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Listening to classical music can (slightly) improve stereo-acuity in normal observers

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Abstract

***Aims*: To test for improvements in stereo-acuity, relative to pre-test measurements, after listening to pieces of classical music and whether any stereo-acuity improvement tended to be found following enjoyable stimuli.**
***Methods:* In a double-masked repeated measures study 15 participants with normal vision had their stereo-acuity measured to threshold using the Frisby stereo-test on five occasions: prior to exposure to the test stimuli, and then on four subsequent occasions each time after listening to a particular stimulus for 10 minutes. Participants also rated their enjoyment of each stimulus.**
***Results:* After listening to each of the musical stimuli stereo-acuity was improved significantly when compared with the pre-test level, but listening to the control white noise stimulus produced no significant improvement in stereo-acuity. There was no significant difference between any of the musical pieces in either their effect on stereo-acuity or enjoyment rating. The white noise stimulus was found to be significantly less enjoyable than any of the musical pieces. This suggested that the effect of the music was possibly due to a change in participants' mood.**
***Conclusion:* Our findings for stereo-acuity are consistent with previous studies that have shown that listening to classical music can improve performance in spatial tasks.**

Key words: Mozart effect, Music, Stereo-acuity

Introduction

In 1993 Rauscher *et al.*[1] reported what has become known as the Mozart effect. They found that participants who had listened to 10 minutes of Mozart's Sonata for 2 Pianos in D major (K448) performed better in spatial tasks taken from the Stanford-Binet intelligence scale[2] than when they listened to either a relaxation tape or silence. One example of a spatial task is the Paper Folding and Cutting task, which some readers may have performed during intelligence tests. Here the participant is shown a diagram of a piece of paper undergoing a sequence of folds and cuts and then asked to choose, from a set of five pictures, the one that depicts how the paper would now look if unfolded.[3,4] Good performance in the task therefore involves a degree of skill in spatial imagining and/or reasoning. The improved performance found in such tasks appeared to last for only 10 minutes after exposure to Mozart. Rauscher *et al.*[1] also concluded that this Mozart effect was due to the music alone and not to any arousal factor.

Others have replicated the finding but suggested, unlike Rauscher *et al.*,[1] that the Mozart effect works via changing arousal and/or mood. Thompson *et al.*[5] asked one group of participants to perform spatial tasks after 10 minutes of either listening to the Mozart K448 stimulus or sitting in silence, and they showed the Mozart effect. Another group was tested after either 10 minutes of listening to Albinoni's Adagio in G minor for Organ and Strings (a more sombre piece of music) or sitting in silence; here there was no significant difference between the two conditions. The participants were also asked to rate their enjoyment of the piece of music and to rate their mood and arousal. The pieces were found to be significantly different on all these measures: for example, for mood the Mozart was significantly less depressing than the Albinoni, and the Mozart was significantly more enjoyable than the Albinoni. Importantly, when these measures were factored out of the analyses the Mozart effect essentially disappeared. This led Thompson *et al.*[5] to conclude that the Mozart effect is 'an artifact of arousal and mood'. Some of these ideas are investigated in this paper. It must be noted that there has been controversy over replication of the Mozart effect and the debate continues as to whether the effect exists at all and, if it does, what the mechanisms are by which it works.[4,6–9]

In the most general terms stereo-tests could be regarded as spatial tasks, as they require the observer to make judgements about the spatial arrangement and depth of surfaces in the world. Given that some studies have shown that listening to music can improve performance in such tasks, the experiment presented examines whether stereo-acuity, as measured to threshold with the Frisby stereo-test, is improved by listening to the Mozart piece used in the Rauscher *et al.*[1] study, to another piece by Mozart and to the piece by Albinoni discussed above. Therefore performance in the

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Frisby stereo-test after listening to various classical pieces was compared with performance both before the test and after listening to a control white noise stimulus. Participants were asked to rate their enjoyment of each piece to see whether this predicted performance.

