SCIENTIFIC REPORT

Improved automated perimetry performance following exposure to Mozart

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Aim: To evaluate the performance on automated perimetry (AP) after listening to a Mozart sonata in normal subjects naive to AP.

Methods: 60 naive normal subjects underwent AP (SITA 24-2). The study group (30 subjects) underwent AP after listening to Mozart's Sonata for Two Pianos in D Major and the control group (30 subjects) underwent AP without previous exposure to the music.

Results: The study group had significantly less fixation loss, false positive, and false negative rates compared to controls ($p < 0.05$).

Conclusion: Listening to Mozart seems to improve AP performance in normal naive subjects.

Music has been used in the medical field for many different purposes: to reduce preoperative anxiety, for rehabilitation of severe brain injured patients during coma recovery, to reduce pain after gynaecological surgery, to decrease agitated behaviour of the demented elderly, and to strengthen coping skills in communication, socialisation, and self expression in patients with psychiatric disorders, to give just a few.^{1–5} From the many different composers and musical styles, Wolfgang Amadeus Mozart is by far the most studied one. Previous studies have shown that exposure to complex music induces improved spatial-temporal learning in rats.⁶ Listening to a Mozart piano sonata also produced significant short term enhancement of spatial-temporal reasoning in college students.⁷ Sarnthein *et al* reported the presence of right frontal and left temporo-parietal electroencephalogram (EEG) coherent activity induced by listening to Mozart, which carried over into the spatial-temporal tasks in some subjects.⁸ These improved abilities were all labelled as the "Mozart effect."⁹

Automated perimetry (AP) is a psychophysical testing that evaluates visual field for neurological disorders and diagnosis and follow up of glaucoma patients. A white stimulus is projected on a white background and the patient is asked to press a response button whenever the stimulus is perceived. The reliability of AP is dependent upon patient cooperation.

The purpose of the study was to evaluate the performance of young subjects naive to AP for visual field testing after brief exposure to a Mozart sonata.

METHODS

The study was approved by the institution ethics committee and the procedures followed were in accordance with the Helsinki Declaration of 1975, as revised in 1983. Sixty subjects enrolled in the study. All subjects underwent a complete eye examination including best corrected visual acuity (VA), refraction, biomicroscopy, ophthalmoscopy, applanation tonometry, and only those with a normal testing

were included. Subjects with refraction beyond +5.00 sph or –5.00 sph, VA less than 20/20, intraocular pressure greater than 21 mm Hg, and cup to disc ratio greater than 0.5 were not included in the study. The subjects enrolled were volunteers, third year students from the medical school. The mean age was 22.6 (SD 1.8) for the study group and 22.9 (2.1) for controls. In both groups, sex distribution was 15 males and 15 females. Ethnicity was similar in both groups and comprised 21 subjects of white race and nine Asians in the study group and 23 of white race and seven Asians in the control group. Mean refractive spherical equivalent for the right eye was –0.48 (1.5) D in the study group and –0.5 (1.3) D in the control group. None of them had ever undergone automated perimetry.

Subjects were assigned to one of two groups so that at the end of the enrolment period both groups would not differ in terms of age, sex, and ethnicity distribution. The study group was exposed to the first 10 minutes of Mozart's Sonata for Two Pianos in D Major (K.448) immediately before visual field testing and the control group had no previous exposure to the music. Subjects from the study group used a headset. The control group stayed in a quiet room for 10 minutes before visual field testing. All subjects underwent AP with the Humphrey field analyser II (model 750, Zeiss-Humphrey Systems, Dublin, CA, USA), program SITA 24-2 in the right eye only. After brief instructions as to how to proceed with the examination, the refractive error was corrected and the perimetry was initialised. The time between completion of the sonata and the conclusion of the visual field testing could not last more than 10 minutes. A masked technician stayed in the room throughout the examination and was unauthorised to interrupt the test until completion of the examination.

For each group, the number of fixation losses, false positive errors, false negative errors, mean deviation (MD), pattern standard deviation (PSD), the number of points depressed at the $p < 5\%$ level in the total deviation (TD) probability plot, the number of points depressed at the $p < 5\%$ level in the pattern deviation (PD) probability plot and the test duration were averaged and compared between the groups. Mann-Whitney test was used to compare differences between study group and controls. A p value of less than 0.05 was considered to be of statistical significance.

RESULTS

Table 1 shows the comparison on the AP performance between the groups. The study group had significantly less fixation loss, false positive error, and false negative error than controls ($p < 0.05$). The MD and PSD values and the number of points depressed at the $p < 5\%$ level in the TD probability

Abbreviations: AP, automated perimetry; FL, fixation loss; FP, false positive errors; MD, mean deviation; PD, pattern deviation; PSD, pattern standard deviation; TD, total deviation; VA, visual acuity

Table 1 Comparison of the performance in automated perimetry between groups

	Study group	Controls	p Value*
Fixation losses	0.01 (0.03)	0.19 (0.24)	<0.0001
False positive errors	0.006 (0.008)	0.02 (0.03)	<0.003
False negative errors	0.002 (0.005)	0.02 (0.02)	0.0002
MD	-1.2 (0.7)	-1.1 (1.0)	0.854
PSD	1.3 (0.2)	1.7 (0.6)	0.183
Points p<5% (total deviation)	6.5 (6.8)	6.7 (7.1)	0.944
Points p<5% (pattern deviation)	2.0 (2.0)	4.6 (3.0)	0.002
Test duration (minutes)	4.7 (0.4)	4.9 (0.5)	0.108

MD, mean deviation; PSD, pattern standard deviation.

