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Study of the Mozart effect in children with epileptic electroencephalograms

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ABSTRACT

Purpose: To establish if listening to Mozart's *Sonata for two pianos in D major* (K448) has an anti-epileptic effect on the EEGs (electroencephalograms) of children.
Methods: Forty five children (2–18 years; mean 7 years 10 months) who had epileptiform activity on EEG were recruited from those attending for scheduled EEG investigations. Mozart's *Sonata for two pianos in D major* (K448) and an age-appropriate control music were played during the EEG. There were five consecutive states during the record, each lasting 5 min; before Mozart music (baseline), during Mozart music, after Mozart music/before control music, during control music and after control music. Epileptic discharges were counted manually and the mean frequency of epileptic discharges calculated in each state.
Results: A significant reduction ($p < 0.0005$) in the frequency of epileptic discharges was found during listening to the Mozart music compared to the baseline. No evidence of a difference in mean epileptic discharges was found between the baseline and the other three states or between listening to the Mozart music and control music.
Conclusion: This study confirms an anti-epileptic effect of Mozart music on the EEG in children, which is not present with control music. The role of 'Mozart therapy' as a treatment for drug-resistant epilepsy warrants further investigation.

1. Introduction

Many forms of music have been found to have a beneficial effect in neurological diseases including; Parkinson's disease, senile dementia and sleep disorders [1]. The "Mozart effect" refers to an enhancement or normalisation of higher brain function associated with listening to Mozart's music. The Mozart effect was first established by Rauscher et al. [2] who found in 36 college students, listening to the first 10 min of the Mozart *Sonata for two pianos in D major* (K448) there was a significant short-term enhancement (10–15 min) of spatial temporal reasoning and spatial IQ scores. Rideout et al. [3] replicated this and found enhanced synchrony in the right frontal and left temporal-parietal areas on listening to Mozart's music. However, other studies have failed to replicate this effect in adults [4] and children [5], which could be due to procedural differences. Mc Kelvie et al. [6] failed to replicate this in children despite using similar methodology, adapting it to enhance the effect with more subjects and a shortened test period. This may be due to a short-term stability in children's spatial temporal reasoning. fMRI studies support the Mozart effect, as when compared to Beethoven and 1930s piano music, Mozart preferentially enhances blood flow in areas involved in spatial temporal reasoning; the dorsolateral prefrontal cortex, occipital cortex and cerebellum [7].

The Mozart effect in epilepsy was first characterised by Hughes et al. [8] who found, on listening to Mozart's K448, a reduction in epileptic activity on the EEGs of 23 out of 29 patients, predominantly in adults. They tested the patients before, during and after the Mozart and the control music. The effect has been replicated by Turner RP et al. [9] in children, using control music, but only two patients were included in this study. Lin et al. [1,10–12] have studied the effect extensively in children, showing both a reduction in epileptic activity on EEG and a clinical benefit, however no control music was used in any of their studies. In this study we repeated the methodology used by Hughes et al. [8] in a cohort of children and used a control music.

Approximately 1/240 children under 16 years of age in the UK have epilepsy [13]. The annual cost of anti-epileptic drugs to the

Abbreviation: EEG, electroencephalogram.

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NHS is £165 million – 0.94% of the total drugs budget [14]. Despite this, 20–40% of patients with epilepsy have inadequate control of seizures with drug therapy [15]. Therefore, a more effective, less expensive and safer treatment for epilepsy would be greatly welcomed.

The purpose of this study was to establish if Mozart's music causes a reduction of epileptic discharges on EEG, compared to control music, in children. The following are the hypotheses which were tested:

1. Frequency of epileptic activity on the EEG will be significantly lower during listening to the Mozart music than in the baseline period.
2. Frequency of epileptic activity on the EEG will not be significantly lower during listening to the control music than in the baseline period.