Methods

Fifteen volunteer participants, aged between 19 and 23 years, took part in the study. To improve group homogeneity, and because they were more readily available within the department, only women were tested in this study. All participants had at least 6/6 uncorrected or corrected vision and heterophoria of less that 10 dioptres assessed by cover test and prism cover test. All had sensory fusion, measured at near and distance with Worth Lights. Motor fusion was assessed with the prism fusion range, with all participants able at near to overcome at least 35^{Δ} base-out prisms and 15^{Δ} base-in, and for distance 15^{Δ} base-out and 5^{Δ} base-in.

Before the test the participant's stereo-acuity was measured to threshold using the 1.5 mm plate of the Frisby stereo-test. Starting at 80 cm, the viewing distance of the test was increased by 10 cm if the participant chose the correct target quadrant in at least two of three presentations. The last distance at which this criterion was achieved was noted. We also measured the inter-pupillary distance of each participant to calculate the thresholds in seconds of arc.

In a repeated measures design the stereo-acuity of each participant was then measured after listening to each of the stimuli. The noise or music stimuli, each of 10 minutes' duration, were copied onto one audio CD in an order known only to the second author until the experiment was complete. The study was therefore double-masked; this was to avoid any bias in the subsequent measurement of stereo-acuity by the first author that may even unwittingly have occurred had she known what stimulus had just been listened to by the participant. To create stimuli of the same duration the musical pieces were extended to 10 minutes as necessary by repeating the excerpt from the start using audio editing software. Audible 'beeps' of middle C were used to mark the start and end of each stimulus. Many other studies have used stimuli constructed in a similar way.

The stimuli on the CD were:

1. *White noise:* A stimulus containing all frequencies in random fluctuation that sounds like a constant 'shhh'. This stimulus had an even intensity that was about the average of the other stimuli.
2. *Mozart's Sonata:* First movement of the Sonata for 2 Pianos in D major (K448) by Mozart played by Murray Perahia and Radu Lupu (original duration 8 minutes 24 seconds) from the 1990 Sony Classical CD 'Music for piano, four hands' (Sony Classical SK39511).
3. *Albinoni's Adagio:* Adagio in G minor by Albinoni, played by La Grande Ecurie at la Chambre du Roy, conducted by Jean-Claude Malgoire (original duration: 8 minutes 24 seconds). Taken from the 1997 Sony CD 'Silence' (SONYTV35CD).
4. *Mozart's Concerto:* Second movement (Andante) of Mozart's Piano Concerto number 21 (K467) played by Robert Casadesus with the Cleveland Orchestra conducted by George Szell (original duration 7 minutes 45 seconds). Taken from the same CD as (3).

The stimuli were presented via headphones connected to a portable CD player, with volume fixed at the middle setting for all stimuli and participants. The stimuli were played in a random order, different for each participant, by using the random play facility on the CD player. The participant controlled the CD player and was asked to start the playing of each stimulus when she was ready and to pause the CD when she heard the 'beep' at the end of the track. The first author noted down each stimulus number from the CD player.

After the stereo-acuity had been measured the participant was asked to rate her enjoyment of the stimulus by making a mark on a horizontal 10 cm line, the left-hand end representing 'very enjoyable' and the right-hand end 'very displeasurable'. Again the first author was careful not to observe the rating as it may have indicated the nature of the stimulus and biased her assessment of later stereo-acuities. Written consent for the data to be used by the researchers was obtained at the end of the experiment. The experiment lasted about 1 hour.

Results

The stereo-acuity of each observer for each of the five conditions was ascertained using the formula provided with the Frisby stereo-test, using each observer's inter-pupillary distance and the greatest viewing distance at which the target in the 1.5 mm plate could be detected. Table 1 shows each participant's stereo-acuity in the pre-test, and after listening to 10 minutes of white noise, Mozart's Sonata, Albinoni's Adagio and Mozart's Concerto. Non-parametric statistical analyses were performed, as for each condition the histograms of the data were negatively skewed. Therefore at the bottom of each column in Table 1 the median and the upper and lower quartiles for each condition are shown. Fig. 1 shows a box-and-whisker plot of the data. Each of the boxes covers the inter-quartile range of the data, containing 50% of the values, with the line across each box indicating the median value for that condition. The lower and upper whiskers show the extent of the 10% and 90% ranges of the data, respectively.

