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General Psychology

Mozart Sharpens and Mahler Degrades the Word Memory Trace

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Advanced Research in Psychology

We investigated the impact of the Mozart effect on word memory when music was heard in the delay rather than using music to induce mood or as background music. A sample of N = 84 participants was randomly assigned to one of three groups listening to a one-minute sound clip of Mozart (*Kleine Nachtmusik*) or Mahler (*Adagietto*) during the delay, with a third control group waiting in silence for the word memory test. Words were positive, negative or neutral and matched for word length and frequency. The word memory task was repeated three times (enforced rehearsal). Word memory was best after Mozart and worst after Mahler, with memory performance in the control condition in between. The Mozart effect occurred for word memory across positive, negative and neutral words. The Mozart effect also occurred independently of ethnicity, or the level of happiness in the participants. We conclude that word memory traces sharpened after Mozart's music because the sonogram and spectrograms showed that this music had self-contained and bounded phrases like in psycholinguistic structures of words and sentences. In contrast, word memory traces may have washed out and degraded during the delay because Mahler's music was flowing like a foreign language speech stream where a native speaker would not be able to parse words.

A one-page article in Nature in 1993 showed that listeners to ten minutes of Mozart's music had a comparably increased score in an IQ test thereafter. This result was coined as the *Mozart effect* and had a large impact in the public domain and as well in the scientific community (Rauscher et al., 1993). Many follow-up studies mention that newborn babies in the US state Georgia received a Mozart tape from the government and reported similar policy decisions (Nantais & Schellenberg, 1999). The original study was followed-up in more than 60 peer-reviewed articles over the years, more than for any other Nature article (Bangerter & Heath, 2004) and publications are still appearing (Talero-Gutiérrez & Saade-Lemus, 2018). The Mozart effect was researched and debated in developmental psychology with particular emphasis on the difference in effects of music listening vs. music making (Ivanov & Geake, 2003; McKelvie & Low, 2002; Rauscher & Hinton, 2006; Waterhouse, 2006a, 2006b). It could be demonstrated that long-term listening to Mozart for six months decreased epilepsy in children, with the exceptions of those who had epileptic discharges in the occipital, visual area in the brain (Brackney & Brooks, 2018; Lin et al., 2011).

In short, the Mozart effect consists of elevated spatial and abstract performance and an increased non-verbal IQ score after having listened to Mozart's sonata for two pianos in D major in comparison to (1) relaxation instructions on tape, and (2) silence (Rauscher et al., 1993). In studies with adults, the emphasis of the debate was about the question whether arousal (Jones et al., 2006; Jones & Estell, 2007), or preference (Nantais & Schellenberg, 1999; Thompson et al., 2001), or mood (Steele et al., 1999) were responsible for the IQ performance improvement. Recently, the original hypothesis that Mozart music would have a distinct effect on brain waves (Rauscher et al., 1995) was confirmed by an independent research group who found an increase in the index of alpha band rhythm activity (a pattern of brain wave activity linked to memory, cognition and an open mind for problem solving) in adults over the life-span but not in those with mild cognitive impairment (learning difficulties) (Verrusio et al., 2015).

In the current study, we investigated whether a Mozart effect could be observed when remembering negative, positive and neutral words. Music lessons appear to improve word memory although Mozart in particular was not tested (Holden, 2003). Music lessons can improve memory in many ways, for instance, by improving fine motor skills as a result of learning to transform musical notations into fluid finger movements (Lange-Küttner & Finn, 2008). Mozart also improved reading fluency in children (Yen-Ning et al., 2017). A comparison of Mozart, Vivaldi and Glass during a verbal memory task showed no significant effect on different age groups of adults, but a positive effect of Vivaldi's (but not Mozart's) music on verbal fluency could be observed in younger adults (Giannouli et al., 2019). Another problem is that the Mozart effect, or any other effect of uplifting music, is dependent on whether divided attention is necessary as with background music, or whether the music itself is associated with particular words as in music lyrics (Ferreri & Verga, 2016). While the background music can increase the cognitive load, musical associations may facilitate binding processes which can help memory. In the current study, we are not increasing participants' cognitive load by using mu-

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sic as a background as overall it does not seem to be helpful for verbal memory (Nguyen & Grahn, 2017). Instead, a short music clip is played in the delay between word presentation and word recognition phase of the memory experiment. Because verbal memory is improved by rehearsal (Lange-Küttner et al., 2017; Lange-Küttner & Sykorova, 2015), we used the same word lists in three repetitions. In this way, we could not only test whether memory performance as such would be improved, but also whether the music in the delay would have an effect on verbal learning.

