The Mozart effect

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In 1993 Rauscher *et al.*[1] made the surprising claim that, after listening to Mozart's sonata for two pianos (K448) for 10 minutes, normal subjects showed significantly better spatial reasoning skills than after periods of listening to relaxation instructions designed to lower blood pressure or silence. The mean spatial IQ scores were 8 and 9 points higher after listening to the music than in the other two conditions. The enhancing effect did not extend beyond 10–15 minutes. These results proved controversial. Some investigators were unable to reproduce the findings[2–4] but others confirmed that listening to Mozart's sonata K448 produced a small increase in spatial-temporal performance, as measured by various tests derived from the Stanford–Binet scale such as paper-cutting and folding procedures[5–7] or pencil-and-paper maze tasks[8]. However, Rauscher has stressed that the Mozart effect is limited to spatial temporal reasoning and that there is no enhancement of general intelligence; some of the negative results, she thinks, may have been due to inappropriate test procedures[9].

So, does the Mozart effect exist? The generality of the original positive findings has been criticized on the grounds that any Mozart effect is due to 'enjoyment arousal' occasioned by this particular music and would not take place in the absence of its appreciation. This interpretation is countered by animal experiments in which separate groups of rats were exposed, *in utero* followed by a postpartum period of 60 days, to Mozart's piano sonata K448, to minimalist music by the composer Philip Glass, to white noise or to silence and then tested for their ability to negotiate a maze. The Mozart group completed the maze test significantly more quickly and with fewer errors ($P < 0.01$) than the other three groups; thus, enjoyment and musical appreciation is unlikely to have been the basis of the improvement[10].

LOCALIZATION OF MUSIC PERCEPTION AND SPATIAL IMAGING WITHIN THE BRAIN

An explanation for the results obtained after listening to music may lie in the manner in which music and spatial imaging are processed within the brain. There have been many studies on the localization of music perception. Techniques such as positron emission tomography (PET) and functional magnetic resonance scanning, together with studies on localized brain lesions, have shown that listening to music activates a wide distribution of brain areas. The primary auditory area lies classically in the transverse and superior temporal gyri, but particular components of musical appreciation involving rhythm, pitch, metre, melody, and timbre are processed in many different areas of the brain. These range from the prefrontal cortex and superior temporal gyrus to the precuneus of the parietal lobe, with much interconnection of the different networks activated[11–13]. Rhythm and pitch discrimination are processed mainly in the left hemisphere whereas timbre and melody are found chiefly in the right. Appreciation of metre does not appear to show hemispheric preference.

Brain areas concerned with mental imaging as tested by spatial temporal tasks (such as the building of three-dimensional cube assemblies in sequence) were also mapped by PET scanning[14]. The results show that the areas activated include the prefrontal, temporal and precuneus regions which overlap with those involved in music processing. It is suggested, therefore, that listening to music would prime the activation of those areas of the brain which are concerned with spatial reasoning.

LONG-TERM EFFECTS OF MUSIC ON THE BRAIN

The original experiments on adults exposed to Mozart's music were of short duration only. In related experiments[15], long-term effects of music were studied in groups of pre-school children aged 3–4 years who were given keyboard music lessons for six months, during which time they studied pitch intervals, fingering techniques, sight reading, musical notation and playing from memory. At the end of training all the children were able to perform simple melodies by Beethoven and Mozart. When they did they were then subjected to spatial-temporal reasoning tests calibrated for age, and their performance was more than 30% better than that of children of similar age given either computer lessons for 6 months or no special training ($P < 0.001$). The improvement was limited to spatial-temporal reasoning; there was no effect on spatial recognition. The effect lasted unchanged for 24 hours after the end of the music lessons but the precise duration of the enhancement was not further explored. The longer duration of the effects than in previous reports was

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attributed to the length of exposure to music and the greater plasticity of the young brain. In further experiments of this kind it has been claimed that the enhancement of spatial-temporal reasoning in children after piano training has resulted in significantly greater scores in higher mathematics[16].