From Table 1 and Fig. 1 it can be seen that after listening to all stimuli there is a modest improvement, at best to 3.1 seconds of arc, in stereo-acuity over that obtained in the pre-test (5.5 seconds of arc). Stereo-acuities obtained after listening to the white noise show the least improvement (to 4.3 seconds of arc).

The data in Table 1 were analysed in a Friedman's χ^2_r test with five levels: the pre-test, white noise, Mozart's Sonata, Albinoni's Adagio and Mozart's Concerto. This showed a significant effect of stimulus on the stereo-acuity ($\chi^2_r = 17.373$, $p < 0.01$, d.f. = 4). However, this analysis only indicates that at least two of the stimuli

Table 1. Stereo-acuities in seconds of arc of the 15 participants under the five conditions

Participant	Pre-test	White noise	Mozart's Sonata	Albinoni's Adagio	Mozart's Concerto
1	6.4	4.3	6.4	4.3	4.3
2	3.5	4.8	2.8	3.1	3.9
3	16.7	13.5	16.7	9.4	13.5
4	3.5	1.9	3.9	1.8	2.8
5	7.4	2.4	4.3	2.6	2.2
6	3.4	3.1	2.6	2.3	3.4
7	14.1	4.0	3.2	3.2	3.2
8	5.5	3.9	3.5	2.8	3.5
9	8.7	12.5	10.3	7.4	6.4
10	15.9	12.9	10.6	12.9	8.9
11	5.5	4.3	3.9	4.3	5.5
12	3.5	3.5	2.2	2.6	5.5
13	4.2	6.0	3.7	4.7	4.2
14	6.4	4.9	4.3	3.1	2.4
15	3.5	3.9	3.1	3.1	2.4
Median	**5.5**	**4.3**	**3.9**	**3.1**	**3.9**
Lower quartile	**3.5**	**3.7**	**3.1**	**2.7**	**3.0**
Upper quartile	**8.0**	**5.4**	**5.3**	**4.5**	**5.5**

produced differences in stereo-acuity. In order to test the source of these differences a series of Wilcoxon matched-pairs signed-ranks tests were conducted. The results of these are summarised in Table 2.

From the top row of Table 2 it is evident that all the pieces of music produced significantly better stereo-acuities than the pre-test value. The stereo-acuities after listening to white noise were not significantly different from the pre-test value (n.s.). The second row of Table 2 indicates that only the stereo-acuities obtained after listening to Albinoni's Adagio were significantly better than those obtained after listening to white noise. The other two pieces of music produced better stereo-acuities than those obtained after listening to white noise but the differences were not statistically significant. However, the last two rows of Table 2 show that overall there were no significant differences between the stereo-acuities obtained after listening to any of the three music stimuli.

