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Exploring Music Tempo's Effect on Reaction Time: A Study on High-School-Aged Teenagers

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ABSTRACT

One of the leading and most preventable causes of death in American teenagers is motor vehicle-related fatalities. The present study investigates how music tempo affected reaction time in 14 to 18-year-olds to explore its potential effects on driving behavior. Participants (n = 36) performed a series of visual reaction-time tests without music and while listening to three songs at different tempos in a randomized order. Although participants' reaction times were slightly slower while listening to fast-tempo music, the findings showed no significant relationship between visual reaction time and music tempo. Results suggest that the tempo of in-car music may not significantly affect teenage driving behavior, specifically reaction time; however, more research is needed to better understand its impact.

INTRODUCTION

Motor vehicle crashes are the leading cause of death among teenagers in the United States, and the risk of getting into a crash is higher for 16 to 19-year-olds than for any other age group (CDC, 2024). Several factors contribute to adolescents' increased risk. For example, in 2023, 42.3% of participants in the Youth Behavior Risk Survey, which included all students in grades 9-12, reported texting or emailing while driving at least once in the 30 days before their survey response (*Youth Risk Behavior Survey | CDC*, n.d.). This is just one form of distracted driving, an issue that led to the injury and deaths of 3275 people in the United States in 2023 (National Highway Traffic Safety Administration, 2023).

However, distracted driving is just one factor that plays into this increased risk of motor vehicle accidents among American teenagers. Another significant factor is teenagers' slower reaction time compared to adults. This can be explained by the results of the study conducted by Feenstra et al. (2011), who found that adolescents, on average, needed more time than adults to respond to questions regarding driving and non-driving related decisions.

With both factors in mind, public health researchers face the question of what preventable variables may lower the risk of car accidents among teenagers. Music, although enjoyed by many drivers, may play a larger role in driving behavior than expected. According to Ghojazadeh et al. (2023), drivers spend about 75% of their time behind the wheel listening to music. Many do this as a method of relieving stress, or with the belief that it helps them focus, when in reality, it more often than not raises the driver's mental workload index, impairing their driving performance (Ghojazadeh et al., 2023). This explains the discussion posed by the Association for Psychological Science (2015), where they explain that the act of listening to music itself, not the act of changing its volume or skipping a song, interferes with teens' ability to maintain their focus while driving.

LITERATURE REVIEW

Variables Impacting Reaction Time

Many music characteristics have been the subject of research regarding their effect on reaction time and driving performance. Farrell (2020) examined the volume or intensity at which the music was played, finding that music at high (74 dB) and medium (37 dB) volumes significantly slowed reaction time. Similarly, Alimohammadi et al. (2015) found that when traffic noise volume or intensity was higher, participants' visual reaction time decreased. Both findings correspond with the work done by Ghojazadeh et al. (2025), whose results concluded that music at both high and medium volumes increased average driving speed and negatively affected drivers' hazard perception. The results of these studies contribute to the consistency of the findings and overall knowledge about the effect of volume on reaction time.

Another characteristic often explored throughout scientific literature is song and/or genre preference. In an article written by the Association for Psychological Science (2015), they reference the research done by Brodsky and Slor in 2012, who found that when teenagers played their preferred music during a 40-minute drive, they played at a higher volume than the control music and had significantly more driving errors. Contrary to these results, in a study conducted by Cowart et al. (2021), they found that there was no statistical difference in the reaction time when listening to preferred and non-preferred music. However, this study lacked the sample size that Brodsky and Slor's study had: Cowart et al. (2021) researched only four subjects, while Brodsky and Slor collected data from 85 novice drivers (Association for Psychological Science, 2015). Nonetheless, the experiment designed by Kasprzak (2023) supports the findings of Brodsky and Slor, as she found that respondents who listened to preferred music had slower reaction times that varied more than those completing the reaction test in silence. These findings show that there is a general consistency and understanding regarding the effect music preference has on reaction time.

Gap in Knowledge

The knowledge surrounding the relationship between music tempo and reaction time is not as clear. When Lin et al. (2023) conducted their experiment to explore this relationship, they found that the effect of music tempo on reaction time was significantly negative, meaning those who listened to fast music were more likely to have faster reaction times than those who listened to slow music. However, in their meta-analysis of the effect of music on driving performance, Ghojazadeh et al. (2023) found that music had a slightly greater positive impact (53.8%) than a negative impact (46.2%). Along with this, while all tempo conditions decreased the average reaction time among participants, there was no significant difference between the three tempo modes (high, medium, and slow) in their effect. Both of these results differ from the findings of Cave and Dhaliwal (2022), who found that while there was no statistically significant difference in performance accuracy, the slow tempo trial showed slightly faster reaction time than the high tempo trial. The variance in results regarding tempo's effect on reaction time points to the need for continued research focusing on this characteristic.

Along with the inconsistency of results regarding tempo's effect on reaction time, there is a lack of research on the population that is most at risk for motor vehicle accidents and impaired reaction time: high school-aged teenagers (Feenstra et al., 2011). Farrell's experiment (2021) consisted only of individuals between the ages of 21 and 25, and Cowart et al. (2021) tested only those aged 20 to 22 years old. The mean age of the Vietnamese undergraduate students in the experiment conducted by Lin et al. (2023) was 23.7 years old. Similarly, although the age range was not explicitly stated, Cave and Dhaliwal (2022) also limited their participant pool to college students enrolled at Douglas College. Ghojazadeh et al. (2023) limited their study to experiments that researched those within the age range of 18 to 60 years old, making their findings more diverse than those of the aforementioned studies, yet equally less representative of drivers in high school, who are commonly between the ages of 14 and 18 years old.

The lack of information regarding music's effect on individuals in high school is concerning, considering that crash risk is relatively higher during the first few months of licensure (CDC, 2024). Moreover, 82.6% of high schoolers in Arkansas, where this study is taking place, aged 16 or older, reported driving a car or other vehicle 30 days before completing the Youth Risk Behavior Survey in 2013 (Shults et al., 2013). The need for further research on both tempo's effect on reaction time and the lack of knowledge around music's effect on high school-aged teenagers leads us to the research question: how does music tempo impact the reaction time of high school-aged teenagers?

