The effects of musical training on speech perception in noise

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Background

Congenital amusia is a fascinating disorder that originates as a musical deficit disorder. This disorder is more commonly known as 'tone-deafness', however, it encompasses so much more than the commonly assumed inability to sing in tune. People with amusia have been known to have difficulties following or maintaining a steady rhythm, recognizing familiar melodies without the aid of lyrics, perceiving pitch, and many other musical abilities without showing any signs of auditory processing problems or learning disabilities (Stewart, 2011). Due to the increasing interest in this disorder a battery was generated in order to more accurately and efficiently identify whether an individual has amusia. In short, the Montreal Battery Evaluation of Amusia (MBEA) is an extensive battery test that evaluates an individual's ability to process music. It requires the individual to distinguish and indentify differences in a series of melodic sequences that contain varying important components such as key and rhythm.

In a familial investigation, the amusia disorder has a confirmed a genetic component according to Peretz, Cummings, and Dubé (2007). They found that individuals with amusia were more likely to have relatives with amusia than those without amusia. It has also been determined that the prevalence of the amusia disorder is about 3 percent of the general population, which greatly limits the sample selection; however, knowing that a genetic connection exists can aid in the identification of more possible participants for further investigations.

In relatively new research, many have taken an interest in the specific musical deficits of the disorder. Foxton, Dean, Gee, Peretz, and Griffiths (2004) explored the fine-grained traits and boundaries of pure tone pitch perception in people with this disorder. However, other investigations have begun to question its specificity to the musical domain and wonder whether amusia could have an effect in other domains, such as language (Liu, Patel, Fourcin, & Stewart, 2010; Hutchins, Gosselin, & Peretz, 2010; Patel, Foxton, & Griffiths, 2005). More specifically, the connections between the amusia disorder and speech perception have been of interest because of the intricate characteristics of speech that convey meaning, such as stress and intonation. Liu et al. conducted a study examining the perception abilities of the intonation qualities (rising and falling pitch changes) of speech within people with amusia. They determined that individuals with amusia had difficulties discriminating, identifying, and imitating statement versus question stimuli. In another study, individuals with amusia were reported to have normal pitch perception abilities for speech when focus-shift speech stimuli were used. These focus shift stimuli placed contrasting information by placing a pitch change, or stress, on a particular word for emphasis (for instance “The DOG is in the yard.” versus “The dog is in the YARD.”).

Behavioral measures from individuals with amusia that expressed no problems understanding pitch changes in speech were all made in a quiet background (the absence of noise). A different result might occur when speech is heard in a noisy background.

Studies have shown using typical listeners (ones without amusia) that listening to normally intoned speech (a varying voice pitch or fundamental frequency) and monotone speech (produced with a flattened fundamental frequency) are equally intelligible in quiet. However, when normally intoned and monotone sentences are presented in a noisy background, the ability to repeat back words in a sentence is poorer when using monotone sentences than normally intoned sentences. Performance drops even more if the incorrect patterns of voice pitch cues are presented (modulated according to an equation rather than the natural rules of language). The poorer performance in the monotone or the incorrect pitch conditions is attributed to incorrect stress which makes it difficult for individuals to parse the natural breaks in words and segments of sentences.

This leads to our current hypothesis, stating that those with amusia would be less affected by voice pitch modifications than typical listeners because they do not focus as intently on the changes in voice pitch for speech comprehension. However, we also hypothesize that those with years of musical experience to be more affected by voice pitch modifications than typical listeners or even those with amusia because individuals with musical training might have had exposure to a larger variety of heightened perception for pitch changing variances and therefore would depend greatly on the specific voice pitch cues provided in speech for comprehension.