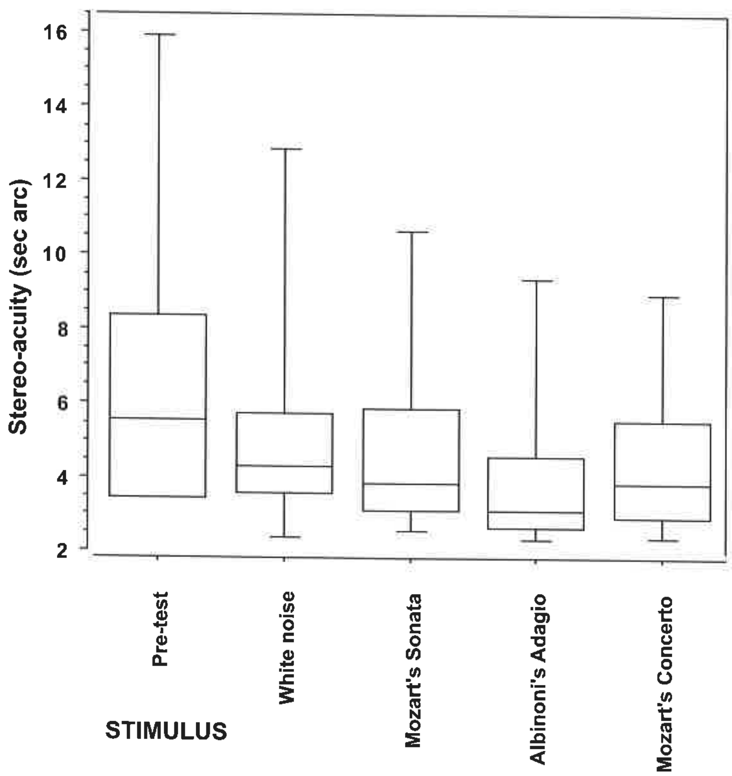

Fig. 1. Box-and-whisker plots of the stereo-acuities of the 15 participants in the pre-test and after listening to 10 minutes of the stimulus indicated on the abscissa. Each of the boxes covers the inter-quartile range of the data, containing 50% of the values, with the line across each box indicating the median value for that condition (see Table 1). The lower and upper whiskers show the extent of the 10% and 90% ranges of the data, respectively.

Table 2. The difference in seconds of arc in stereo-acuity between the medians of two conditions and the results of separate Wilcoxon signed-ranks tests

	White noise	Mozart's Sonata	Albinoni's Adagio	Mozart's Concerto
Pre-test	1.2 n.s.	1.7*	2.4**	1.7*
White noise	–	0.5 n.s.	1.2**	0.5 n.s.
Mozart's Sonata	–	–	0.7 n.s.	0.0
Albinoni's Adagio	–	–	–	0.7 n.s.

*$p < 0.05$; **$p < 0.01$; n.s., not significant.

Table 3. Enjoyment ratings (out of 10) for the 15 participants of the four stimuli

Participant	White noise	Mozart's Sonata	Albinoni's Adagio	Mozart's Concerto
1	1.7	8.4	5.9	9.7
2	2.0	8.7	5.0	6.5
3	1.7	9.3	8.5	8.6
4	0.0	8.3	7.7	4.7
5	1.9	8.3	7.0	8.9
6	1.7	9.4	9.9	9.4
7	3.3	7.7	6.7	6.0
8	1.7	5.1	7.9	5.3
9	0.1	2.4	3.4	4.0
10	0.6	2.5	5.2	4.4
11	0.1	5.3	5.7	7.4
12	2.1	7.7	6.1	7.1
13	0.7	5.7	2.2	4.8
14	1.5	5.0	5.7	5.4
15	0.7	9.4	6.4	9.4
Median	**1.7**	**7.7**	**6.1**	**6.5**
Lower quartile	**0.7**	**5.2**	**5.5**	**5.1**
Upper quartile	**1.8**	**8.6**	**7.4**	**8.8**

The enjoyment ratings of the four stimuli are shown in Table 3 for each participant, following the same format as Table 1. The higher the enjoyment rating the more enjoyable was the stimulus. The enjoyment ratings of the white noise stimulus were not normally distributed and are shown in Fig. 2 as a box-and-whisker plot of the data in Table 3. The white noise stimulus was not very enjoyable and the three musical stimuli were on average given very similar and higher enjoyment ratings. Wilcoxon matched-pairs signed-ranks tests showed that all the musical stimuli were rated as significantly more enjoyable than the white noise (all $T = 0.0$, $p < 0.001$). Conversely Wilcoxon matched-pairs signed-ranks tests showed that none of the enjoyment ratings of the musical stimuli were significantly different from each other (smallest $T = 36.5$, n.s.).

After the experiment was completed a paper was published[10] that suggested the Mozart effect should occur mostly in non-musicians. Consequently the participants in our study were contacted and asked whether they considered themselves musical (for example: trained on a musical instrument, still playing a musical instrument) or not. Only 5 of the 10 participants classed themselves as musicians. We tested whether the music in our study had improved the stereo-acuity relative to the pre-test level mainly in the non-musicians. As the data were not normally distributed, this was evaluated using separate Mann–Whitney U-tests for each of the musical stimuli, using each participant's improvement, in seconds of arc, relative to their pre-test value. This showed that any stereo-acuity improvement following exposure to any stimulus was not significantly different between the musicians and non-musicians for any of the stimuli (smallest $U = 15.0$, $p = 0.2207$). However, it is possible that a study designed specifically to test this hypothesis, with more stringent criteria for assignment of participants to the two groups, might have found a difference.