We compared the enchanting music of Wolfgang Amadeus Mozart's *Kleine Nachtmusik* (Smith & Joyce, 2004) with the calming music Gustav Mahler's *Adagietto* in the delay phase as in previous research both were confirmed to have positive vs. negative (depressive) mood induction powers (Storbeck & Clore, 2005). Mozart's *Kleine Nachtmusik* is also called Serenade No. 13 for strings in G major. The composition *Adagietto* by Mahler is also known as Symphony No. 5 and is mostly played in C minor. The hypothesis was because low arousal music can enhance verbal memory (Nguyen & Grahn, 2017), that in the verbal domain, the Mahler music clip may compete with the Mozart effect. In a third control condition, the delay was unfilled and participants just waited for the verbal memory test.

METHOD

PARTICIPANTS

G*Power (version 3.1.9.4) analysis (Faul et al., 2007), with an effect size of .25, an alpha level of .05 and power of .95, showed that to test the main group effect of the Mozart effect in the music delay, a sample of N = 87 needed to be tested. A sample of N= 87 was tested, however, in the analysis phase, boxplots showed three participants' data sets with random responses resulting in pronounced negative D' values for accuracy. The analysis was thus conducted with N = 84 participants (56 females, 28 males) between the age of 19 and 65 (M = 32 years, SD = 11 years). Each experimental group had 28 participants, with 19 women in the Mozart group, 16 women in the Mahler group and 21 women in the silent control group. The sample consisted of 53.6% (n= 45) participants identifying as White, 17.9% (n = 15) Black, 17.9% (n = 15) Asian, 3.6% (n = 3) Mixed and 7.1% (n = 6) Other. All participants lived in London, UK. They were fluent English speakers, had no hearing problems, and none of them received compensation for attending this study. Because we tested European music which may be less familiar for participants from cultures of other continents, we split the sample into a white sample (n = 45) and an ethnic minority sample (n = 39).

APPARATUS AND MATERIAL

The experimental program SuperLab 5.0 was used to program the memory task. The task was tested on a Toshiba laptop with a 15'' screen. Thirty target words of various length were presented in a randomized sequence in the middle of the screen for 750 ms with 500 ms interstimulus interval, on a white background, in Arial small letters, font size 20. The thirty target (and the thirty distracter) words were selected from the British National Corpus (Leech et al., 2014), with word frequencies either above 150 or below 50. There were three word categories, positive, negative and neutral. Word length in terms of letters and syllables were matched between targets and distracters as much as possible, see Table A1.

After the presentation, an exactly one-minute long music sound file was played. The Mozart 1-minute sound clip was produced from the Serenade No. 13 in G-Major, K.52. The Mahler 1-minute sound clip was produced from the Symphony No. 5, Adagietto. The sampling rate of both music clips was 44100 Hz. Figure 1 shows the sonograms and the spectrograms of the Mozart and the Mahler sound files (Adobe Audition). Because the list with thirty words was quite long, we kept the delay with the music limited to one minute. Participants repeated the entire memory task two times, so they would hear the music clip three minutes in total. Figure 1 shows that the Mahler music was quieter and with less distinguishable phrases which produced a more continuous flow of music than the Mozart piece, see the upper sonogram in decibel (db). Participants were provided with headphones and were able to adjust the volume to create individually comfortable hearing of the music. The Mahler music was also of lower frequency throughout, see the lower sound spectrogram with the scale in Hertz (Hz).

In the test phase, participants saw all thirty target and distracter words of Table A1 in a randomized sequence. Words were presented until the participants pressed the response button (self-paced) without a maximum time limit.

