The Effect of the Presence of Music on Reaction Time

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Abstract

The purpose of this project was to discover how the presence of music affected the reaction time of people. This has relevance to drivers and athletes. Since more and more people operate vehicles it is important to understand how their conditions affect their performance and likeliness to crash. The effect of presence of music on reaction time was determined by having two different groups perform the same RT experiment; one listened to music of their choice, the other did not listen to music. It was thought that music would aid in participants' reaction time (i.e. decreasing reaction time). The results collected during this investigation were 752ms and 701ms for music and no music groups, respectively. However, listeners adapted to the music and were able to perform almost as well as those in the control group. This means that music actually hindered participants' reaction time rather than helping it. The results showed that the hypothesis was refuted. This happened because music created a distraction and diverted attention from the brain to the music. Possible errors were a lack of participants, lack of trials, and difference of enjoyment. Future research could be the effect of enjoyment of music on RT.

Introduction

The brain performs many functions due to the immense number of tasks it is responsible for facilitating. The brain activates various sectors designated to specific funcitons when presented with a stimulus or multiple stimuli. Music, for example, has a major effect on the brain because the sound triggers electrical signals to be sent that influence processing. A result of the signals are increased motor and concentrative skills, which can be represented by reaction time. Investigating the effects of music on the processing is critical in understanding music's benefits on humans.

Music is a harmonic method of expressing a message that appeals to the emotions of the audience. On the outside, music instills happiness in a person, which may or may not relax him or her. In the brain, music has a more complex effect. An electroencephalogram (EEG) measures brain waves over a period of a few hours. Using one, a scientist can determine the effects of different variables on brain wave patterns. Specific brain waves such as alpha, beta, delta, gamma, and theta waves, are the main foci of an EEG. Each type of brain wave is emitted based on different amounts of electrical activity. Electrical activity is measured in Hertz (Hz), the SI unit of frequency, where a wave completes 1 cycle per second. Waves are sinusoidal, meaning they take the form of a sine curve. Brain waves are classified based on how many cycles are in one second.

Gamma waves are the fastest brain waves (38-42 Hz), and they are associated with the processing of information and consciousness (BrainWorks). These types of waves generally get emitted when a person is hyper aware of a specific situation, or when his or her concentration peaks. This would mean that in situations where high processing is crucial such REM sleep, where short-term memory becomes long-term memory. Gamma waves are also present when someone concentrates or makes quick movements. While sleeping and moving frantically differ, they both require intense mental work. Beta waves are brain waves whose properties overlap with gamma rays. Ranging from 12 to 38 Hz, they dominate peoples' consciousness when awake. Beta waves are high in frequency but low in amplitude (Abhang & Mehrotra, 2016). This means that many waves occur in a second, but the maximum distance from the position of equilibrium of a wave. These are the hills and valleys of a sinusoidal curve. An increase in beta waves allows conscious focus and memory to improve. However, if the increase is too drastic, focus and memory become anxiety and depression.

Lower frequency waves include alpha, theta, and delta waves. Alpha waves range from 8 to 12 Hz, and they induce feelings of relaxation and calmness, which improve stress problems. As a result, tasks performed can be finished more efficiently and accurately. Theta and Delta waves are most common in times of sleep or deep meditation. Balancing these waves also improves learning and mental processes (BrainWorks).

In music, particularly important types of waves include alpha and beta waves. A recent study done on the effect of the genre of music on mental activity suggested that preferred music increased alpha wave frequency and amplitude (Kučikienė & Praninskienė, 2018). This is significant because it supports the idea that music aids in concentration, and inevitably helps in complex tasks. Music tends to tune out worries of the listener, enabling them to focus on one subject. Like a camera angle, when focusing in on one area, it becomes clear. All other sensory information and processes regarding memory get tuned out when music is introduced. Focusing on one task leads to clarity and improved concentration.

Moreover, since the brain must perform a myriad of tasks, specific parts manage certain concepts. The left hemisphere is associated with logical and critical thinking, while the right hemisphere governs visual-spatial relations and creativity. Music activates many parts of the brain, thus strengthening it. The temporal lobe, which spans both hemispheres, processes music. Specifically, the left hemisphere processes the lyrics while the right hemisphere processes the sound. Music also stimulates the frontal lobe, which can be used to "enhance [the brain's] functions" (University of Central Florida). Additionally, movement is required to play music, and the cerebellum manages muscle coordination. Therefore Alzheimer's patients can learn how to play music again even when they cannot remember names. Memory is associated with the hippocampus, and music is thought to increase neurogenesis in that region. As a result, new neurons are produced and memory improves (University of Central Florida). This is why listening to classical music aids in cognitive skills such as doing math. Strengthening of the brain increases awareness and concentration, which can be represented by reaction time.