Hypothesis

Due to the heterogeneity of results from similar studies, it is difficult to determine the effect of tempo on reaction time. However, considering that auditory stimuli during manual tasks can impact mental workload (Ghuntla et al., 2014), music may pose a threat to young drivers. Explained by the arousal mood hypothesis, which suggests that background music affects cognitive performance by impacting arousal and mood (De Francesco et al., 2025), listening to music while driving may delay the driver's cognitive functioning abilities, therefore slowing their reaction time. With this in mind, reaction time is expected to increase in the presence of music at any tempo. When comparing expected reaction times between tempo conditions, fast-tempo music may further impair reaction time due to the speed at which auditory stimuli have to be processed compared to moderate- and slow-tempo music.

METHODS

Recruitment Process

The minimum age to begin learning how to drive varies by state, but the youngest age limit among states in the US is 14 years old, which serves as the minimum age for participation in this study (*Teens & Novice Drivers*, n.d.). Considering that 14 years old is the minimum age applicable to driving effects, along with the lack of research on varying tempos' effect on reaction times in young drivers, participation was limited to high schoolers, or non-high schoolers falling within the 14 to 18 year age range. Individuals outside this age range, those not associated with the school where the study was conducted, and those who failed to provide parental consent if under 18 were excluded from participation. With this criterion in place, recruitment was primarily geared towards students attending the school where the study was conducted.

A Google Form collected consent, explained the purpose of the study (excluding details on the dependent variable to prevent confounding), estimated the time needed, gave a voluntary participation statement, and outlined the benefits, risks, and maintenance of confidentiality. Participants or their guardians gave consent. Names and emails were collected to send materials, and confidentiality was maintained by coding data, limiting access to the researcher and mentor.

After IRB approval, information about the study was spread by word of mouth, social media, and on Schoology, a school communication platform, along with the link to complete the recruitment form.

Materials

The Human Benchmark online visual reaction time (VRT) test was employed for this experiment due to its established relevance in assessing responses to visual stimuli, which are closely associated with automobile accident prevention, as well as its capacity to provide immediate, objective reaction time feedback. All reaction time tests were administered on a 2024 MacBook Air, chosen for its consistent processing speed and display performance, and participants were instructed to interact with the screen using a Logitech Pebble Mouse 2 M350s, a Bluetooth mouse, to standardize input devices and reduce variability due to differing hardware. In all experimental trials except for the control run (no music), participants listened to music while wearing Bose QuietComfort 35 noise-cancelling headphones, selected to minimize auditory distractions and ensure uniform audio quality across trials. A TI-84 calculator was used to generate a randomized order of three integers assigned to music conditions, thereby reducing potential order effects. Participants completed informed consent, a pre-test questionnaire, and a post-test questionnaire through Google Forms to facilitate efficient data collection and ensure uniformity in survey administration. The post-test questionnaire contained YouTube links to the songs participants listened to during experimentation in order for them to accurately rate their enjoyment of each song. Reaction time tests were administered in an empty classroom for each participant to maintain controlled environmental conditions, including noise levels, temperature, and lighting conditions. Raw data was collected via notebook and later transferred to and analyzed in Google Sheets.

Experimental Design

This experiment aimed to understand the impact of musical tempo on reaction time in 14 to 18-year-olds, thus making tempo the independent variable and reaction time the dependent variable. As many potential variables could have affected the reaction time of participants, the same three songs and materials were used (reaction time test, laptop, mouse, calculator, headphones…) for all participants. Similarly, volume was kept controlled at approximately 50 dB during all trials for all participants, except for the no music control group (Farrell, 2021; Karageorghis et al., 2021).

This study was designed as a repeated-measures quasi-experiment employing a within-subjects factor. Each participant was instructed to complete 5 reaction time tests for each of four tempo conditions: a no music control group, low tempo (66-76 BPM), moderate tempo (108-120 BPM), and high tempo (120-155 BPM). These tempo ranges were assigned based on Italian musical tempo markings: *Adagio* (translating to "slow and stately"), *Moderato* (translating to "moderate"), and *Allegro* (translating to "fast") (Swinney, n.d.). The songs chosen for experimentation, "Awake" (Tycho, 2014), "Horizon" (Tycho, 2016), and "Fingerbib" (Aphex Twin, 1996), were chosen because they are both electronic and lyricless. Lyrics were treated as a confounding variable in this study and therefore avoided during the design due to the effect that higher synaptic processing and use of mental resources have on reaction time (Brodsky & Ziv, 2015; Karageorghis et al., 2021). Along with this, the songs chosen were electronic because electronic music generally contains repetitive melodic and rhythmic features, as well as a few harmonic shifts, thereby exhibiting characteristics that would result in confounding (Solberg & Jensenius, 2017). Upon choosing the songs, the music video YouTube links were converted to MP3 files, then uploaded into a BPM analyzer in order to ensure the tempos fell into the correct BPM ranges (Tunebat, n.d.). All three audio files were speed adjusted to fit into their respective tempo categories: "Awake" (Tycho, 2014) was set to a playback speed of 0.85 at 75 BPM, "Horizon" (Tycho, 2016) was set to a playback speed of 0.95 at 115 BPM, and "Fingerbib" (Aphex Twin, 1996) was set to a playback speed of 1.10 at 146 BPM (123apps, n.d.). Each of these songs was assigned an integer between 1 and 3 (1 = slow tempo, 2 = moderate tempo, and 3 = fast tempo) for later use in randomizing order for each participant during experimentation.

Along with a series of reaction time tests, participants were also given pre- and post-test questionnaires that included voluntary participation statements and asked about participant demographics, musical experience, self-rated song enjoyment, and whether they recognized the songs used during the experiment. The pre-test questionnaire asked participants for their name and demographic information, including age, gender, and race/ethnicity, along with whether or not they had experience working with music and what constituted their experience if they had any (e.g., playing an instrument, singing in a choir, musical theatre). The post-test questionnaire asked participants if they recognized the songs played during experimentation and to rate how much they enjoyed each song on a scale from one to ten to see if there was a correlation between arousal and reaction time (Cowart et al., 2021; Kasprzak, 2023).

Embedded links to each song's music video were provided for accurate rating. Following these questions was a debriefing statement and a final question asking participants if they would like to withdraw their data from the study.