2. Materials and methods

2.1. Participants

Participants were recruited from those attending for routine EEGs or video-telemetry monitoring in the Department of Paediatric Neurosciences, Royal Hospital for Sick Children, Edinburgh. Patients were selected based on previous awake EEGs in which the report stated that frequent epileptic discharges were present (focal or generalised). Patients were excluded if the EEG recorded showed no epileptic discharges on the day of the study. Forty five participants were recruited to the study. Consent to the research and publication of the results was obtained for all participants from their parents. The planned EEG was performed first and the study EEG afterwards. Ethical approval for the study was gained from Edinburgh University.

2.2. Procedure

The study was conducted in the EEG room (routine EEG) or on the ward (video-telemetry monitoring unit) in the Department of Paediatric Neurosciences at the Royal Hospital for Sick Children, Edinburgh. EEGs were recorded on 18-channel instruments using the International 10–20 System of Electrode Placement. Patients had to be awake during the study, to try and maintain a constant state of awareness. The patients were exposed to 5 states with no breaks in between, each lasting 5 min: 1) Before Mozart music (baseline) 2) During Mozart music 3) After Mozart music/before control music 4) During control music 5) After control music.

The Mozart music used was the first 5 min of the first movement (*Allegro con spirito)* of the *Sonata for two pianos in D Major* (K448). Age-appropriate control music was used. When the study was designed we asked the parents which music the children would like to listen to and were then able to establish age appropriate control music (to make enjoyment of control music as constant a factor as possible). The pieces then selected were; <8 years old: Teletubbies "Say Eh-Oh!", 8–10 years old: The singing kettle "Eelly-Ally-O!" and >10 years old: Busted "Year 3000".

Each EEG was reviewed by the paediatric neurologist and the number of spikes in every 10 s epoch was manually counted throughout the study. The average (mean) spike count per ten seconds was then calculated for each state for all participants.

2.3. Statistical analysis

Statistics were performed using SPSS 17. Data was tested for normality with Shapiro-Wilks test. Comparisons were made using two-tailed hypothesis tests. All groups were compared using Friedman's ANOVA. Individual comparisons were made using the sign test and adjusted with the Bonferroni correction.

3. Results

Forty five patients were included in the study; 23 female and 22 male. They were aged 2–18 years (mean age 7 years 10 months). Twenty four had epilepsy with structural/unknown aetiology and 21 had genetic aetiology. The seizure frequency range of the participants was from 0 to >10 seizures per day. They were on zero to four anti-epileptic drugs.

Table 1 summarises the descriptive statistics of the frequency of epileptic spikes in 10 s epochs in each of the five states. The overall median number of spikes in a 10 s epoch is lower during the Mozart music (1.19, range 22.04) than the control music (1.33, range 19.6).

Fig. 1 is a box plot showing the distribution of the data. In each state there is a wide range of distribution of frequency of epileptic discharges in a 10 s epoch. The same patients have outlying values in each state. This is clinically viable and they have therefore been included in the study. The two most extreme outliers are three and six both of whom were in non-convulsive status epilepticus.

The Shapiro-Wilks test of normality shows that the data is not normally distributed, with significance $p < 0.0005$ for all states. Statistical tests were chosen accordingly. A Friedman's ANOVA was used to compare all five states and evidence of a difference between states was found ($p = 0.002$).

The sign test, using the exact method, was used to find out which states differed significantly. The results are shown in Table 2. At the 5% significance level, the only statistically significant difference is between the baseline and the Mozart music, with $p < 0.0005$. Table 3 shows a breakdown of the sign analysis. This shows that the probability of there being a greater average number of spikes during baseline compared to Mozart (positive difference, 35/45 = 0.78) is much higher than it being greater during Mozart compared to baseline (negative difference, 10/45 = 0.22). This shows the direction of this difference, with significantly fewer spikes on the EEG during the Mozart than baseline period.