We intended to include a group of individuals with amusia in our study, but due to the low prevalence of amusia it was difficult to find individuals with this condition; therefore this study only includes participants with and without musical training

Participants

There were 12 total participants: 3 strong musically trained individuals, having 10 years or more of musical training including college level training, 3 musically trained individuals, having 10 years or more of musical training and no college training, 3 musically trained individuals with 1-10 years of musical training and 3 individuals with zero musical training. All participants were between the ages of 20 and 30 years and were screened at 20 dB HL for normal hearing. The participants also reported no history of neurological or physiological disorders.

Table 1. Displays participant descriptions regarding musical training, perfect pitch, years of musical training and a general report of the participant's musical background.

Participant	Musical Training?	Perfect Pitch?	Years of training?	Description
1	Yes	No	14	Started at age 9, college music major
2	Yes	No	14	Started at age 10, college music major
3	Yes	No	14	Started at age 10, college music minor
4	Yes	No	13	Started at age 5, no college training
5	Yes	No	12	Stared at age 5, no college training
6	Yes	No	11	Started before age 10, no college training
7	Yes	No	8	Started at age 10, no college training
8	Yes	No	5	Started at age 8, stopped before high school
9	Yes	No	4	Training through middle school
10	No	No	0	Some training in middle school
11	No	No	0	No training
12	No	No	0	No training

Stimuli

Speech stimuli were digitally recorded from five females who were native American English speakers. There were a total of 180 sentences, each containing five keywords which were used to score participant responses. The 180 sentences were divided into six equal conditions: natural speech/unmodified, flattened voice pitch/'mono-tone', exaggerated/'baby-talk', and modified voice pitch which was frequency modulated at modulation rates of 2.5 Hz and or 5 Hz.

All speech samples were naturally produced by five speaker and the modifications to the voice pitch were made using the program PRATT. The natural speech stimuli were unchanged for the experiment. Flattened voice pitch/'mono-tone' speech stimuli were generated by flattening the voice pitch at the median pitch. Exaggerated/'baby-talk' speech stimuli were generated by multiplying the voice pitch by a factor of 1.75. Inverted speech stimuli were created by computing the inverse of the original voice pitch and replacing it with the new inverted pitch pattern. The modified voice pitch stimuli were generated by replacing the original voice pitch pattern with a cyclical sinusoidal pitch pattern. These new pitch patterns were generated at 2.5Hz and 5Hz.

All speech sentences were then combined with speech-shaped noise. The noise spectrum was created using the spectrum of the natural/unchanged speech samples.

Speech stimuli used in this investigation are the same stimuli used in a prior study conducted by Miller, Schlauch, and Watson (2010).

Methods

First, participants completed an online test of musical ability (http://www.brams.umontreal.ca/amusia-demo/, created in the laboratory of Isabelle Peretz at the University of Montreal) which examined the individual's musical abilities. This test contained three different parts. The first two involved pitch detection and the third was a temporal test. The first pitch detection test required individuals to identify whether a melody contained a "wrong" note, as if the note did not belong. The second pitch detection test required individuals to identify whether the melody contained a "sour" note, as if the note sounded out of tune. The temporal test required individuals to identify a strange time change, as if a note in the melody was "off beat." In each of the subtests, participants pushed a button indicating 'yes' if they detected one of these possible variances. The test lasted about 15 minutes. Participants listened to the stimuli for the test over earphones with the volume set to a comfortable level. The test was completed in 15 minutes.

Second, participants completed a speech understanding test. In a sound-isolated booth, participants listened to the generated 180 speech sentences in noise. Each sentence was presented via supra-aural earphones and monaurally, in the right ear. Participants were required to repeat aloud what they heard as well as type their responses, for a written record, to the best of their ability. After each sentences participants pushed a button to initiate the proceeding sentence. A researcher was in the booth with the participants to score the oral responses.

Results

The results of the online test of musical ability were generated automatically based on the participant's responses within the program. Overall performance scores were recorded, as well as scores for each subtest. Table 2 shows overall scores for each participant as well as scores for the pitch subtest, one of primary interest for this study.