Procedure

Before joining this study, participants filled out the recruitment and informed consent form. Once this form was submitted and appropriate consent was given, participants received both the pre- and post-test questionnaires by email. After completing the recruitment form and pre-test questionnaire, each participant was brought individually into an empty classroom for experimentation. Only the participant and the researcher were present in the room.

Before participants entered the room, the laptop used was set to Do Not Disturb, the Human Benchmark reaction time test was pulled up, and the Bluetooth mouse was connected to the laptop. The researcher then generated a randomized set of integers between 1 and 3 for the randomization of trial order using the RandomIntNoRep[1,3] calculator function to prevent altered results due to the practice of visual information processing (Ghuntla et al., 2014). This step was repeated before each participant entered the room, generating a unique, randomized order of tempo conditions for each participant to listen to. Bluetooth headphones were then connected to the researcher's phone to play the audio files without revealing the songs to participants.

Once the setup was complete, participants entered the room and sat down in front of the laptop. It is important to note that a notebook was used to record raw data, as the researcher's laptop was being used for reaction time testing and a phone for music control. Because of this, the researcher needed to sit in proximity to the participant and the laptop in order to accurately record reaction time data presented on the screen. Once both the participant and the researcher were seated, instructions were provided, and the voluntary nature of the study was reiterated. The participant was given the choice to complete as many practice tests as they wanted before data collection.

Participants first completed five reaction time tests without listening to any music. After five reaction times were recorded, participants were instructed to put on the headphones. They then repeated the first step, completing five reaction time tests under each tempo condition in a randomly generated order for each participant. After completing all four trials, participants were given verbal instructions to complete the post-test questionnaire sent to their provided email address with a careful explanation, considering the order of the songs on the form was not necessarily the same as the order they were used in the experiment.

After all participants had completed experimentation and filled out both questionnaires, the raw data were transferred to Google Sheets for data analysis. Once the data were organized, it was analyzed through ANOVA tests and the calculation of Pearson correlation coefficients to determine the significance and correlation strength of the tested variables on reaction time.

RESULTS

Of the 37 participants who completed the study, one participant's data were excluded from the analysis due to both distraction from uncontrolled noise and inconsistency in the method of interface interaction (alternating between interacting with the VRT test via a Bluetooth mouse and a trackpad). Of the 36 participants whose data were analyzed, all completed the recruitment form, pre-test questionnaire, and VRT tests. However, one participant failed to complete the post-test questionnaire, resulting in song recognition and enjoyment data collection from only 35 of the participants.

When a repeated-measures ANOVA test was performed, statistical significance was defined as results with a p-value less than 0.05 ($\alpha = 0.05$ significance level), meaning there was less than a 5% probability that observed differences occurred by chance. When a Pearson correlation coefficient (r) was calculated, the strength of the correlation was interpreted as follows: very weak if $0 \leq |r| \leq 0.19$, weak if $0.2 \leq |r| \leq 0.39$, moderate if $0.4 \leq |r| \leq 0.59$, strong if $0.6 \leq |r| \leq 0.79$, and very strong if $0.8 \leq |r| \leq 1$.

When calculating Pearson correlation coefficients for categorical variables, these variables were assigned numerical codes in Google Sheets to enable analysis. For example, the gender variable was represented using binary coding, where male participants were assigned the value "0" and female participants were assigned "1." The same coding was applied to yes/no variables, with "No" coded as 0 and "Yes" as 1, allowing these categorical variables to be included in the correlation calculation.