The Happiness Scale. We used the happiness scale of Lyubomirsky and Lepper (1999) to measure mood. It consists of four questions and has been used with young adults as well as in retirement communities. The test has a high retest reliability of Pearson's r > .85 after a month. In the current study, happiness is measured with a 7-point Likert-scale. One item is reversed. The first question requires participants to rate themselves as being in general *not a very happy person* (1) to being *a very happy person* (7). The second question tests relative happiness in comparison to peers. The third question assesses the resilience of happiness in the face of adversity. The fourth was the reversed question asking about depression. The happiness questions were also presented on a white screen with centered black letters in Arial 20. Participants pressed the respective number key on the keyboard as a response. Response times were self-paced.

PROCEDURE

The study was approved by the departmental Ethics committee. Participants were briefed and debriefed via the computer-based program. The instructions were 'We are investigating if there is a connection between mood and memory. Therefore, a short questionnaire, audio files or silence and some words will be presented in a computer-based program. You will experience three repeated memory tests. The study is anonymous and takes about 15 minutes. The collected data will be securely stored to maintain privacy, and the data will be destroyed after ten years. Press any key to continue.' This was followed by informed consent on screen by pressing the key 'C'. Participants were not able to continue the experiment if they did not give their consent.

This was followed by personal questions about their gender, age in years, ethnicity, English language fluency, and whether they had hearing problems. Only participants who agreed that they were fluent English speakers and had no hearing problems were able to continue the experiment. Thereafter, they answered the four questions about their happiness on a scale of 1-7. This short questionnaire was followed by the memory task.

The instruction for the memory task was 'Please look at a sequence of words and try to remember each word as best as you can.' The instruction for the two music conditions was the same: 'Now you will listen to music for 1 minute.' The instruction for the control condition was 'Now you will have 1 minute of silence.' In the memory recognition phase, the