Reaction time (RT) is defined as the time taken for a participant to respond to a stimulus or multiple stimuli. Many factors influence the RT of a participant, including the person's condition, the number of stimuli, and the presence of distractions. A specific type of "distraction" - music - plays a critical role in many peoples' lives.

There are two types of reaction time: simple response time and complex response time. Simple reaction time (SRT) refers to the time it takes for a person to respond to a single stimulus in one way (Psytoolkit). An example of this would be clicking a mouse when the color of a screen changes from blue to green. This type of reaction time rarely applies to real concepts because an outcome almost never has one factor that influences it. It would only refer to one concept such as pushing the brake pedal at a red light while driving. However, driving is very complex and has many rules that must be followed simultaneously.

Complex reaction time (CRT) refers to the time a participant takes to accurately respond to a stimuli given multiple options (Psytoolkit). In a simulation, complex reaction time may be tested with a more thorough experiment than an SRT test. For instance, an experiment with five choices would have only one correct choice; the experiment would measure speed and accuracy. With accuracy introduced, not only will the time a participant takes to respond have to be measured, so will the number of correct versus the number of incorrect responses. This paradigm corresponds to activities such as playing sports or driving. In driving, a complex reaction time task would apply to stopping, going, yielding to other drivers, merging into other lanes, and paying attention to objects around the car. Since the brain must think about so many factors, this would affect reaction time. In fact, the average reaction time tends to slow down by 40 ms for each factor added (neurobs). In situations where multiple factors play a crucial role in processes such as operating vehicles, reaction time increases, resulting in a higher risk of unfavorable outcomes (e.g. crashing).

However, several other notable factors must be taken into account when interpreting reaction time. For example, auditory stimuli will produce different results from visual stimuli. A study investigating how various types of stimuli affect simple reaction time showed that people responded in 284 ms on average to auditory stimuli and 331 ms on average to visual stimuli (Shelton & Kumar 2010). A 47 millisecond difference in terms of reaction time is significant since the brain registers a stimulus in a miniscule amount of time. The results also propose the question of how sound is registered faster than light if light travels faster. Light travels faster, but it does not get processed by the brain as fast as hearing. Audio reaches the brain in 8-10 ms while light reaches the brain in 20-40 ms, and must be heavily processed by cells. The audio processing center is closer to the brain stem than the visual processing center, so sound is processed first. The type of stimuli is important to consider and keep constant (unless the intent is to investigate this).

Sound is also important to consider in terms of music. Neurologically, the brain has learned how to filter out identical noises or noises that are constantly heard - auditory sensory gating. As a result, the brain prioritizes changes in stimuli or new stimuli (Novella 2019). As a result, the brain concentrates on unfamiliar or unusual sounds. Even if they are familiar, the change in waves impacts the brain by keeping it alert. The millions of compositions in all the genres of music enable the brain to be alert because each song is different. Moreover, the changing of sound waves is prioritized over white noise, making music "interesting." This idea suggests that the presence of music would support reaction time by filtering out other distractions.

Additionally, fatigue and exhaustion influence reaction time. An experiment done on athletes regarding how fatigued they were on how quickly they could perform a taekwondo roundhouse kick. Performance time did not increase, but reaction time increased from 145ms to 223ms on average (Sant'Ana et al., 2017). Fatigue does not influence how the action is performed, but how quickly a stimulus is processed. The change is even larger on average compared to the type of stimulus. Athletes - especially in intense situations - are hindered by fatigue because their brains cannot cause the body to react quickly enough. Drivers need to have a low reaction time when operating a vehicle so if an unexpected event occurs, he or she can quickly manage it.

Reaction time also depends on the intensity of the stimulus. Intensity of a stimulus refers to the time a stimulus exists for and the "forcefulness" of the stimulus. An exponential decay model can be used to describe the effect of stimulus length on reaction time. As length increases, response time decreases. Not only do people experience a faster reaction time with a more intense stimulus, they also produce a more intense response (Murray 1970).

A commonly overlooked factor that impacts reaction time involves the experience a participant acquires from an experiment. Similar to many activities, practice produces better results. Reaction time decreases as time passes. However, at a certain point, fatigue and boredom cause increased reaction time. The overall learning curve graphically looks like a decrease in reaction time to a certain point (varies per person) where the slope slowly levels out and begins to increase. In situations regarding complex reaction time, the notification of an error results in subsequent failures. This happens because the brain releases cortisol which induces a feeling of discouragement (Ibañez 2018).