Tempo's Effect on Mean Reaction Time

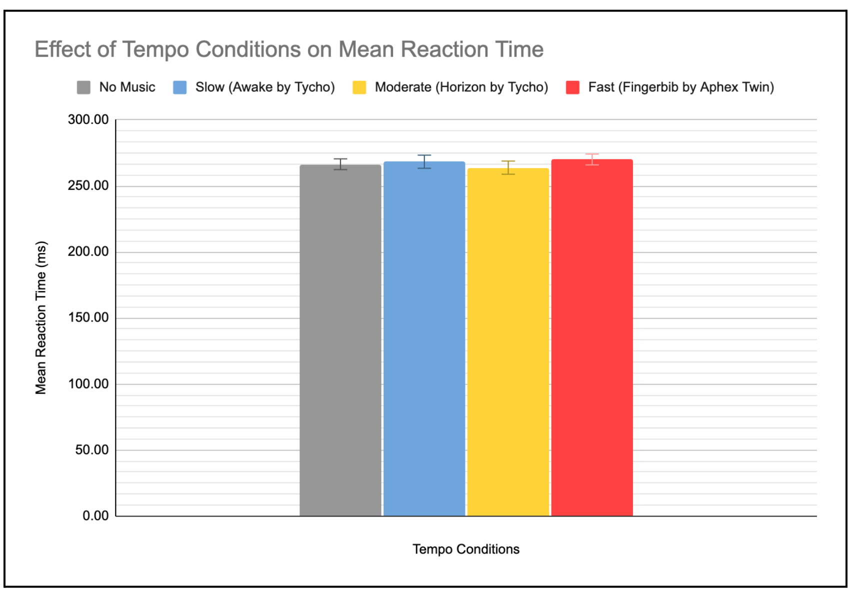

Figure 1

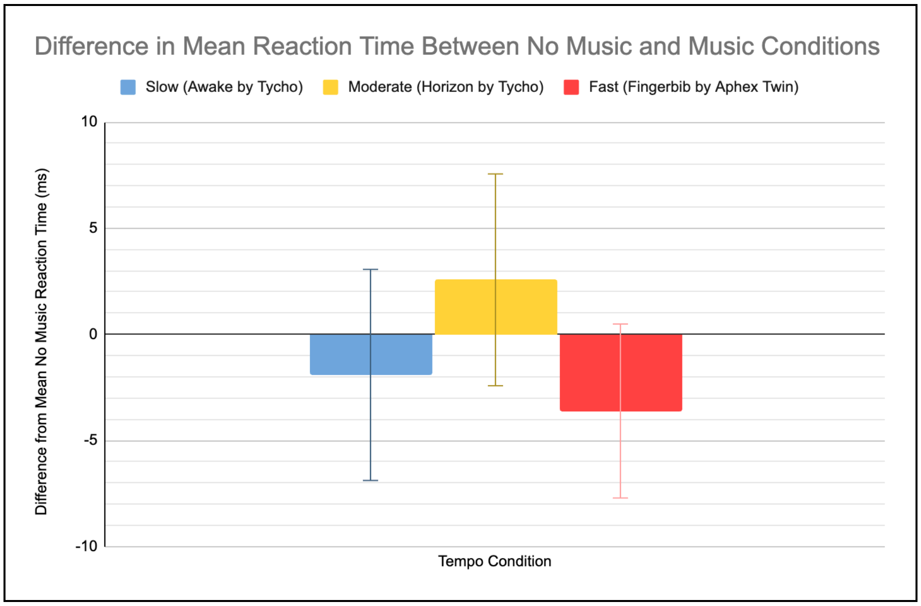

Figure 2: The difference in mean reaction times between the control group and the tempo conditions (No music - Tempo Condition). Difference in mean VRT from control group: -1.91 ms (slow), 2.57 ms (moderate), & -3.61 ms (fast).

The mean visual reaction times of all participants under each tempo condition were 266.49 ms with a standard error (SE) of 4.08 ms for no music, 268.40 ms with an SE of 4.97 ms for slow tempo (75 BPM), 263.92 ms with an SE of 4.99 ms for moderate tempo (115 BPM), and 270.10 ms with an SE of 4.10 ms for fast tempo (146 BPM) (Figure 1). The differences in mean reaction times of high school-aged teenagers across all tempo conditions proved statistically insignificant in this sample. A repeated-measures ANOVA test for all tempo conditions resulted in insufficient evidence to show that the mean reaction time between tempo conditions was unequal, with the p-value of 0.553. Participants had the slowest mean reaction time when listening to fast-tempo music (Fingerbib by Aphex Twin) and the fastest mean reaction time when listening to moderate-tempo music (Horizon by Tycho) (see Figure 1). To determine the significance of mean reaction time differences for each tempo condition, two-tailed paired T-tests were run for each tempo condition against the no music control condition. For all three tempo conditions, data suggested that the difference in mean reaction times was statistically insignificant, with the p-values: 0.6537 (slow), 0.5835 (moderate), and 0.4351 (fast). This insignificance is further suggested by the very small effect size ($f^2 = 0.007$) of music tempo on reaction time and the lack of variance between the control groups and tempo conditions, including the minimal difference between means across groups and the overlap of the margin of error seen in Figures 1 and 2.

Demographic Variables

The demographic variables accounted for in the pre-test questionnaire (age, race/ethnicity, and gender) were analyzed as covariates to determine if they had unintended effects on the relationship between tempo conditions and reaction time.

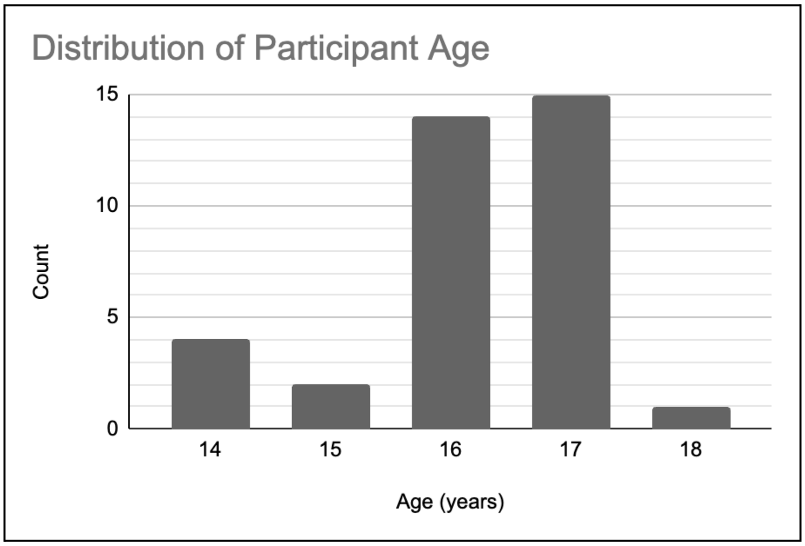

Figure 3

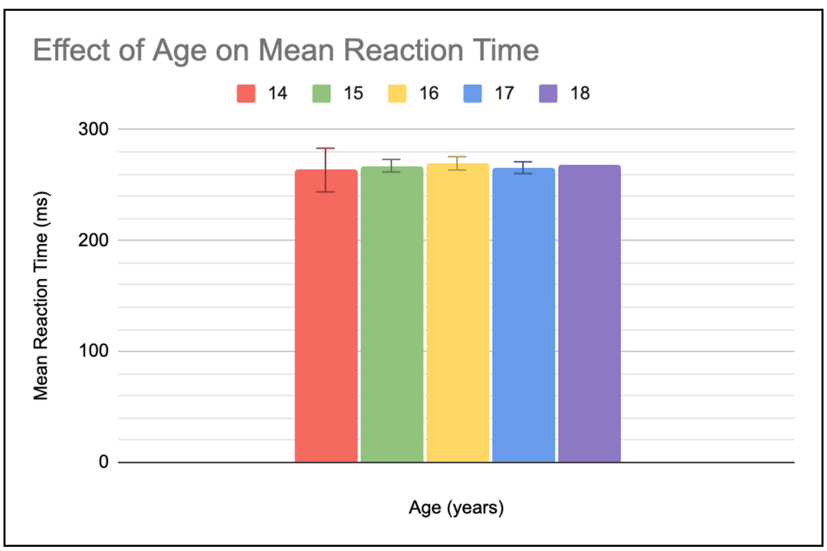

Figure 4: Mean VRT: 263.6 ms (14), 267.58 ms (15), 269.63 ms (16), 265.81 ms (17), & 268.6 (18). Only one participant was 18, so no margin of error could be calculated for this age group.