Discussion

Fig. 1, Table 1 and Table 2 show that listening to classical music for 10 minutes tends to significantly improve stereo-acuity over a pre-test measure. Listening to white noise leads to no such improvement. Only after listening to the Albinoni's Adagio was the stereo-acuity better than that obtained after listening to white noise. However, it was also found that there was no difference between the stereo-acuities obtained after listening to any of the pieces of music, suggesting that all classical music had similar effects. The findings for the Mozart pieces are consistent with the original report of the Mozart effect.[1] However, the finding that Albinoni's Adagio also had a positive effect on stereo-acuity is at odds with previous findings for this piece.[5] Our findings for the enjoyment ratings for the Mozart pieces (Fig. 2, Table 3) are consistent with those of Thompson *et al.*[5], but interestingly our participants rated Albinoni's Adagio with a similar level of enjoyment as the Mozart pieces. This may explain why listening to this piece also improved stereo-acuity and why our findings for the Adagio are unlike those previously reported.

The differences between conditions are only modest even when significant, being only at most about 2.5 seconds of arc. This change may therefore appear clinically unimportant. However, it is worth noting that

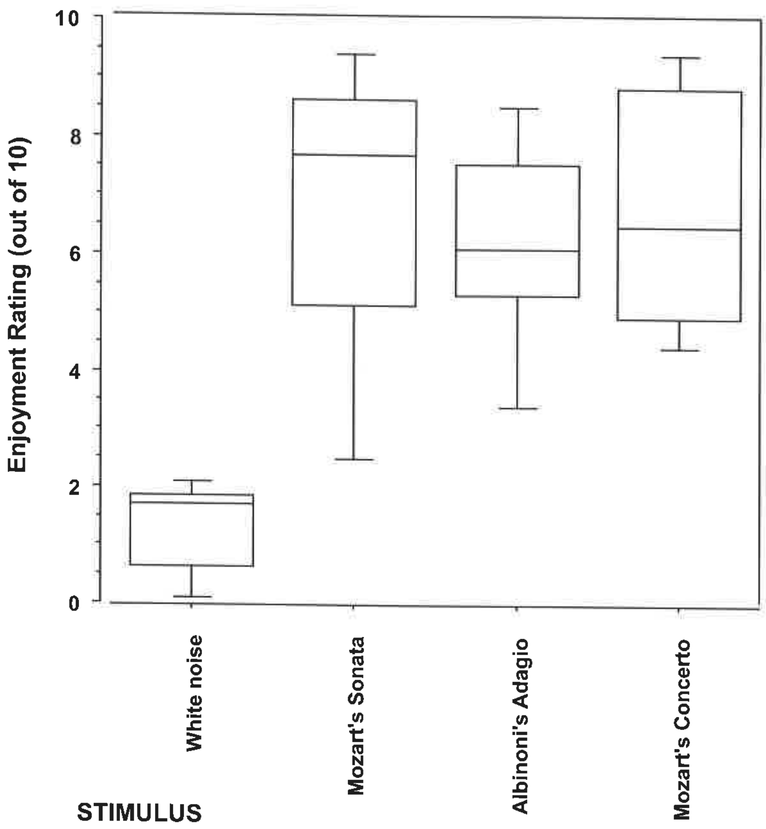

Fig. 2. Box-and-whisker plots of the enjoyment ratings for the 15 participants of each of the stimuli indicated on the abscissa. The higher was the enjoyment of the stimulus, the higher the rating. The boxes and whiskers follow the same format as in Fig. 1 (see Table 3).

the improvements appeared after listening to music for only 10 minutes, and in a normal group who already had very good stereo-acuity with very little room for improvement. It might therefore be interesting to conduct similar studies on groups who have weaker stereopsis and perhaps after greater exposure to the musical stimuli. For example, some studies have shown benefits of repeated listening to music on children's cognitive development.[11,12]

Only women were tested in this study, mainly for convenience. Subsequent to our data collection it has been reported that listening to music may produce more benefit in terms of improving spatial reasoning performance in females than in males.[13] It would therefore be of interest to look for any gender differences in stereo-acuity changes as reported here.

In contrast to the active listening as tested in our study there has also been previous research looking at the effect of background music on emotion and performance.[14,15] Therefore the effect of music, and type of music, played in clinical waiting rooms on subsequent tests might also be an area for future research.[16]

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