4. Discussion

A significant decrease in epileptic activity on EEG was found in the children, during listening to Mozart music compared to the baseline. This is consistent with Hughes et al. [8] who found a reduction in epileptic activity on EEG in 23 out of 29 patients during listening to Mozart music compared to the baseline, predominantly in adults. Turner et al. [9] replicated this effect in two children. This study used similar methodology to these two studies, the main difference being that Turner et al. [9] used Beethoven's "Fur Elise" and Hughes et al. [8] used "old time pop piano tunes" as the control music. Despite this, none of these studies, including ours, found a significant decrease in epileptifrom EEG activity during or after listening to the control music compared to the baseline. This supports the idea that this effect is unique to Mozart, or at least to similarly structured music. Lin et al. [10] have conducted further studies to confirm an anti-epileptic effect of Mozart music in

Table 1
Descriptive statistics of the average number of spikes per 10 s epoch, in each of the five states.

	Baseline	Mozart	Post-Mozart	Control	Post-control
N	45	45	45	45	45
Mean	3.23	2.85	3.02	3.16	3.37
Median	1.17	1.19	1.21	1.33	1.23
SD	4.57	4.49	4.67	4.63	5.06
Minimum	0.03	0.00	0.00	0.00	0.00
Maximum	20.50	22.04	20.00	19.60	20.50

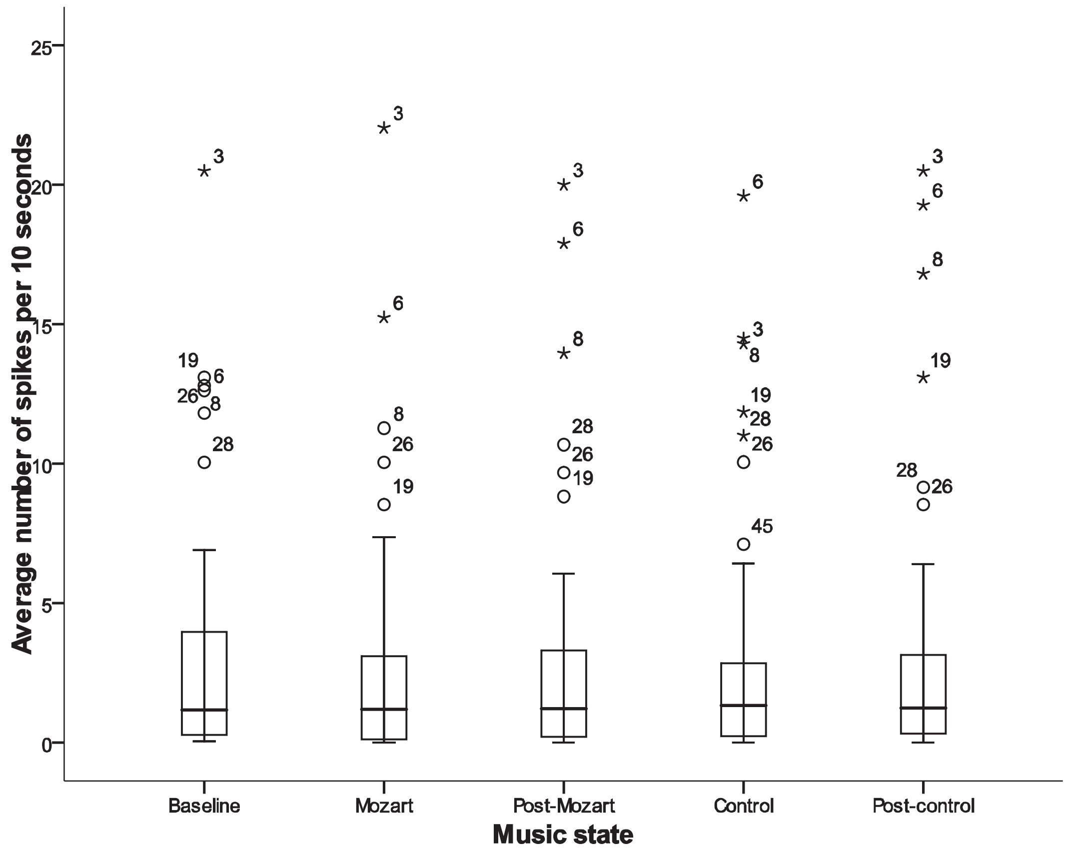

Fig. 1. Box plot showing the distribution of the data (mean number of spikes per 10 s epoch) in each state. Outliers are labelled by the corresponding patient number.