The mean age of participants in this study was 16.196 years, with a standard error of 0.1682 years, suggesting a large concentration of participants within the middle of the 14-18 year-old age range (Figure 3). The age distribution of participants was not distributed uniformly (see Figure 3), with the majority of participants involved between the ages of 16 (14 participants) and 17 years old (15 participants, respectively). Due to this uneven distribution, a one-way ANOVA test was inappropriate for analysis, so a Pearson correlation coefficient was used instead. The Pearson correlation coefficient showed a very weak positive correlation between mean reaction time and participant age in this study, at an r-value of 0.013. The weakness of this correlation may point to a statistically insignificant relationship between age and mean reaction time in this sample, further supported by the weak Spearman's Rank Correlation (ρ) of -0.08. The overlap of reaction time margins of error between age groups (see Figure 4) suggests that either the difference in mean reaction times between age groups in this sample is insignificant, or the lack of variance in participant age in this study did not affect overall mean reaction time between age groups.

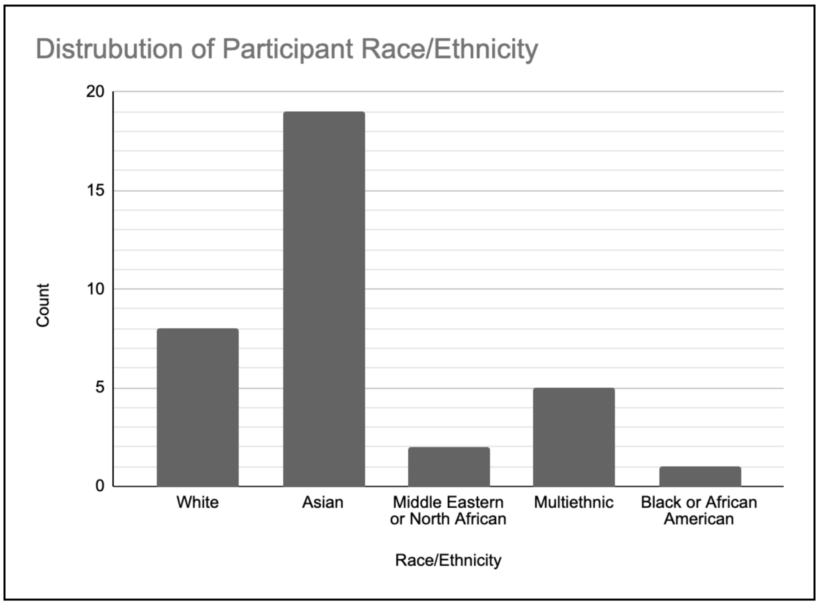

Figure 5

The racial/ethnic distribution of participants in this study was uneven, with the majority self-identifying as Asian (20 participants). Other racial/ethnic groups represented in this study included White, Multiethnic (anyone who selected two or more racial/ethnic groups or "Multiethnic" in the pre-test questionnaire), Middle Eastern or North African, and Black or African American (see Figure 5). Due to the uneven distribution of racial/ethnic identities among participants and the large number of Asian participants, a one-way ANOVA test was run to determine if the overall mean reaction times of Asian and non-Asian participants across all tempo conditions were unequal. The results of the one-way ANOVA test determined that the difference in mean reaction times between Asian and non-Asian participants was statistically insignificant, with a p-value of 0.2516, suggesting that racial/ethnic identity had no likely impact on the VRT of participants in this sample.

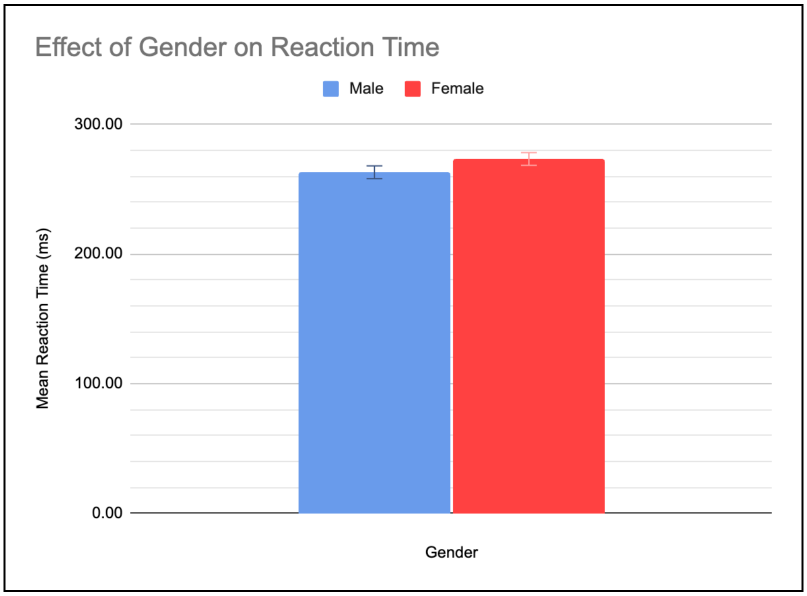

Figure 6

The distribution of participant gender was relatively even, with 20 participants identifying as male and 16 identifying as female. Males had a faster mean VRT across all tempo conditions when compared to females, where male participants' mean was 262.85 ms with an SE of 5.34 ms and female participants' was 272.7 ms with an SE of 4.92 ms (see Figure 6). Both a one-way ANOVA test and a Pearson correlation coefficient were used to determine the significance of this difference in mean reaction time. The Pearson correlation coefficient was 0.222, showing that there was a weak positive relationship between gender and reaction time in this study. Similarly, the one-way ANOVA test showed that the difference in mean reaction times between male and female participants in this study was statistically insignificant, with a p-value of 0.192 and an effect size (f) of 0.23. This insignificance is further indicated by the overlap in the margin of error, as seen in Figure 6.

