4-1-2013

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Effects of Music Tempos on Flight Performance

Submitted to the Faculty of Purdue University, in Partial Fulfillment of the Requirements of the Master of Science degree in Aerospace Management

Alexandra R. Kieta*, John Young, Derek Stewart

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Abstract

To date, research on how listening to music affects performance in high-cognitive demand environments has ranged from those working in information technology to everyday drivers. Some research asserts listening to music does have an effect on human task performance (whether positive or negative) and other research asserts there are no statistically significant effects. This research study focused on how varying music tempos affect pilot performance during certain flight maneuvers. With significant findings, measures could be taken to improve pilot, crew and passenger safety; however, no statistically significant results were found that listening to different music tempos had any effect on pilot performance.
Literature Review

Listening to music while driving has only been a moderately researched area, as indicated by academic literature. As late as the early 1980’s, research on the psychology of music was criticized for failing to account for how listening to music had become fully imbedded in the stream of daily life (North & Hargreaves, 1999). Currently, research has been conducted on the effects of listening to music in various high-cognitive demand occupations. This literature review delves into opposing research that asserts there is either no effect or some effect to better grasp the results from selected, representative studies. From these results, the need for similar research to be done in aviation, particularly with pilots, is a logical continuation.

Because no known research has been conducted on how music tempos affect pilot performance, one must begin with the general effects music has on cognitive performance in other high-cognitive demand occupations and tasks. Background music is widely thought to potentially disrupt cognitive performance “when there is a potential for interference, e.g., between the vocal content of the music and the phonological characteristics of working memory” (Angel et al., 2010, p. 1063). If true, this could be detrimental for pilots who are listening to music with lyrics and concurrently talking with air traffic controllers. Other research indicates specific cognitive tasks, such as spatial processing and linguistic processing – both pertinent for pilots – has shown to be affected by background music (Angel, Polzella & Elvers, 2010). In the study, participants’ response accuracy for a spatial processing task (comparing and contrasting two histograms) decreased when background music was present; however, response times and accuracy for a linguistic task (identifying and relating letters) increased with task difficulty, as did the speed of spatial processing, when background music was present (Angel et al., 2010). All
the aforementioned research, with both positive and negative findings, can contribute to understanding the psychology of music in other high-cognitive demand tasks, such as driving.

Historically, there have been mixed results on the effects of listening to music while driving. One study found that as music tempo increased, so did driving risks due to competition for attentional and cognitive space of the increased mental load (Brodsky, 2002). Specifically, as the tempo of background music increased, so did simulated driving speed and traffic violations, including disregard for red traffic lights and increased collisions (Brodsky, 2002). Another study, conducted using simulators for driving laps while concurrently listening to music, implicated that musical features such as tempo (low arousal and high arousal) and participants’ musical preference (self-selected versus experimenter-selected music) were important (Cassidy & MacDonald, 2010). In contrast to listening to self-selected music, listening to experimenter-selected music resulted in the poorest driving performance with increased inaccuracies, especially with high arousal (HA) music. Low arousal (LA) music showed the slowest lap speeds, while HA and self-selected music showed the highest lap speeds. Additionally, driving inaccuracies were the highest with HA music and lowest with self-selected music. Overall, it was found that HA music was more detrimental to performance, when compared with LA music (Cassidy & MacDonald, 2010).

In another driving experiment, participants drove laps and concurrently either listened to LA or HA music, in addition to either performing a backward-counting task or not (North & Hargreaves, 1999). Results showed that listening to HA music while driving led to longer lap times, longer times to complete the backwards-counting task, and increased perceived difficulty of the backwards-counting task. The multitasking in the driving performance research conducted by North & Hargreaves (1999) simulates the multitasking demands of the pilot during flight.
Since these studies implicate listening to music while driving and performing concurrent tasks requires more cognitive space (and even more with HA music) and worse performance, this could have potentially detrimental indications for pilots who listen to music while they fly.

In contrast, some research argues that listening to music while driving is beneficial in terms of relaxation and concentration (Dibben & Williamson, 2007). Supporting this assertion, a study using professional truck drivers and simulated driving showed that when the drivers used music to counter monotony, there were no indications of performance deterioration, as measured by subjective feelings of fatigue or mental effort (Oron-Gilad, Ronen, & Shinar, 2008). In this study, listening to music while driving was shown as an appropriate measure taken to maintain alertness (Oron-Gilad et al., 2008).