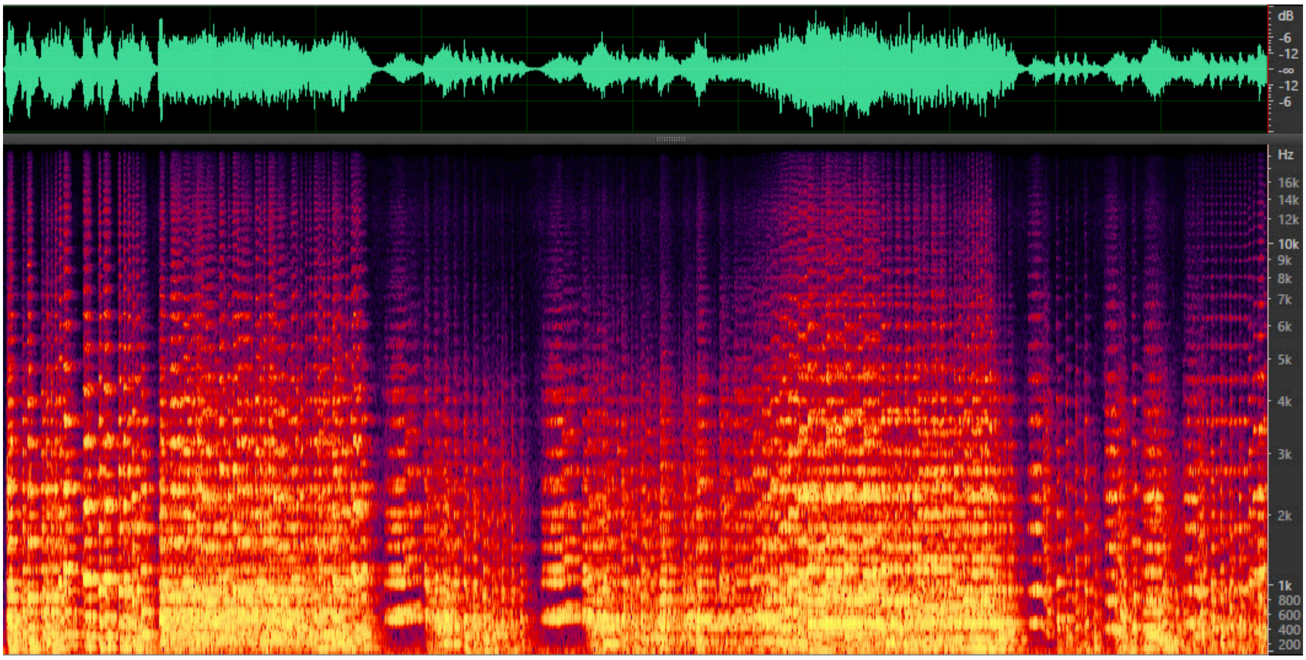

Figure 1a: Sonograms and spectograms of the memory delay music.

Mozart's Kleine Nachtmusik

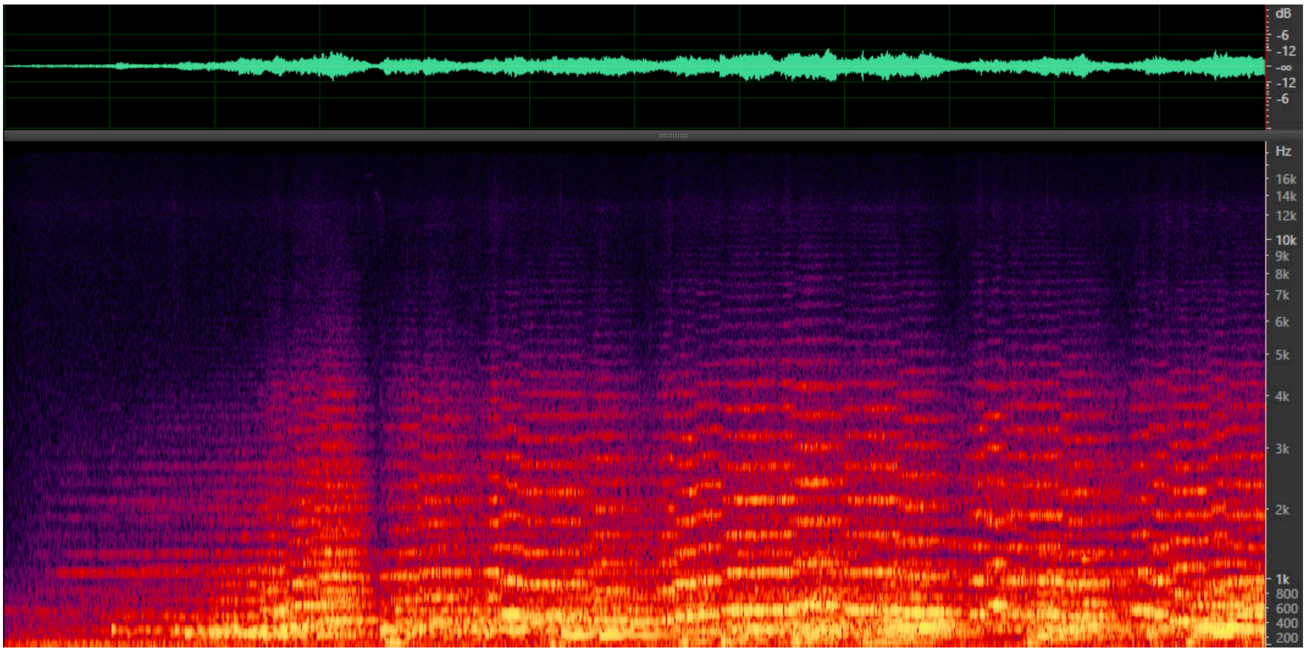

Figure 1b: Sonograms and spectograms of the memory delay music.

Mahler's Adagietto

instruction was to press the key 'C' if they remembered the words, or to press the key 'M' if they did not. It was necessary to press a key to continue. When all sixty words were judged, participants were informed that the task would be repeated. The experiment ended in debriefing the participant.