In addition, distractions lengthen reaction time. Interestingly, background noise caused response time to lengthen in an experiment where participants were asked to complete a task while being distracted (California Training Institute). These results conflict with the idea of music aiding reaction time because music supposedly increases alertness. The difference is that noise is simply the presence of sound, while music appeals to a person's emotion. Different sounds produce different outcomes. Noise sends disordered frequencies to the brain that may not be interpreted as pleasant; music sends ordered tones to the brain that please the brain (Davis 2018).

Other notable factors include age, gender, alcohol consumption, stimulant drug consumption, and punishment. Numerous studies show that males react faster, but females react more accurately. Males are biologically more competitive than females, so they want to be first whenever possible (Niederle & Vesterlund 2007). Again, reaction time tends to decrease as people approach their twenties. From then, reaction time increases throughout the remainder of a person's life. Alcohol causes muscle activation to decrease, or the brain does not communicate with the body as quickly, slowing reaction time. On the other hand, caffeine - in moderate doses - decreases reaction time. Stimulant drugs like caffeine decrease reaction time because they catalyze dopamine production. The increased alertness, as discussed earlier, allows people to have faster reaction times (California Training Institute).

Overall, studying the effects of music on reaction time helps explore methods of increasing awareness and concentration. Music activates various parts of the brain which help in understanding how the human brain works and how music can help people with conditions such as Alzheimer's. Additionally, increasing reaction time is important for situations such as maneuvering vehicles or participating in sports. Both require quick thinking and high spatial awareness. While many factors impact a person's reaction time, music is often overlooked despite having a significant impact on the brain. Studying the effect of music on reaction time applies to how music can strengthen the brain altogether.

Question: How does exposure to music affect a person's reaction time?

Hypothesis: If the presence of music affects participants' reaction time, then the participants who listen to music while performing a reaction time test will react faster because of an increase in brain activity from being stimulated by music (Kučikienė & Praninskienė, 2018).

Materials and Methods

Materials:

Computer, program that tests reaction time (made in E-Prime 2.0), 8 participants, a phone with music, computer mouse, computer keyboard, headphones

Procedures for Designing Experiment:

1. Go to a facility that has the software E-Prime-2.0 (e.g. ASU Memory and Attention Control Lab) and make a program that tests reaction time (simple drag-and-drop structure). Have results be recorded and used in Microsoft Excel. If this is not possible, download a 5-choice reaction time experiment from the internet.
2. The next steps (2-13) refer to making the program in E-Prime. Other experiments like this have been done, so for a more thorough explanation, visit an expert tutorial. First, open E-Prime and open a standard basic experiment.
3. Open the tab that is labeled "session proc" for a timeline. This will be used to organize the events in the experiment
4. Start with a text box that welcomes participants to the experiment and informs them of what they must do (instructions will be written and spoken).
5. Next, insert a BlockList and make a table for the procedure "PracProc" for practice trial.
6. Insert columns that are labelled StimText and Correct. StimText is what will be presented on the screen (e.g. AABAA) and correct would be the correct answer (B).
7. It is important that AAAAA, BBBBB, CCCCC, DDDDD, and EEEEE are not included
8. Type a StimText and its correct answer for each variation of a stimulus. For practice trials, change the weight to 3 and type each variation of a stimulus. For Block trials, change weight to 15 and type each variation and correct answer.
9. Find the properties tab and make sure selection is random and the trials do not repeat after they have been selected.
10. Add a text box to make a fixation point (a plus sign for example) and change its properties so that it is centered on the screen and its duration is only 200-500 milliseconds (keep time constant). This text box should be after the blocklist on the timeline.
11. Next, put a feedback display on the timeline after the fixation point and change its properties to reference a random row on the blocklist.
12. This next step ONLY applies to the practice block: insert another feedback display that compares the given answer to the correct answer and shows "correct" or shows "incorrect."
13. Repeat steps 2-11 for the block trials, and insert a final text box that informs participants that the experiment is over. Steps 14-20 refer to the experiment itself.