Table 2
Table showing the *p* -values calculated when comparing the mean number of spikes per 10 s epochs of the different states. These were generated using the two-tailed sign test and corrected using the Bonferroni correction.

Comparison	*p* -value	Bonferroni adjusted *p* -value
Baseline and Mozart	$p < 0.0005$	$p < 0.0005$
Baseline and post-Mozart	0.097	0.485
Baseline and control	0.291	1.455
Baseline and post-control	1.000	5.000
Mozart and control	0.127	0.635

Table 3
Breakdown of sign analysis of the comparison of the mean number of spikes per 10 s epochs during the baseline compared to the Mozart states, with a corrected *p*-value < 0.0005. a. Baseline < Mozart, b. Baseline > Mozart, c. Baseline = Mozart.

	N
Negative differences[a]	10
Positive differences[b]	35
Ties[c]	0
Total	45

children. They analysed the epileptic activity on the EEGs of 58 Taiwanese children before, during and after listening to Mozart's *Sonata for two pianos in D Major* (K448). They found interictal discharges were reduced in most patients (81%) during listening to the Mozart music. However, they did not use a control music. Our study has confirmed the Mozart effect in children, but furthermore has shown this effect does not occur with control music.

The reason for the Mozart effect is an area of active research. One theory is that as Mozart started composing at age 4, he exploited the inherent spatial temporal firing patterns of the cortex [16] and hence his music resonates cortical structure. This is demonstrated by the trion model. Mouncastle first described the cortical structure, consisting of organised columns of cells that all have the same properties of place and modality. This was subsequently described by the Trion model which suggests there are three levels of activation of neurons involved in processing music [17]. Mapping of the Trion model on to pitches and instruments gives compositions with similar characteristics to Mozart's music [18]. It is also thought that epilepsy involves trions firing together in synchrony, which is abnormally enhanced and strengthened.

It has been found that repeated exposure to a small array of closely spaced electrodes out of phase has an anti-epileptic effect, by causing learning of the patterns described above [18]. It is hypothesised that Mozart's music contains this sequence of innate memory patterns and causes an anti-epileptic effect by this mechanism. This effect may be similar to a phenomenon known as "quenching"; an increase in seizure threshold and an inhibition of seizure development from specific stimulation of the amygdale [19]. However, as pointed out by Hughes et al. [8], it is unlikely that Mozart's K448 has this supernormal effect, as not all patients in their or our study had an anti-epileptic effect when listening to Mozart's music.

Another area of ongoing research is the distinctive aspects of Mozart's music which facilitate this anti-epileptic effect and whether it is present with other similarly structured music. It is thought the long periodicities and repetition of the melodic line in Mozart's music reflect aspects of our brain and bodily function. The long periodicities in Mozart's music have been found on computer analysis and simultaneously shown to affect the EEG, compared to control music which does not have long periodicities and does not affect the EEG. Other music which has long periodicities, such as by the Bachs may therefore have a similar antiepileptic effect [20]. Most notably, Mozart's music has and reverses a repeating melodic line more often than other composers, including Bach [20]. Lin et al. [1] identified the lower harmonics in Mozart K448 and K545, which both reduced epileptiform activity, as significant. Yanni (Acroyali/Standing in Motion) which is similarly structured to Mozart has been found to cause the “Mozart effect” with enhanced spatial-temporal reasoning [21].

