¹ Context Effects on Auditory Category Knowledge

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¹⁴ Context Effects on Auditory Category Knowledge

¹⁵ Introduction:

¹⁶ In order for us to perceive the world around us, we must use categorical knowledge.

¹⁷ From breaking apart a song, to phonetics used within speech, auditory category knowledge

¹⁸ is essential for individuals to understand auditory events (Michael I. Posner, Steven W.

¹⁹ Keele, 1968, pg 4). Two areas of category knowledge can be applied to auditory events and

²⁰ are necessary in order for us to infer meaning. The first stems from an associative

²¹ connection to an acoustic event (e.g. doorbell ring) - an isolated concept (Robert

²² Goldstone, 1996). In this way, similar acoustic patterns may be compared to those that we

²³ have within our minds. The second broad area of conceptual objects are referred to as

²⁴ interrelated concepts (Ferdinand de Saussure, 1959/1916; Robert Goldstone, 1996). When

²⁵ applied to auditory objects, it refers to how auditory objects are mapped to sound patterns

²⁶ which are linked within a web. The interrelatedness of the concepts are then defined by

²⁷ themselves but also through their relation to other concepts (Shannon L.M. Heald, Stephen

²⁸ C. Van Hedger, Howard C. Nusbaum, 2014). Concepts themselves within the web of

²⁹ related concepts provides the avenue for generalization. Therefore, the main difference

³⁰ between isolated and interrelated concepts is that isolated concepts do not have

³¹ systematicity that interrelated concepts have, and therefore cannot be generalized. The

³² current study draws on the research of our previous study which examined how generalized

³³ note knowledge can guide an estimate of a starting tone to match a target tone with

³⁴ experts (those who have absolute pitch) and novices (Shannon L.M. Heald, Stephen C. Van

³⁵ Hedger, Howard C. Nusbaum (2014)). In this study, individuals, regardless of experience,

³⁶ were asked to adjust a probe tone to match the target tone pitch. However, the tone was

³⁷ presented as a continuum or within a word. Instead of looking at the variation between

³⁸ experts and novices, we were interested in looking at how context effects change the bias

³⁹ patterns (Shannon L.M. Heald, Stephen C. Van Hedger, Howard C. Nusbaum (2014)). The

40 idea would be that for words, individuals would show more bias because the word context

41 encourages a person to hear the sound more categorically. We expect individuals to show

42 more error in reproducing a given token from a word continuum and for vowels there

43 should be less error. This belief is strengthened by findings in the Heald et al. paper as

44 word context enhances the use of category knowledge and as such, it may diminish the

45 ability to replicate the exact token from the continuum heard. We hope to explore this

46 belief by examining the individual deviation between the probe and target tone, finding the

47 error of what people reproduce based on whether they heard a vowel continuum or word,

48 and be able to understand what information people retain based on context.

Methods

50 We based our methodology from our previous paper that examined auditory category

51 knowledge within experts and novices.[1]

52 Twenty undergraduates were recruited from the University of Chicago community and

53 were between 18 and 26 years of age. It was not a requirement of the study for individuals

54 to have musical experience, however, we asked participants to report their music experience

55 in a questionnaire after the study. Participants were either given course credit or paid for

56 their participation in the study. All participants did not report a hearing disorder.

57 The experiment itself consisted of a tone adjustment task where a target tone was

58 matched by varying the frequency of a probe tone (sinewave tones were generated using

59 Matlab). On each trial, participants were asked to click the button with a T on it to hear

60 the target tone, followed by one second of white noise (Shannon L.M. Heald, Stephen C.

61 Van Hedger, Howard C. Nusbaum (2014)). Individuals had to then press a button labeled

62 P to hear the probe tone. The timing between listening to the target tone and the probe

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[1] Heald, S. L., Van Hedger, S. C., & Nusbaum, H. C. (2014). Auditory category knowledge in experts and novices. Frontiers in Neuroscience, 8, 260.

tone was not predetermined but rather set by the participant. Individuals were then asked

to try their best to adjust the probe tone to match the target tone they first heard.