MUSIC AND THE ELECTROENCEPHALOGRAPHIC PATTERN

Attempts have been made to investigate the electrical discharge patterns of brain areas after exposure to music. In one study, listening to the Mozart sonata K448 for 10 minutes, in contrast to listening to a short story, resulted in enhanced synchrony of the firing pattern of the right frontal and left temporoparietal areas of the brain, which persisted for 12 minutes[6]. Listening to the sonata was also accompanied by increased power of the beta spectrum of the electroencephalogram in the right temporal, left temporal and right frontal regions[17]. In a further study, listening to music (not that of Mozart) also resulted in greater beta power, particularly in the area of the precuneus bilaterally[18].

MOZART EFFECT ON EPILEPSY

A more impressive indication of a Mozart effect is to be seen in epilepsy. In 23 of 29 patients with focal discharges or bursts of generalized spike and wave complexes who listened to the Mozart piano sonata K448 there was a significant decrease in epileptiform activity as shown by the electroencephalogram (EEG)[19]. Some individual patients showed especially striking improvement. In one male, unconscious with status epilepticus, ictal patterns were present 62% of the time, whereas during exposure to Mozart's music this value fell to 21%. In two other patients with status epilepticus continuous bilateral spike and wave complexes were recorded 90–100% of the time before the music, suddenly falling to about 50% 5 minutes after the music began. The fact that improvement took place even in a comatose patient demonstrates again that appreciation of the music is not a necessary feature of the Mozart effect.

To determine whether this music could exert a longer effect, studies were conducted in an eight-year-old girl with a particularly intractable form of childhood epilepsy, the Lennox–Gastaut syndrome, with many drop attacks accompanied by bilateral spike and wave complexes and focal discharges from the right posterior temporal area[20]. Mozart's sonata was played every 10 minutes for each hour of the day when she was awake. At the end of the waking period the number of clinical seizures had fallen from 9 during the initial four hours to one during the last four hours and the number of seconds during which general discharges occurred fell from 317 to 178. The following day the number of attacks was two in seven and half hours.

SPECIFICITY OF MOZART'S MUSIC

To what extent are the changes attributable specifically to Mozart's music? Following the initial experiments of Rauscher *et al.*[1] most researchers have used Mozart's double piano sonata K448, which the Mozart authority Alfred Einstein called 'one of the most profound and most mature of all Mozart's compositions', but his piano concerto no 23 in A major K488 also proved to be effective[8]. Some investigators observed that no enhancement of spatial temporal tests was seen after the minimalist music of Philip Glass[5], and there was no improvement in epileptiform EEG tracings after old-time pop music[19]. Rideout *et al.*, however, report that a contemporary composition by the Greek-American musician Yanni, which they suggest is similar to the Mozart sonata in tempo, structure, melody and harmony, was also effective[7]. In an attempt to determine the physical characteristics which were responsible for the Mozart effect, Hughes and Fino[21] subjected a wide range of music to computer analysis. As many as 81 selections of Mozart, 67 of J C Bach, 67 of J S Bach, 39 of Chopin, and 148 from 55 other composers were analysed. The characteristic shown by much of Mozart's music and shared with the two Bachs was a high degree of long-term periodicity, especially within the 10–60 s range.

Another similarity between the music of Mozart and the two Bachs was the emphasis on the average power of particular notes, notably G3 (196 Hz), C5 (523 Hz) and B5 (987 Hz). In contrast, Philip Glass' minimalist music and old-time pop music, which had both proved without effect on spatial behavioural tasks or on epilepsy, showed little long-term periodicity. It is suggested that music with a high degree of long-term periodicity, whether of Mozart or other composers, would resonate within the brain to decrease seizure activity and to enhance spatial-temporal performance.

CONCLUSION

An enhancement of spatial-temporal reasoning performance after listening to Mozart's music for 10 minutes has been reported by several, but not all, researchers. Even in the studies with positive results the enhancement is small and lasts about 12 minutes. The effect varies between individuals and depends upon the spatial tasks chosen; general intelligence is not affected. Rather more impressively, there is a beneficial effect on some patients with epilepsy. The results are not specific to Mozart's compositions but the exact musical criteria required have not been completely defined.

The practical use of such observations is as yet uncertain, especially since many of the experiments relate only to short listening periods to Mozart's piano sonata K448. More studies are necessary, involving longer-term exposure to Mozart and to a wide selection of other composers, before the effect can be fully assessed.

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