It could, alternatively, be due to a change in the level of awareness during listening to Mozart’s music. Jausovec et al. [22] found Mozart caused changes on the EEG exclusively in areas related to attentional processes, which were not seen in the controls, Bradyns’ and Hadyns’ music. The two control pieces of music are very different in terms of induced mood, musical tempo and complexity, suggesting Mozart’s music has its effect independently of these factors. However, there is substantial evidence against level of awareness being the mechanism of the Mozart effect. Rauscher et al. [2] found no major effect on pulse rate, as a measure of arousal during listening to Mozart’s music. This is further supported by fMRI studies that show no significant effect of Mozart’s music on areas of the brain involved in emotional response or arousal [7]. It has also been found that interictal discharges decrease when listening to Mozart music regardless of whether the patient is awake, asleep [10] or in status epilepticus/coma [8].

Another theory for the Mozart effect is that it is due to enhancement of parasympathetic tone. Lower parasympathetic tone has been implicated in many medical conditions, including epilepsy. It has been found that Mozart K448 significantly reduces epileptic activity on the EEG in children, where most children had increased parasympathetic tone, measured by heart rate variability [23].

No evidence of a difference in the number of epileptic discharges was found on listening to Mozart music compared to the control music, which you would expect if the effect is unique to Mozart’s music. This is consistent with what was found in Hughes et al. [8] study. One reason for this could be a carryover effect of the Mozart music dampening down epileptic activity when the control music was being listened to. There was however no evidence of a difference in the number of epileptic discharges on the EEG in the immediate post-Mozart period which makes a carryover effect less likely. This could be tested by having a break between the two types of music or changing the order of the music. A carryover effect of the Mozart music was however found in Rauscher et al. [16], Hughes et al. [8] and Lin et al. [10] studies, and may not have been found in this study due to study size and other study limitations.

This study, along with other studies, has demonstrated that there is an anti-epileptic effect of Mozart music on the EEG. The possible long-term therapeutic use of this effect has begun to be investigated. It is thought repeated exposure to Mozart music could prime the brain, to induce physiological changes, including the normalising effect on epileptic activity. This was demonstrated in an 8 year old girl with refractory Lennox-Gastaut syndrome listening to Mozart music for 10 min every hour over 24 h reduced clinical seizures and related generalised discharges, which carried over to the next day [24]. A more long-term effect was demonstrated in a 56 year old man with refractory epilepsy. He had marked improvement in seizure control when listening to Mozart for about 45 min each day [25]. A recent study in 18 children with epilepsy with clinically well controlled seizures on anti-epileptic medications, found a significant reduction in epileptic activity on EEG when listening to Mozart music for 8 min every day for 6 months [11]. The same author has also investigated the clinical effect in 11 children with refractory epilepsy (continuing on at least two anti-epileptic drugs); eight of the patients were seizure-free or had very good clinical responses after 6 months of listening to Mozart music [12]. Neither of these studies used control music. The potential therapeutic effect in children with epilepsy requires further investigation and replication of this effect, with the use of control music.

Another question to be established, is whether there are particular groups of children with epilepsy who would benefit more from this effect. The effect of Mozart music has been found to be greater in children with central, frontal, generalised and temporal discharges but less so in those with occipital discharges [11]. It has been found there is none or only a minimal effect of age, gender, IQ and epileptic aetiology on the Mozart effect in children [11]. This work needs replication and further investigation, looking in to other individual factors which may be significant in a large controlled study.

Where possible the quiet environment, temperature, minimal distraction and volume of music were kept constant in the study. However, in a minority of patients there were variations to allow them to take part in the study such as watching videos or there being another patient sharing their room for video-telemetry monitoring. For any patient where there was a variation in environment this was kept constant for the individual patient’s study and we therefore do not consider these to be major limitations.

5. Conclusion

This study has confirmed that Mozart K448 music decreases epileptic activity on the EEG in children and that this effect is not present with control music. There is great potential to further investigate this effect and the possible use of music as a therapy for epilepsy in children, as well as adults. Given the large proportion of people suffering from epilepsy refractory to the current medical treatment and the financial burden of antiepileptic medication in our society, a new therapy would be welcomed.

Conflict of interest

None.

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