Participants adjusted the probe tone by manually clicking and listening to other tones that

were present on the screen after the presentation of the target tone. The participants could

arrange the tones in any fashion they wanted, with the goal of placing the tone that

sounded most like the target tone in the first position (or top of the screen) and the least

likely option last. These tones were comprised of tones that were higher in frequency in the

series as well as tones that were lower in frequency. Higher frequency tones modified the

target tone in 66-cent increments, while the lower frequency tones modified the target tone

in 33 cent increments. A step size of 33 cents was chosen because it is above most listeners

threshold for noticing pitch differences. Participants were given as long as they needed to

adjust the probe tone. When participants were certain of their answer, they confirmed

their answer and continued onto the next trial. This was a within subjects design. Within

the vowel condition, participants heard a continuum of vowels that varied in acoustic

frequency range in both the target and probe tones. In the second condition, participants

heard a vowel and then heard a word that had the same or similar vowel as the target

vowel. There were 18 probes in total across both conditions, and there were multiple target

tones used across trials that were counterbalanced in a randomized fashion to omit any

over or underestimation of the tones.

Results

While results are preliminary, the first calculation was examining if there was a

difference in error bias (represents how many 33-cent steps an individual took towards

reaching what they perceived was correct) based on whether the tone presented to the

individual started high or low. To visualize this, we first combined both datasets (words

and vowels) and indicated whether the row corresponded to a word (embedded) or a vowel

(not embedded) that the participant heard. We used two datasets, context effects and

89   wordsandvowels which were tidied and cleaned in R prior to data analysis.The tones were

90   delineated based on whether they were high pitch or low pitch with 1-9 (exclusive)

91   representing low tones, and 9-18 (inclusive) representing high tones. Our first visual

92   comparison was to see whether the Probe had an impact on the error bias the participant

93   demonstrated. Mean Position Difference was calculated by taking the position of the actual

94   target tone and subtracting it from the position of the tone the individual chose/thought

95   was correct. As referenced in Table 1 each subject bias toward the tones, or mean position

96   difference between the probe and target tone is displayed. Overall, half of the individuals

97   overestimated the target tone, while the other half underestimated the target tone.

98   Figure 3, however, represents the range of tones used in the experiment and the starting

99   tones indicate the probe tones. This figure is based on the (2014) paper that this

100 experiment is predicated on. In Figure 1 we can see that the there was a difference in bias

101 between participants identification of vowels versus words when given a high tone

102 compared to a lower tone. Specifically, individuals tend to overestimate the target tone

103 position when presented with a high probe first compared to a lower tone probe.

104 Individuals are more likely to underestimate the position of the target tone when presented

105 with a low tone probe, however, the effect is most prominent for words rather than vowels.

106 This finding would be in line with our hypothesis that individuals would hear the sound

107 more categorically within in a word, and thus showcase more bias because of the context

108 effect. Likewise, individuals that heard the higher probe tone showed more overestimation

109 for the embedded condition (words) than vowels. While the boxplot shows some evidence

110 for differing error bias rates based on the probe tone, we wanted to further investigate

111 whether there was a crossover point whereby a low tone effects the mean position difference

112 of a vowel more . To examine this, we created a line plot seen in Figure 2. Visual

113 examination, as seen in Figure 2, showcases that a word or vowel (embedded versus

114 non-embedded) effects the overall bias for the tones in a different way. This graph also

115 indicates that high probe tones presented with vowels embedded within a word (embedded)

have a higher bias than vowels themselves. Overall, this graph depicts that words have a

higher bias rate when presented with both a high or low tone probe comparatively

speaking to a vowel. The results from visual inspection also fall within our hypothesis that

words will elicit more bias as it enhances category knowledge and thus reduces the

likelihood that the individual can recreate the actual sound heard. To further disambiguate

the relationship between the target tone position and bias a participant had toward

estimating the correct tone, we conducted a 2-way ANOVA comparing the effect of

"TTPosition" on "MeanPosDiff", two variables in our dataset that represent target tone

position and bias, respectively. This analysis yielded a very strong p-value of a < 0.01.

From this analysis, we can infer that there is an effect of the target tone position (low or

high) on the overall bias a participant demonstrates on a given trial. Further examination

of the data will include looking at individual crossover points within each of the 19 subjects

to see when the bias between words and vowels flips based on their starting tone, and how

bias changes over the duration of a trial.

Discussion

Taken together, the preliminary analyzed data from this experiment provide evidence

that context effects can enhance categorical knowledge, and thus provides supporting

evidence for the lack of invariance problem (Irene Appelbaum (1996)). Here, listeners had

more difficulty with the acoustic variability of the tone for words because of the heightened

use of categorical knowledge whereas that context effect was not present for the vowel

continuum. Thus, we have showcased empirical evidence that context effects modulate the

accuracy of individuals selecting tones.