Musical Experience

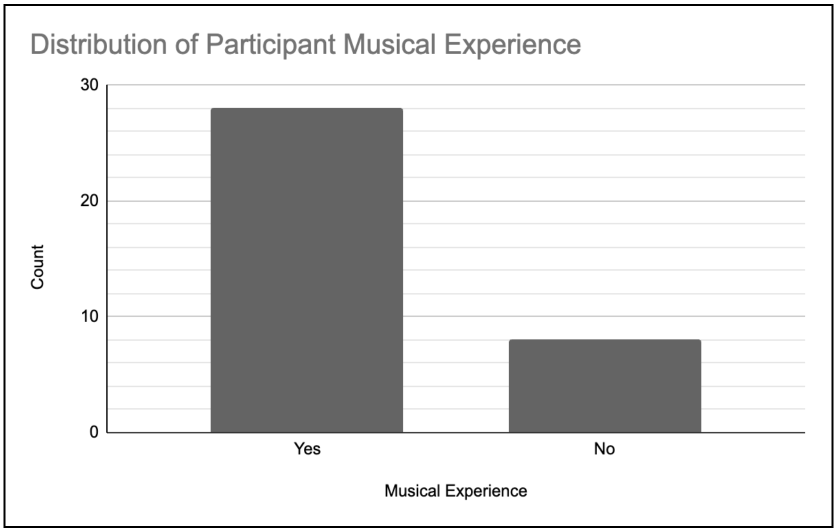

Figure 7

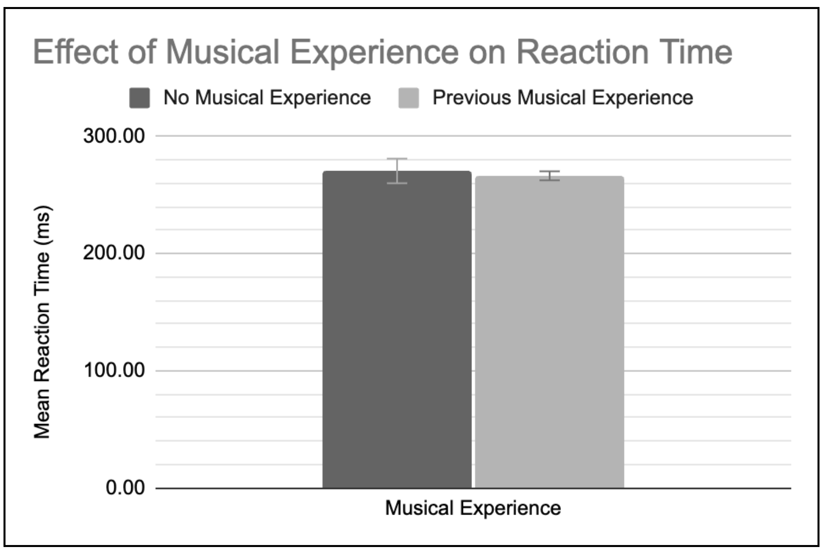

Figure 8: Mean VRT: 270.47 ms (no musical experience) & 266.3 ms (previous musical experience)

Information participants gave during the pre-test about their experience with music was also analyzed as a covariate for their effect on mean reaction time. Although a one-way ANOVA test showed that the difference in overall reaction time between those with musical experience and those without in this study was insignificant, with a p-value of 0.6479 and an effect size (f) of 0.079, the distribution of these groups (see Figure 7) was highly uneven, with 78% of participants claiming to have musical experience. Due to this inequality, a Pearson correlation coefficient was calculated as well, determining that there was a very weak negative relationship between musical experience and reaction time at an r-value of -0.0788. The difference between mean reaction times between these groups was minimal, as seen in the overlap of the margin of error in Figure 8, indicating that either musical experience had an insignificant effect on reaction time in this sample or that there wasn't enough variation in musical experience in this study to affect reaction time.