Experimental Procedures:

1. As participants enter, give them a number starting with 101 or 201 (101 is music, 201 is no music).
2. Instructions appear on screen, but also verbally instruct participants on how the experiment must be performed. When a stimulus is seen on the screen, they must respond to it by pressing corresponding keyboard keys as quickly and as accurately as possible.
3. Inform participants that a fixation cross representing a plus sign will be presented for about 0.5 seconds between trials to center the eyes.
4. Tell all participants that they will be given an opportunity to rest for about a minute every 300 trials until they have reached 900 trials. Additionally, a practice round of 60 trials will occur before the 900 trials.
5. Instruct participants who are supposed to listen to music to turn on their music.
6. Have everyone start and complete the experiment at their own pace. Results are automatically recorded into a txt file which will later be imported to Excel.
7. Finalize results by taking out all trials above 1500 ms (use the "locate" feature to locate the outliers) and averaging the remaining trials.

Statistical Methods

All data is averaged and outliers of 1500 ms or higher are invalidated to find a final average that is not skewed by a couple of trials. Results above 1500ms would throw off results. Additionally, all incorrect answers were invalidated regardless of the RT.

Results (Data Tables and Graphs)

The Effect of Presence of Music on Reaction Time					
Presence of Music (Yes/No)	Average Reaction Time (milliseconds)				
	Trials (blocks of 300, practice is 60)				
	Practice	Block 1	Block 2	Block 3	Average
Music	852.564	746.934	714.401	696.907	752.702
No Music	725.038	696.79	688.133	697.226	701.797

Fig. 1. The table shows the average reaction time of all people in one experimental group (music versus no music) over 960 trials (60 practice, 3 blocks of 300). The total average is also displayed with a 51 millisecond difference between listening and not listening to music.

Effect of Presence of Music on Reaction Time					
Presence of Music	Reaction Time (milliseconds)				
	Trials (Blocks of 300, Practice is 60 trials)				
	Practice	Block 1	Block 2	Block 3	Average
Music (people 1-5)	846.596	726.874	684.107	659.552	729.282
	762.862	672.064	694.404	722.06	721.846
	958.75	948.152	933.956	890.581	932.86
	865.632	664.216	569.329	561.141	665.08
	828.981	723.364	690.212	651.2	723.439
No Music (people 6-10)	688.576	703.591	682.986	691.32	691.618
	724.727	707.996	712.201	693.868	709.698
	758.724	723.351	734.509	774.598	747.795
	728.125	652.223	622.835	629.116	658.075
	N/A	N/A	N/A	N/A	N/A

Fig. 2. This table shows the averages of each person over the various blocks mentioned earlier. The table is descriptive because it shows individual scores.

t-Test: Two-Sample Assuming Equal Variances		
	Music	No Music
Mean	752.7017	701.7967
Variance	4861.921	257.6103
Observations	4	4
Pooled Variance	2559.765	
Hypothesized Mean Difference	0	
df	6	
t Stat	1.422903	
P(T<=t) one-tail	0.102307	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.204614	
t Critical two-tail	2.446912	

Fig. 3. This T-Test shows statistical significance of the results. The highlighted area tells how reliable the results are. 0.2>0.05, so the data is not significant, meaning data could have occurred by chance, and it cannot be fully determined whether music completely influenced the experimental group. However, it is still very likely it did occur due to changing the IV, so the data could be reliable; 0.2 means that there is a 20% chance the results were accidental.

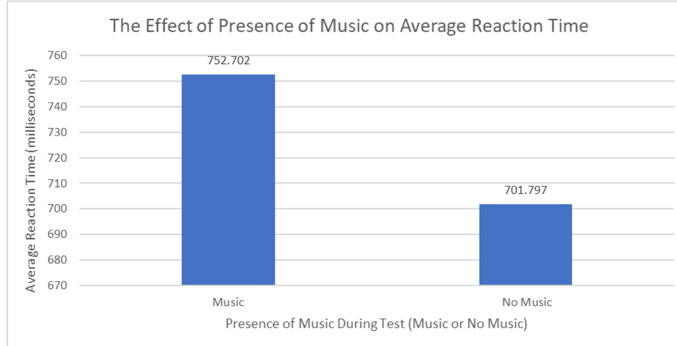

Fig. 4. The bar graph shows the effects of music on reaction time as an average of all 960 responses. Music caused an increased response time by approximately 51 milliseconds.