Sentence Understanding

Participant responses were graded on how well they were able to repeat the speech sentences, which was based on the number of correctly produced keywords. All data were calculated in terms of percent correct (number of identified keywords / total number of keywords) and averaged. Results are also shown in Table 2.

Table 2. Displays participant scores in terms of percentages from the online amusia test, including the pitch specific section within that online test, as well as the scores obtained from each participant from the listening test. The scores from the listening test are divided amongst the six different stimuli conditions.

Participant	Flat	RV	EX	F5	F2	NNN	Online Test score	Online Test score (pitch)
1	52.6	50.6	41.3	38	39.3	55.3	90	96
2	35.3	27.3	34	28	28.6	46	86	79
3	47.3	34.6	49.3	43.3	37.3	58.6	88	92
4	46	40.6	37.3	45.3	44.6	58.6	95	92
5	44	28.6	44.6	33.3	28	60.6	90	96
6	58.6	53.3	51.3	47.3	42.6	54.6	94	92
7	42.6	21.3	43.3	30	28	56.6	88	88
8	58.6	44.6	45.3	40.6	46	70	90	96
9	54.6	36.6	42	28	28.6	62	88	100
10	48	41.3	39.3	33.3	39.3	60	74	75
11	46	33.3	42	39.3	29.3	58	83	92
12	48.6	40.6	42.6	39.3	38	51.3	74	58
Ave.	48.5	37.7	42.7	37.1	35.8	57.6	86.7	88

Correlation calculations were made and graphs were generated to further investigate relationships in the data. Figure 1 depicts a positive correlation between years of musical training and performance on the online test of musical ability. This analysis found that performance on the online test increases with years of musical training. The coefficient of determination, R^2, confirms this prediction in stating that over half of the variance amongst the online tests scores can be accounted for based on the number of years of musical training and experience.

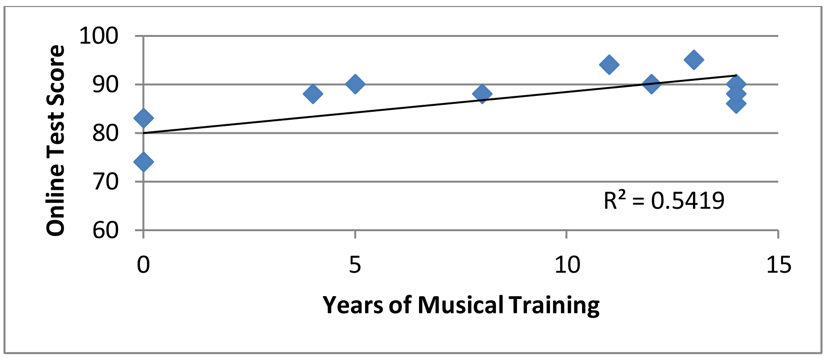

Figure 1. Correlation between the number of years of musical training and scores from the online test from each participant.

Figures 2 and 3 were generated to illustrate additional possible correlations within the data by comparing participants' online test scores to their speech understanding scores based on stimuli modifications. No significant correlations were found between any of the speech conditions and the scores on the online test of musical ability.