Song Recognition

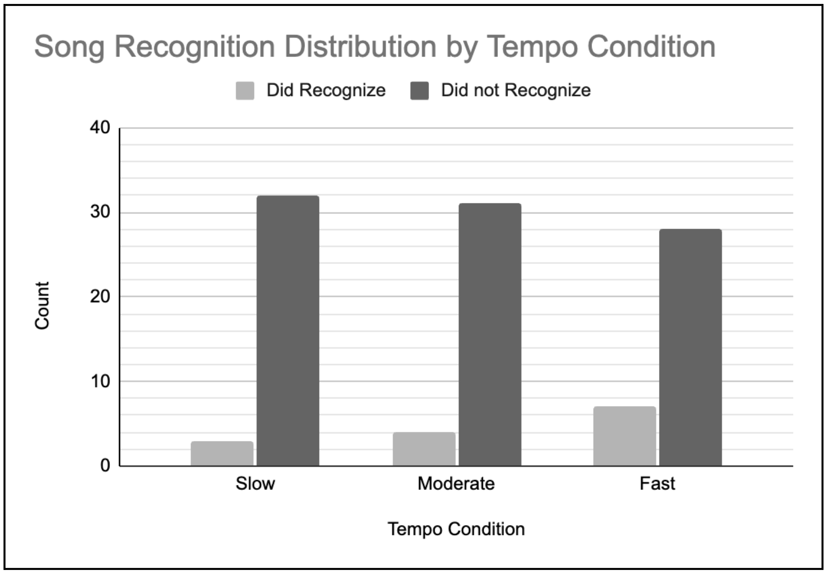

Figure 9

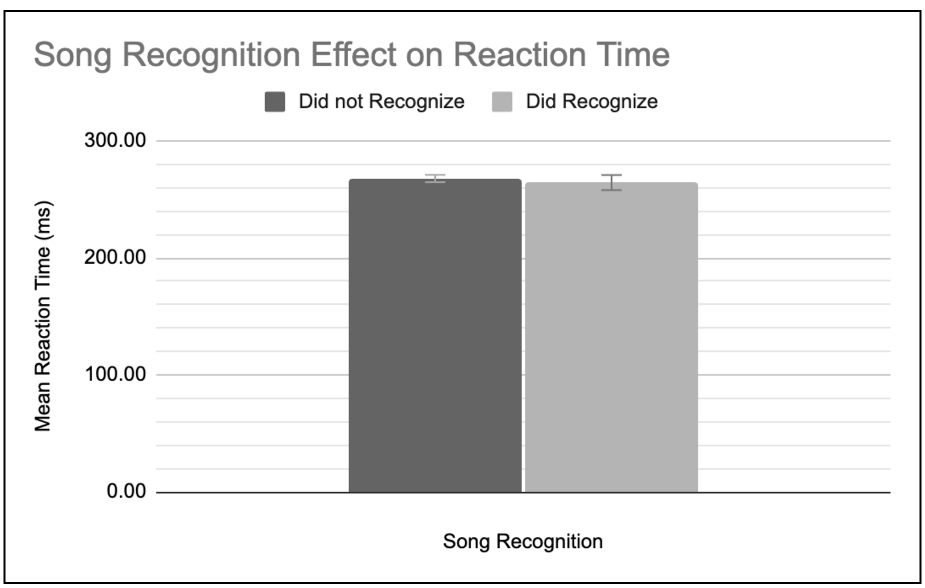

Figure 10

Participants' self-reported recognition of the songs used during VRT testing was considered as a covariate in reaction time. The mean reaction time of those who listened to a song that they reported as not recognizing was 267.92 ms, with a standard error of 3.13 ms, while the mean RT of those who listened to a song they reported as recognizing was 264.46 ms, with a standard error of 6.44 ms (see Figure 10). Due to the infrequency of participants who reported recognizing songs used during VRT testing (see Figure 9), an ANOVA test was inappropriate for analysis, so a Pearson correlation coefficient was calculated. The r-value, -0.0432, showed a very weak negative correlation between song recognition and reaction time, pointing to a statistically insignificant relationship between song recognition and reaction time in this study. This insignificance is further supported by the overlap in the margin of error seen in Figure 10.

Self-Rated Enjoyment

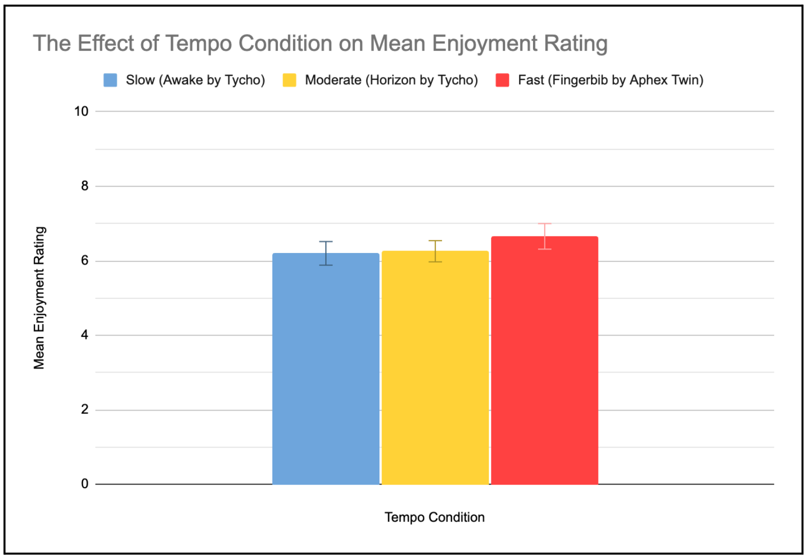

Figure 11: Mean ratings: 6.2/10 (slow), 6.257/10 (moderate), and 6.657/10 (fast). SE: 0.32 (slow), 0.29 (moderate), and 0.34 (fast).

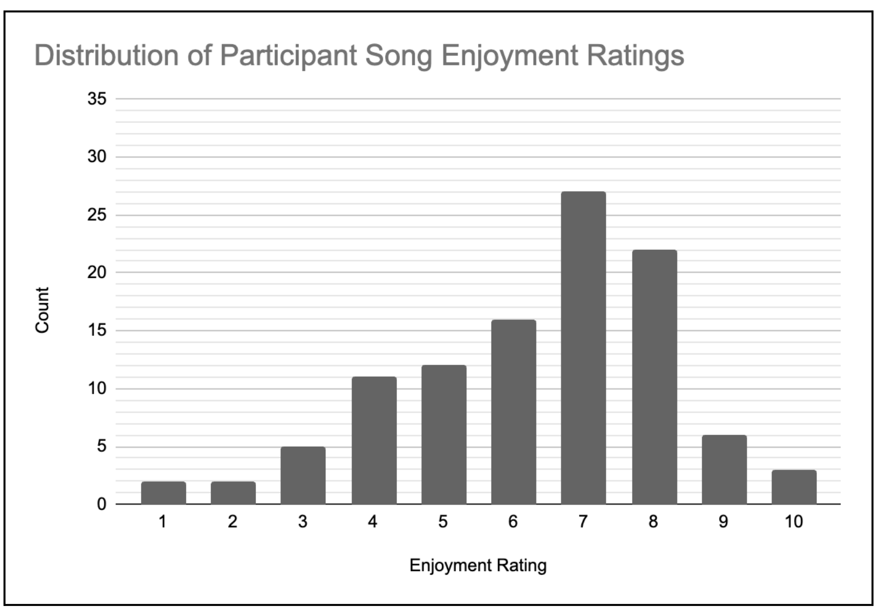

Figure 12: n = 105 (35 participants × one rating for each of three songs)

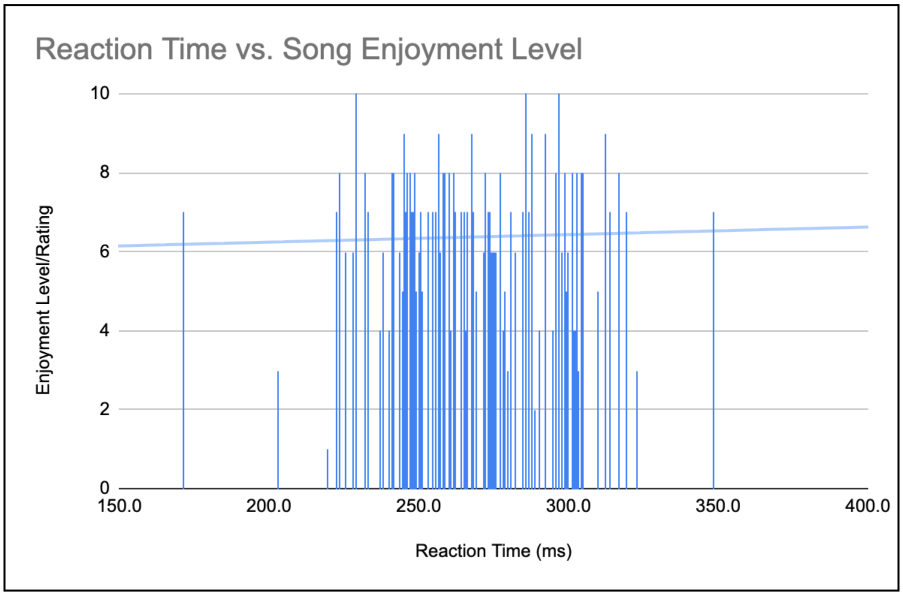

Figure 13: This graph displays the regression line for the relationship between song enjoyment level (scale from 1 to 10) and reaction time. Each line represents the mean reaction time of one participant under each tempo condition, excluding the no music control group (ex. Participant 7's mean reaction time across five trials under the moderate tempo condition).