Data generation. Accuracy data were corrected by deducting false positives, that is, participants had responded that they had seen a word when in fact they did not. This protected against a yes-bias in participants' responses (Macmillan & Creelman, 2005).

RESULTS

Happiness. One-way ANOVA with happiness as the dependent variable showed that there was no significant difference in happiness between the three experimental groups (Mozart $M = 5.03$, Mahler $M = 4.75$, Silence $M = 5.04$), $F(2, 84) = .76$, $p = .573$. The same model with ethnicity (white $M = 4.90$, ethnic $M = 4.99$) as between-subject factor and age as covariate showed also no significant difference in happiness, $F(2, 84) = .12$, $p = .727$. Independent samples t-test showed that men ($M = 4.86$) and women ($M = 4.98$) did not differ in their happiness, $t(2, 84) = .46$, $p = .645$. On a scale of 1-7, all values approach a score of 5 which speaks to a similar level of happiness as in US college samples (Lyubomirsky & Lepper, 1999).

The Mozart effect: Accuracy. A 3 (word type) by 3 (repetition) by 3 (delay type) by 2 (ethnicity) analysis of variance with repeated measures on the first and second factor was run, with happiness as a covariate. Happiness was not significant as a main effect or in interactions, $p_s > .076$. The delay type was more important for word memory, $F(2, 84) = 3.03$, $p = .054$, $\eta^2 = .07$ than ethnicity, $F(1, 84) = .053$, $p = .818$. The Mozart delay group remembered $M = 50.96\%$ of the words, the silence delay group remembered $M = 42.72\%$ and the Mahler delay group remembered $M = 39.89\%$ of the words. Post-hoc pairwise comparisons within the model (Bonferroni-corrected, one-tailed) showed that the Mozart delay group remembered significantly more than the Mahler delay group, $MD = 11.06$, $p = .030$, CI 95% [-.35, 22.48] which confirmed our hypothesis about the Mozart effect. The two delay groups did not differ against the control group, $p_s > .120$.

The repetition effect was marginally significant, $F(2, 84) = 2.97$, $p = .054$, $\eta^2 = .04$. Memory accuracy subtly increased during the repetition (first block: $M = 43.57\%$, second block: $M = 44.89\%$, third block: $M = 45.10\%$) but without significant difference in any of the pairwise comparisons, $p_s > .999$.

The Mozart effect: Reaction Times. The same analysis of variance was run for latencies. No statistical effect of the between-subject factors was significant, $p_s > .073$. Happiness was not significant as a main effect or in interactions, $p_s > .636$. The within-subjects effects showed that repetition was also important for reaction times, degrees of freedom correction Huynh-Feldt, $F(1.63, 84) = 3.66$, $p = .041$, $\eta^2 = .04$. Word recognition accelerated with repetition (first block: $M = 1404$ ms, second block: $M = 1192$ ms, third block: $M = 1114$ ms). Post-hoc pairwise comparisons (Bonferroni-corrected, one-tailed) showed the first repetition was the most efficient in increasing speed, $MD = -212.42$, $p < .001$, CI 95% [-280.37, -144.47] compared to the difference between the second and third task repetition $MD = -77.95$, $p = .032$, CI 95% [-159.34, 3.33].

DISCUSSION

We were interested in the question whether we could obtain the Mozart effect when presenting just a brief 1-minute delay between the word presentation and word recognition phase. Overall, each participant heard three minutes delay time music. We could confirm the hypothesis that Mozart music improves word memory in comparison to music of Mahler, but not in comparison to a control condition of just silence. The Mozart effect did occur for word memory across positive, negative and neutral words. The Mozart effect also did occur independently of ethnicity, or the level of happiness in the participants. We neither used the music to induce mood (Storbeck & Clore, 2005), nor as background music to the task which would have increased cognitive load (Ferreri & Verga, 2016). Instead we tested whether Mozart's or Mahler's music in the memory test delay would improve or degrade the memory traces of the presentation words. We could find both effects, improvement of word memory traces after Mozart and degradation of word memory traces after Mahler.