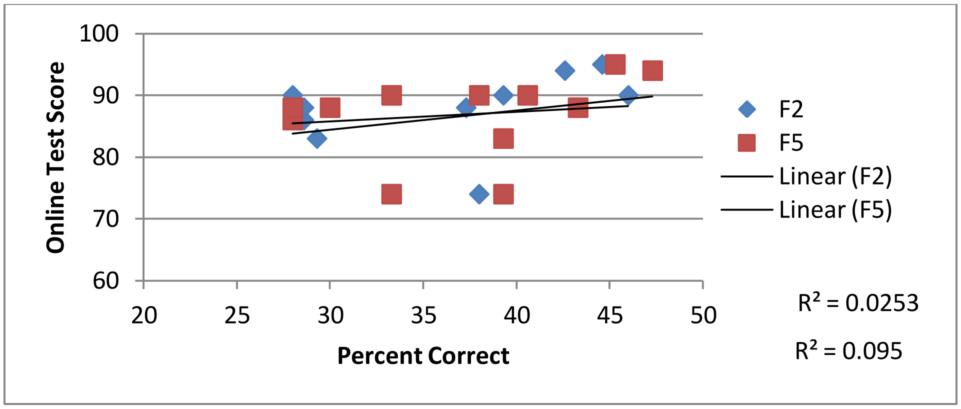

Figure 2. Correlation of online test scores of musical ability and scores from the speech understanding test from each participant. Specifically depicting the F2 and F5 frequency modulated stimuli.

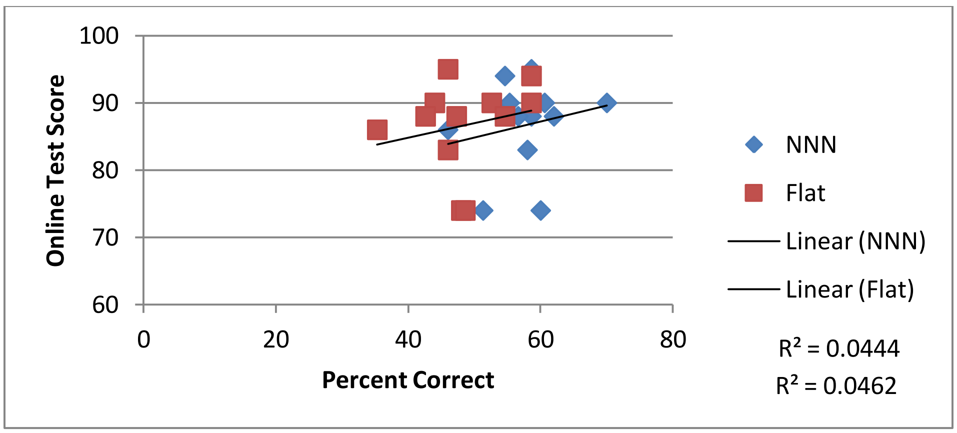

Figure 3. Correlation of online test scores of musical ability and scores from the speech understanding test from each participant. Specifically depicting the natural (NNN) and flattened/'mono-tone' (Flat) stimuli.

Comparison to Prior Research

In the previously mentioned investigation by Miller et al. (2010), similar results were established within the speech understanding component. Table 3 illustrates the speech understanding scores obtained in this study and the one conducted by Miller et al. These scores were obtained by using the average unchanged stimuli (NNN) score as a reference and calculating the difference in relation to the other five stimuli conditions.

Table 3. Displays the difference in average percent correct, from the natural speech stimuli (NNN) across the six stimuli conditions.

Stimuli Condition	Miller et al. Score (difference)	This Study (difference)
NNN	0	0
Flat	10.7	9.1
EX	12.2	14.9
RV	21.1	19.9
F2	22.2	21.8
F5	21.8	20.5

Discussion and Conclusions

When comparing the online test scores of musical ability to the speech understanding measures no significant differences were observed. That is, individuals with little or no musical training did not perform better when abnormal pitch patterns were presented than individuals with musical training when listening in noise. This study did find that there was a significant correlation in the number of years of musical training and the online test of musical ability. This suggests that the online test of musical ability was able to accurately represent differences in musical training between participants.

The absence of a significant link relating the level of musical ability and the speech understanding scores in noise for typically intoned and abnormal intonation contours could have several origins. One could be the lack of power within the study. Acquiring a larger sample size of participants with a wider range of musical training, and could supply a stronger pool of data to analyze. Another explanation could be that perhaps musical training does not affect performance in understanding speech in noise because everyone has experience perceiving speech in noise.

Directions for future studies may be to investigate individuals with absolute pitch and compare their results to those of a typical listener who may listen more globally. Another option of investigation would be to incorporate individuals with amusia to learn if their deficit is unique to music or also has an effect on speech understanding in noise.

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