Participants' self-reported enjoyment levels (on a scale from 1 to 10) were also analyzed as a covariate for the effect of tempo conditions on reaction time. Mean ratings for each song (tempo condition) were relatively close, with each song having a mean rating between 6 and 7 (see Figure 11). To identify the strength of the relationship between enjoyment ratings and reaction time speeds of participants, a Pearson correlation coefficient was calculated, yielding an r-value of 0.0297. This weak, positive relationship between song enjoyment and mean reaction time can be seen in Figure 13, suggesting an insignificant correlation between the two variables in this sample. However, the margin of error for mean enjoyment ratings for all three songs overlapped in Figure 11, suggesting that there may not have been enough variance in enjoyment levels to affect reaction time in this study. Additionally, the sample size of this study likely contributed to the non-uniformity of the rating distribution as seen in Figure 12, which may have contributed to the weakness of the relationship between song enjoyment and reaction time.

DISCUSSION

Conclusion

This study is among the first to examine the relationship between music tempo and reaction time in 14- to 18-year-olds. The presence of music was expected to produce slower reaction times than in the no-music control group, based on the arousal-mood hypothesis, due to an increased mental workload index. The fast-tempo condition was further expected to slow reaction time under the assumption that faster auditory stimuli take more cognitive resources to process in comparison to moderate- and slow-tempo auditory stimuli.

The results of this study imply that music at any tempo may not significantly alter reaction time. These results differ from the findings of the reaction time studies conducted by Ghojadezah et al. (2023) and Lin et al. (2023), who both found significant relationships between tempo conditions and reaction time. However, these results align with those of Cave and Dhaliwal (2022), who similarly found that the difference in reaction time between tempo conditions was insignificant. Additionally, although reaction time was the slowest under the fast-tempo condition, this difference in reaction time proved insignificant in comparison to both the no music control group and other tempo conditions. These results may suggest that neither the presence of music nor its tempo affects reaction time.

Along with music tempo, the relationship between all covariates accounted for in the pre- and post-test questionnaires (demographic variables, musical experience, song recognition, and song enjoyment) and reaction time in this study were statistically insignificant. While this insignificance may suggest that these covariates had minimal effect on reaction time, it could also point to an insufficient variation of the variable data.

Implications

The findings of this study can help traffic safety experts better understand the impact that music tempo has on driving behavior. As this study found that there was an insignificant difference in reaction time when participants listened to music compared to when they didn't, 14 to 18-year-olds' reaction time when making quick traffic decisions is unlikely to vary significantly based on the presence of music in the car. Moreover, the insignificant difference in reaction time between tempo conditions suggests that 14 to 18-year-old drivers may not experience a significant difference in their reaction time during traffic incidents based on the tempo of music playing in the car. The overall findings of this study suggest that the tempo of music high-school-aged drivers listen to is likely an insignificant factor in automobile accidents related to reaction time. However, more research is needed to further support the understanding of music tempo on reaction time in this age group.

Limitations

A major limitation of this study was the relatively small sample size. With only 36 participants, variability in reaction time across tempo conditions was large, likely making the differences between groups insignificant. Additionally, the small number of participants may have resulted in insufficient statistical power, which may have resulted in a high rate of false negatives, failing to identify meaningful differences and relationships between visual reaction time and music tempo. Future research should aim to analyze a larger sample size to obtain more accurate results. Incentivizing participation could be a better method of participant recruitment in future research.

Similarly, because of the sample size, the distribution of covariates provided insufficient variation to test for their effect on reaction time. For example, the distribution of participants who recognized songs was relatively uniform among the three songs tested (see Figure 9), suggesting that there is not enough variation between the three songs to suggest a significant difference in reaction time between them. The same can be said about the uneven distribution of race, age, song enjoyment, and musical experience. Future studies should aim to recruit a diverse group of participants for the covariates being tested.

Additionally, the results of this study address the impact on reaction time in relation to the Human Benchmark visual reaction time test. Though this may give traffic safety experts insight into how music tempo affects high-school-aged teenagers' driving behavior, it is not an accurate measure of that complex behavior. Visual reaction time is a significant factor in driving behavior when it comes to the speed at which a driver can respond, but it cannot predict drivers' responses in the same way as a driving simulator or driving tasks. Future studies should aim to test the impact of tempo on driving behavior using a driving simulator to obtain more ecological validity and applicable data.

Moreover, although the order of tempo/conditions that participants listened to was randomized for each participant and all possible condition orders were represented in this study, randomization was not checked for balance across participants. Because of this, there may have been an overrepresentation of a tempo condition that participants listened to first, resulting in confounding due to a lack of VRT test practice (Ghuntla et al., 2014). Future studies should aim to maintain a balance of all possible condition orders to prevent potential confounding due to a lack of practice.

Another limitation of this study was the inconsistency of experiment time and location. Due to the demanding schedules that many high school students have, flexibility of experiment time and location was necessary to ensure participation in this study. Some participants were tested in the morning, while others were tested during the afternoon, depending on their availability. Although the locations used for experimentation were both quiet and controlled environments, unintended effects may have occurred due to variation in experiment location.

Some participants seemed to just be clicking the screen, aiming to get the fastest reaction time, rather than letting themselves react naturally to the change in color. While this may have affected some reaction times, only one participant produced a statistically significant outlier under one tempo condition, so their data was retained in the study.

Furthermore, although the selection of music used in this study was limited to electronic songs, the use of different songs across tempo conditions did not account for the differences in other musical characteristics between songs. Because of this, the differences in reaction time, or lack thereof, between tempo conditions may reflect the characteristics of the songs themselves instead of tempo alone. Future studies should aim to account for the differences in musical characteristics across (e.g., rhythm, melody, emotional valence) songs in addition to their difference in tempo, or consider manipulating the tempo of the same musical piece and evenly distributing the number of participants who listen to each tempo condition to avoid confounding due to differences in other musical characteristics.

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