Contrary to previous accounts that have focused on arousal (Jones et al., 2006; Jones & Estell, 2007), preference (Nantais & Schellenberg, 1999; Thompson et al., 2001), mood (Steele et al., 1999) and enjoyment (Lim & Park, 2018) as explanations for the Mozart effect, we would like to offer another account which derives from psycholinguistic research (Toukhsati & Rickard, 2012). We acknowledge that such organismic factors clearly offer a psychophysiological account of the Mozart effect (Verrusio et al., 2015). However, the actual cognitive mechanism of the Mozart effect may have its roots in language processing (Scott, 2005). The sonograms of the Mozart and Mahler clearly showed that the *Kleine Nachtmusik* has more diverse phrases, while the *Adagietto* consists of a very flowing music which is similar to the flow of language that one does not understand like at the beginning of life, or when hearing a foreign language. Young children need to learn to bootstrap words from the language flow (Friedrich & Friederici, 2008; Nazzi & Houston, 2006) which then are combined into phrases (Friederici & Oberecker, 2008). Thus, in short, the clearly delineated phrase structure in the Mozart music may have supported the word memory trace, while the flowing stream of the Mahler music would have washed up word boundaries in the memory trace like the edges of visual object shapes in a watercolour drawing. This could be called 'tone painting' (Patel, 2008, p. 320) although what is usually meant with this concept is the imitation of meaningful sounds such as environmental or animal sounds.

What is meant here is that a phrase has a contour in the way that we parse words or sentences from the speech stream, and this can be achieved in various ways, by changing the pitch (stress) (Nazzi et al., 1998), or by inserting a pause (Lange-Küttner et al., 2013; Männel et al., 2013; Männel & Friederici, 2009; Mueller et al., 2008), both of which creates contrast and boundaries within the stream of language or the flow of music. These are temporal modulations which occur both in music and speech (Ding et al., 2017) and do not need to involve meaning. For instance, in another recent study, a piece of newly composed instrumental music lasting 2 minutes and 15 seconds during encoding generated superior shape memory when the shape and the beat co-occurred rather than were out of synchrony (Hickey et al., 2020).

The current study has some limitations. We conducted only one experiment without a replication yet. There may have been significant interactions given a larger sample size, however, the p-values for the interactions were not approaching significance. We did find some gender differences which we do not report because we did not have a sex-balanced sample, with more women than men in each group. Nevertheless, we believe that our demonstration that the Mozart effect produces superior word memory when implemented during the memory delay provides strong experimental evidence that Mozart's and Mahler's music have an enhancing or degrading effect on the word memory trace itself.

Appendix

Table A1: Word Categories (negative, neutral, positive) matched for Word length by Syllables

Target Words				DistracterWords			
	Frequency	Syllables	Letters		Frequency	Syllables	Letters
			Negative Words				
problem	565	2	7	patient	242	2	7
death	230	1	5	court	344	1	5
issue	269	2	5	reason	289	2	6
test	159	1	4	force	250	1	5
loss	154	1	4	cost	269	1	4
anger	34	2	5	abuse	37	2	5
bomb	39	1	4	cold	25	1	4
devil	20	2	5	horror	26	2	6
stress	42	1	6	rape	20	1	4
breach	35	1	6	guilt	18	1	5
			Positive Words				
party	529	2	5	music	150	2	5
love	150	1	4	heart	152	1	5
parent	201	2	6	morning	219	2	7
friend	315	1	6	home	390	1	4
health	246	1	6	light	191	1	5
beauty	44	2	6	bonus	18	2	5
kiss	19	1	4	mate	25	1	5
humour	23	2	6	favour	28	2	6
luck	32	1	4	laugh	19	1	5
joke	33	1	4	charm	15	1	5
			Neutral Words				
service	549	2	7	table	231	2	5
sense	229	1	5	land	208	1	4
paper	237	2	5	product	217	2	7
month	398	1	5	name	326	1	4
face	315	1	4	hour	302	1	4
reply	36	2	5	album	26	2	5
zone	37	1	4	palm	19	1	4
painter	20	2	7	monkey	11	2	6
moon	31	1	4	bell	28	1	4
view	44	1	4	print	34	1	5

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