References

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Table 1

Overall Bias in Correct Tone

Position Selection for Subjects

Subject	mean.MeanPosDiff
1	0.10
2	-0.37
3	-0.60
4	0.58
5	-0.27
6	0.13
7	0.56
8	0.18
9	0.17
10	-0.17
11	-0.08
12	0.27
13	0.03
14	0.66
15	-0.40
16	0.32
17	-0.47
18	-0.20
19	-0.55
20	-0.99
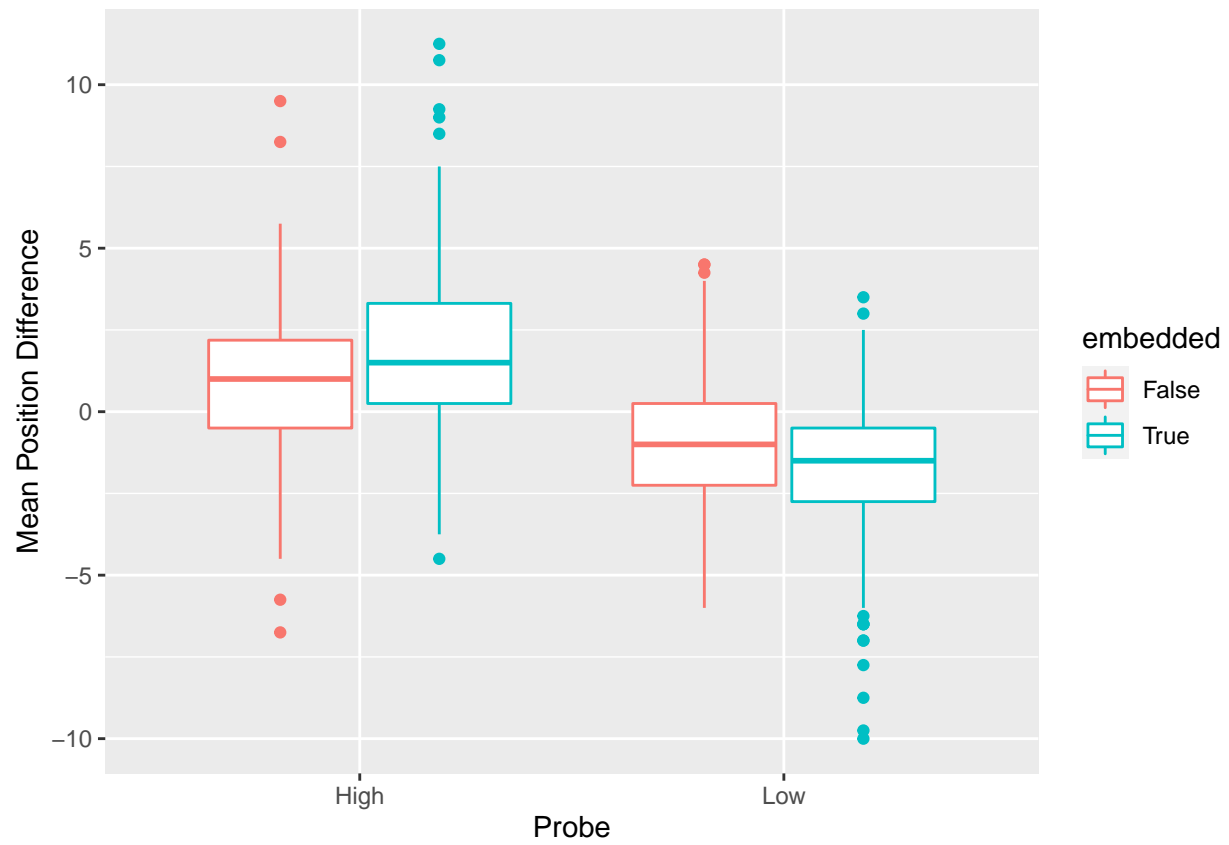
Figure 1. Boxplot of speech perception differences between words and vowels
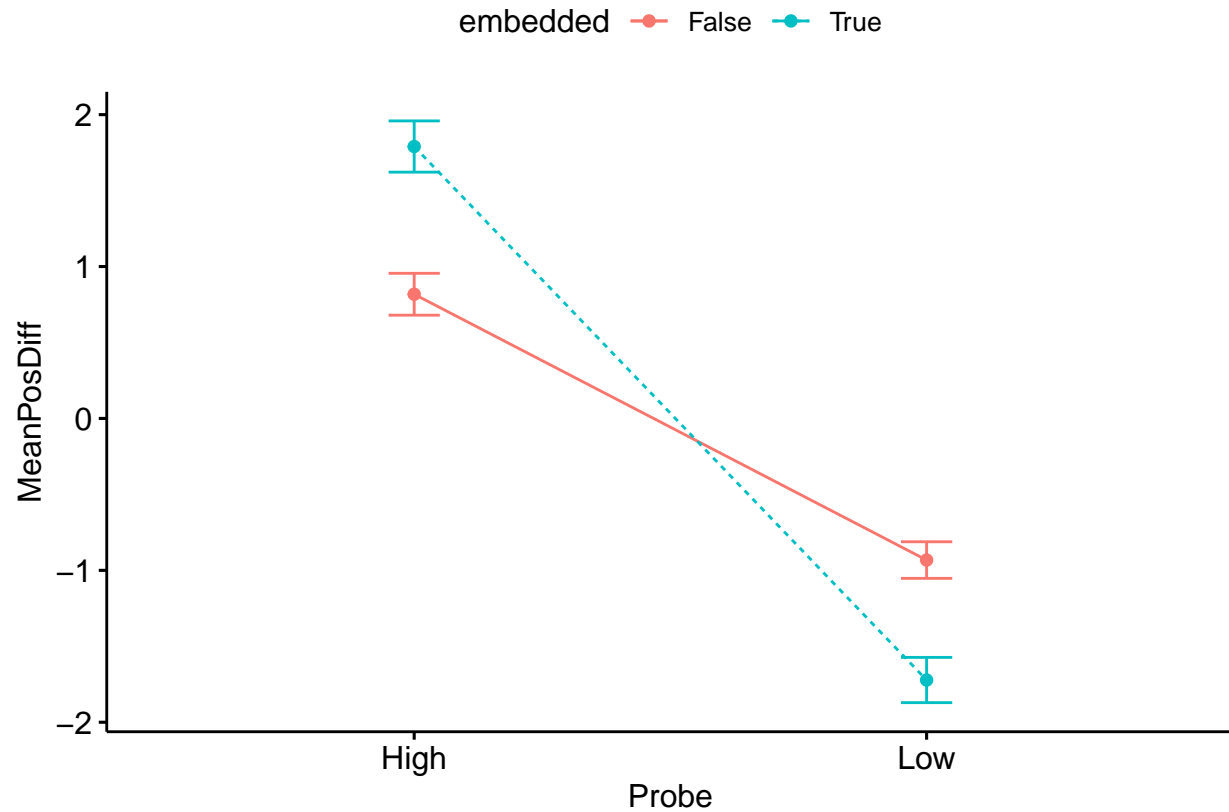
Figure 2. Difference in context effects for words and vowels
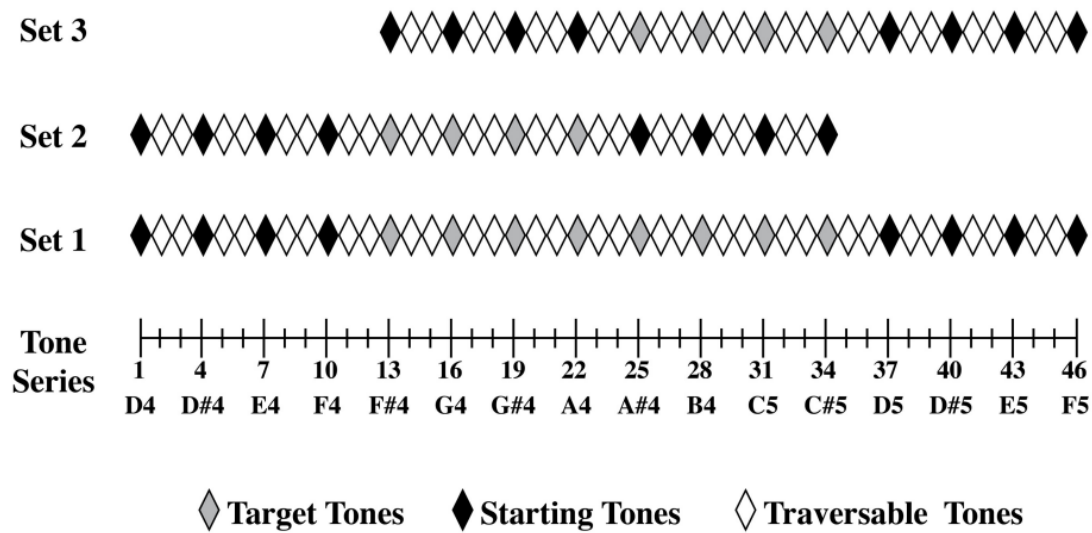

Figure 3. Diagram of the range of tones used for the probe and target tones