*Mann-Whitney test.

plot did not differ between groups, nor did the test duration. The number of points depressed at the p<5% level in the PD probability plot for the control group was significantly higher than that for the study group.

DISCUSSION

Subjects exposed to the Mozart sonata before visual field testing performed better than controls with regard to reliability parameters. In order to ascertain that a visual field test is likely to contain reliable diagnostic information, three indices of reliability were defined—namely, fixation loss (FL) rate, false positive errors (FP), and false negative errors (FN). The FL rate is a measure of how steadily the patient gazes at the fixation stimulus.¹⁰ The FP score measures the tendency of a patient to press the response button when no stimulus is presented.¹⁰ In the SITA strategy, the FP rate is calculated as a function of patient responses made during times that no response is expected.¹⁰ The FN measures the tendency of a patient to fail to press the response button when a distinctly visible stimulus has been presented.¹⁰ The FL, FP, and FN rates for the study group were 1%, 0.6%, and 0.2% compared to 19%, 2%, and 2% for controls, respectively (table 1). The control group still had good reliability parameters although inferior to those of the study group. However, when considering that FP rates exceeding 15% may indicate compromised test result, the control group is unlikely to contain reliable diagnostic information. Besides the number of points depressed at the p<5% level in the PD probability plot for the control group was significantly higher than that for the study group. The PD plot shows sensitivity losses after an adjustment has been made to remove any generalised depressions such as caused by cataract and highlights only significant localised visual field loss.¹⁰ Normal individuals with no experience with AP may present a number of points depressed at the p<5% level in the PD plot when undergoing the SITA test for the first time.¹¹ Hence, subjects in the control group had AP test results with less specificity compared to the study group.

The Mozart effect is a short lived (lasting approximately 10 minutes) improvement in spatial-temporal reasoning related to the trion model of the cortex. The trion model is a mathematical realisation of Mountcastle's organisational principle for the cerebral cortex. In summary, it proposes that the cortical column can be excited into complex firing patterns which, in the trion model, are exploited in the performance of spatial recognition tasks.⁹ Rauscher and Shaw, using a neurophysiological theory (Leng and Shaw), proposed that exposure to music might excite the cortical firing patterns used in spatial-temporal reasoning, thereby affecting cognitive abilities in tasks that share the same neural code-spatial temporal tasks.⁹ In other words, listening to music and executing spatial tasks share neural pathways in the cortex, so that listening to the Mozart sonata serves to "prime" these neural pathways for the subsequent execution of spatial reasoning tasks.¹²

Spatial-temporal reasoning is required for higher brain functions relevant to chess and mathematics. It can be measured by a paper folding and cutting task. The standard AP is a psychophysical test that measures retinal sensitivity at multiple locations in the central visual field. A Goldmann size III white light stimulus is projected for 100–200 ms on a white 10 cd/m² bowl shaped background. The patient is instructed to look steadily at the central fixation stimulus and is required to press a response button whenever a white stimulus is seen. As it stands, AP testing is unrelated to spatial-temporal reasoning, thus, the Mozart effect is not a feasible explanation for the improved performance in those who previously listened to the sonata in the study.

Visual images are built from incoming information of parallel neural pathways responsible for different features such as motion, depth, shape, and colour of objects. In order to express a particular combination of properties in the visual field at a specific time point, independent groups of neurons have to be momentarily associated with each other. Hence, there must be a mechanism by which the brain can associate all the information being processed independently by different populations of neurons in different cortical areas.¹³ Treisman *et al* and Julesz have shown in psychophysical studies that these associations demand attention focused on each element of the visual field.^{14 15} Based on these premises, we could assume that listening to the Mozart sonata can either "prime" the pathways responsible for visual images, possibly shape or colour (as in the round white stimulus of AP) or improve attention to some extent.

Despite the large body of evidence that music in general and Mozart in particular has positive effects in a number of performance tasks, our study does not prove that the Mozart sonata was the causative factor for the improved performance. Subjects from the control group stayed in a quiet room 10 minutes before visual field testing with no headset, whereas subjects from the study group spent that time listening to the sonata with headphones. Hence, one may argue that the headphone itself could have been the causative factor. However, by keeping the control group under those circumstances would closely simulate the environment of an ophthalmology practice. They could not be given a different sort of "music control" in that, not only Mozart, but complexly structured music, regardless of style or period, may interfere with cognitive performance.⁹ Besides, sitting in a quiet room before examination could have increased anxiety, which music would alleviate. However, we believe that 10 minutes is a short period of time to cause anxiety to such an extent that it would bias the results. Ten minutes is the time previous authors have used to assess the "Mozart effect." Would a shorter or even longer period make any difference? This study was not designed to answer that question.

In conclusion, our study has shown that young subjects naive to automated perimetry can improve the test performance when previously exposed to the initial 10 minutes of

the Mozart Sonata for Two Pianos in D Major providing more reliable test results.

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