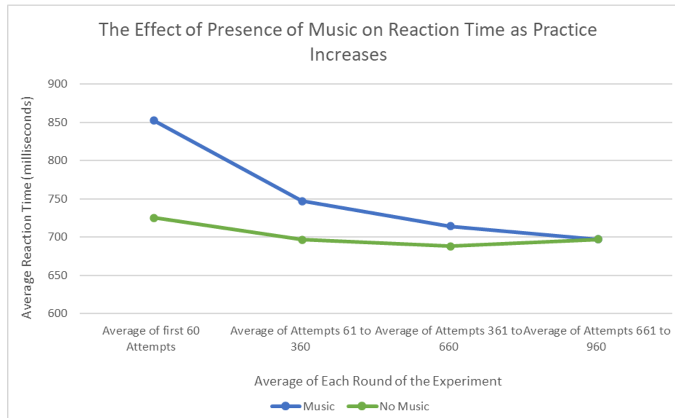

Fig. 5. Line Graph Caption: The graph shows the effects of music on reaction time as participants gained experience with the reaction time test. Music slows down the testers at first, but they seem to approach a similar reaction time as the control group by the end of 960 trials.

Data Analysis:

The graph suggests that music slows reaction time at first but will have a positive effect on users after a while (approximately 25 minutes). At the end of block 1, the control group responded with an average of 696 milliseconds, while the experimental group responded with an average of 746 milliseconds. However, by the end of block 3, both groups responded with an average of approximately 697 milliseconds. The data could suggest that music delays reaction time at first, but slowly improves the user over time. The experiment takes about 25 minutes to complete, which means that music may enhance the brain after 25 minutes of exposure. However, more trials are needed to support this idea. The curve of the group exposed to music is significantly steeper than the group that did not listen to music. Based on previous literature we can expect that the graph should start to curve back upward, representing increasing reaction time. The control group's data stayed almost linear, but there is a slight curve, which can be expected from both groups.

Discussion

Exposure to music does affect reaction time. Originally, it was expected that if reaction time was affected by music, RT would decrease due to increased brain activity from stimulation. However, the hypothesis was not supported by the data, which suggested the opposite was true. On the other hand, the graphs match the expected learning curve, but the experimental group seems to be learning more slowly. More trials would be needed to figure out if the music group's RT will decrease further before rising again. The lack of participants was likely a major source of error because one person's data can skew the whole graph. For example, the third person's average in the music group was 932 milliseconds, whereas the rest were around 700 milliseconds. When data was collected, researchers ran an unpaired two-tailed T-Test with equal variances in Excel. The T-Test was unpaired because the people in the separate groups were different from each other. The T-Test revealed to the researchers that the data was insignificant. The test indicates that the results may not have solely been influenced by music. Use of stimulants prior to experimentation could have boosted some participants; lack of or excessiveness of sleep before testing would have altered brain waves in participants; other distractions would have hindered participants' processing skills. Additionally, the hypothesis may be incorrect because attention may be shifted to the music, distracting the user from the current task. This brings up the question: how much does a person need to enjoy a song to receive maximum benefits in the brain? While the idea of rating songs comes with many sources of errors (inability for some to gauge how much they truly "enjoy" a song), a survey could be handed out with 5-10 different songs, and reaction time is tested with each song. On the other hand, thoughts of previous songs would prevent accurate results unless trials are spread over a few hours. This could also be solved by using different people in each group. However, using different people in each group may have been a source of error in the current experiment because each person has different processing speeds. To solve this, again, more participants should be implemented into the next experiment (ideally 30 in each group). Moreover, exposure to music provides an auditory stimulus to the participants to respond to, and the brain processes auditory stimuli two to five times faster than visual stimuli, shifting attention to the other stimulus. Further research can be done on how demanding sounds are compared to light, and how different intensities impact processing. This could connect to driving as well because it would reveal statistics as to how people react during the day versus during the night. It could reveal how people would react in intense situations. A more thorough process can measure the bioelectrical oscillations of the brain when exposed to different music. In such an experiment, an EEG would be required to measure brainwaves while a participant listens to music. Alternatively, brainwaves could be measured before and after taking a reaction time test. Data would be influenced by factors including how competitive a participant is compared to another. EEG experiments require advanced math, extensive research on a subject, and 1.5 years to gather data, so those experiments would be done as a long-term project. The concept of music and RT connects to class because RT is dependent on genetics and mutations. For example, if there is a mutation that decreases audio sensory gating, RT will increase due to the brain having to focus on multiple stimuli. Overall, data suggests that music hinders processing at first. More research must be done with significantly more people to enforce this claim, as it contrasts previous findings. Other experiments include the effect of enjoyment of specific genres of music on reaction time, intensity of visual and/or auditory stimuli on processing, and different songs (based on preference) on bioelectrical oscillations of the brain.

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