.
3. She made the bed with clean sheets.
4. The sport shirt has short sleeves.
5. He washed his hands with soap and water.
6. The child dropped the dish and it broke.
7. The bread was made from whole wheat.
8. The opposite of hot is cold.
9. The war plane dropped a bomb.
10. She cut the cake with a knife.
11. A chair has four legs.
12. The team was trained by their coach.
13. People wear shoes on their feet.

14. When sheep graze in a field, they eat grass.
15. A rose is a type of flower.
16. Football is a dangerous sport.
17. The heavy rains caused a flood.
18. Bob wore a watch on his wrist.
19. Monday is the first day of the week.
20. The pan that was just in the oven is very hot.
21. Rain falls from clouds in the sky.
22. The boy laughed because the joke was very funny.
23. A quarter is worth twenty-five cents.
24. An orange is a type of fruit.
25. People wear scarves around their necks.
26. I wrote my name on a piece of paper.
27. For your birthday I baked a cake.
28. Birds build their nests in trees.
29. My parents, sister and I are a family.
30. The good boy is helping his mother and father.
31. People wear gloves on their hands.
32. A book tells a story.
33. A pigeon is a kind of bird.
34. The sick woman went to see a doctor.
35. The lady uses a hairbrush to brush her hair.
36. At breakfast he drank some orange juice.
37. Last night, they had beef for dinner.
38. A racecar can go very fast.

39. Many people like to start the day with a cup of coffee.

40. He brought the book to school from home.

41. Post-Test Sentences

1. Dad looked at the pork
2. Mom talked about the pie.
3. We think that it is sweet.
4. She talked about the leaves.
5. He read about the wheels.
6. This is her favorite time.
7. There are many pieces.
8. She pointed at his ears.
9. He talked about the ice.
10. Dad thinks that it is dark.
11. I wear my hat on my head.
12. Red and green are colors.
13. The stars come out at night.
14. February has twenty-eight days.
15. The picture is hung high on the bedroom wall.
16. We heard the ticking of the clock.
17. She laid the meal on the table.
18. She looked at herself in her mirror.
19. Elephants are big animals.
20. After my bath, I dried off with a towel.
21. The wrong shot led the farm.
22. The black top ran the spring.
23. The great car met the milk.
24. The old corn cost the blood.

25. The short arm sent the cow.
26. The low walk read the hat.
27. The rich paint said the land.
28. The big bank felt the bag.
29. The sick seat grew the chain.
30. The salt dog caused the shoe.
- 42.

43. Appendix B: PsychoPy Experiment Interface

44. Instructions

For this experiment, you will listen to sentences and type what you hear. If you are unsure, make your best guess. You will hear each sentence only once, so listen carefully.
When you are ready, press ENTER to begin.

45.

46. Volume Test

This is a volume test. Use the volume keys to adjust the volume
Press SPACE to play the voice again.
Press ENTER to continue.

47.

48.

49.

50. Prompt Accompanying Audio

Please type what you hear and
press ENTER to continue

51.

Please type what you hear and
press ENTER to continue

the color of a lemon is yellow

52.

53.

54.

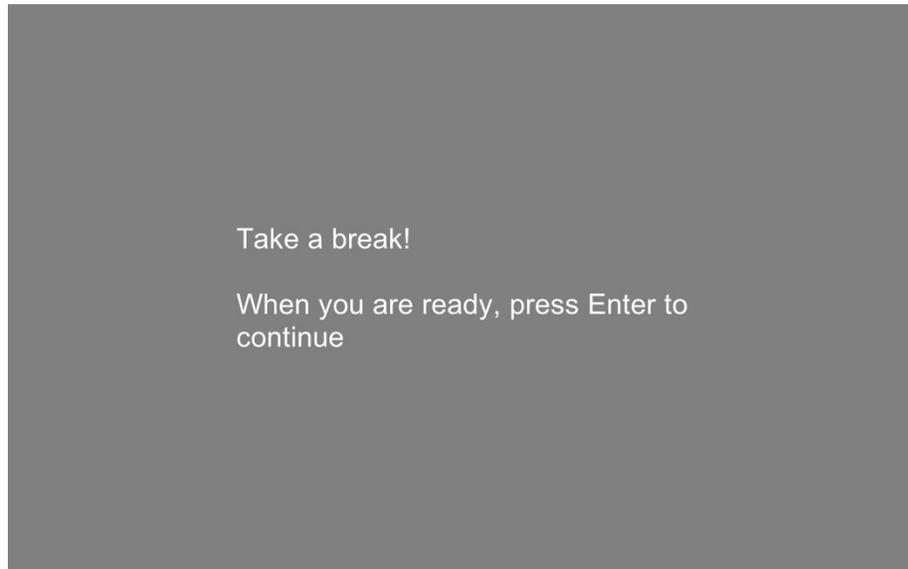
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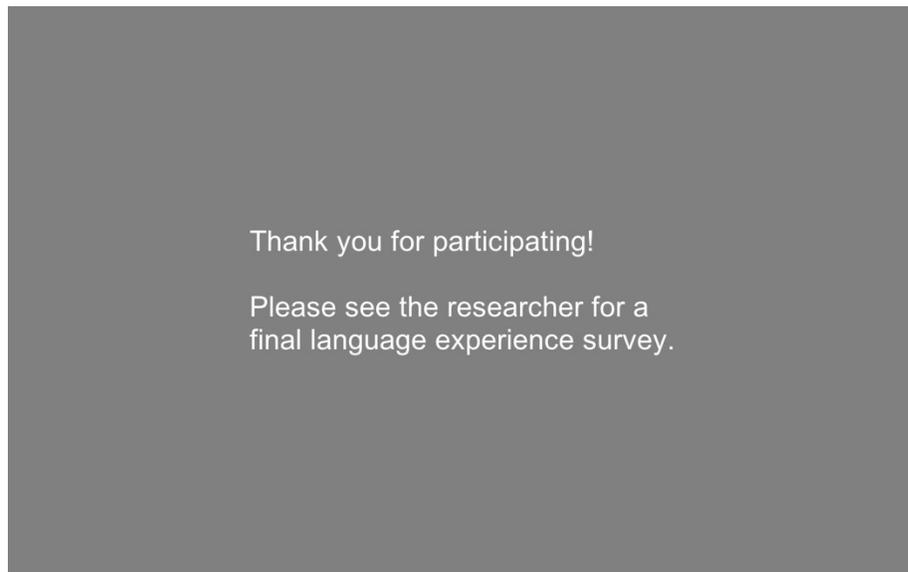
58.

59. Break



60.

61. End Screen



62.

63.

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