Despite the multitude of research indicating that music does have an effect on human task performance, there is a comparable amount of research indicating there are no statistically significant effects. One such driving study used a simulated traffic environment where participants drove in both complex and monotonous driving situations, concurrently listened to music, and verbally reported their mental effort at certain points (Ünal, Steg & Epstude, 2012). This study found that listening to music while driving increased participants’ mental effort, regardless of if the driving situation was complex or monotonous; however, participants who listened to music performed just as well as the participants who did not listen to music (Ünal, Steg & Epstude, 2012). These results indicate drivers “regulated their mental efforts as a cognitive compensatory strategy to deal with demanding driving tasks, such as being confronted with a hazard,” thereby not negatively affecting driving performance (Ünal et al., 2012, p. 276). Another study with similar results was conducted using driving simulators and individually selected music that was categorized as either positive or negative (van der Zwagg, Dijksterhuis,
de Waard, Mulder, Westerink, & Brookhuis, 2012). Participants’ moods, mental efforts and overall driving performance were assessed. Results found less swerving was observed in higher cognitive demanding drives regardless of music presence, indicating no negative effects of listening to music on driving safety performance (van der Zwagg et al., 2012). The self-reported mental efforts increased during the drives regardless of whether the music was positive or negative, indicating the increased use of participants’ cognitive space with concurrent tasks. It was noted the additional mental load added by listening to music could have been minimal, as driving can be mainly automated; however, novice drivers might have drastically different results (van der Zwagg et al., 2012). For pilots, this implication could mean unaffected performance in regards to safety, except with inexperienced pilots where the increased cognitive load in flight could have unfavorable outcomes.

Although no known research has been previously conducted on whether listening to music affects pilot performance in flight, there is recent music psychology research in aviation. One such study was conducted on monitoring and controlling stress levels and heart rates of passengers with music during a simulated flight with some turbulence (Liu, Hu, & Rauterberg, 2010). If a heart rate monitor showed a participant’s heart rate was higher than the top of the normal range of 80 BPM, indicating stress, calming music was played through the participant’s headphones. The results showed that after four minutes of listening to the selected music each time a participant’s heart rate rose above 80 BPM, participants’ heart rates returned to and stayed within the normal range (high 50’s BPM and low 70’s BPM), and led to reduced self-reported stress levels during the flight (Liu, Hu, & Rauterberg, 2010).

Another aviation study dealing with music focused on one of the leading causes of aviation accidents - pilot spatial disorientation (Brunghart & Simpson, 2008). In this study, pilots
chose which audible alert would provide them with information about the attitude of the aircraft in order to decrease the occurrence of incorrect perceptions that caused them to feel that the aircraft was in a different orientation than it actually was. The pilots flew Cirrus SR-22 aircraft equipped with a laboratory computer that ran the audio through headphones. The audio signals systematically changed with the attitude of the aircraft to provide subtle cues to which direction the pilots needed to maneuver to restore straight and level flight. For example, when the plane banked right, the sound shifted to the right, and when the aircraft was straight and level, the pilot heard a centered sound (Brunghart & Simpson, 2008). These audio cues reduced the pilot’s errors in “identifying aircraft pitch by roughly 6%, decreased the number of incorrect roll identifications by roughly 18%, and reduced the number of errors in identifying slow changes in the attitude of the aircraft by more than 50%, thereby allowing blindfolded pilots to maneuver the aircraft out of an unusual attitude and back into a straight and level flight pattern” (Brunghart & Simpson, 2008).

Implications of these findings, relating to controlling stress during flight and improving pilots’ situational awareness, can be applied to research on how music tempos affect pilot performance. In concurrence with research on the effects of listening to music on driving performance and other high-cognitive demand tasks and occupations, it is important to expand this research to discover whether listening to music while flying improves cognitive performance, hinders it, or has no effect. The findings could potentially have important safety implications for the aviation industry.

**Research Problem**

Many studies have been conducted on how music affects performance on different tasks in high-cognitive demand occupations, similar to flying. In general, research dealing with
evidence for the effects of background music on human performance appears inconsistent (Angel et al., 2010). An overwhelming majority of this human performance research provides information for those in the transportation realm, dealing with driving. Most drivers in the United States choose to listen to music as they drive. There are mixed conclusions for both negative and positive influences that listening to music has on driving a vehicle (Dibben & Williamson, 2007).

To a growing degree, many private pilots listen to music while in the cockpit, such as during long cross-country flights (Brunghart & Simpson, 2008). Because of this, it is important to understand how listening to different music tempos affect their performance in a high-cognitive demand environment - the cockpit.

Applying previous research from similar domains, such as driving, the researcher was able to do an exploratory study on whether listening to music has any effect on flight performance. Therefore, the research questions are: (a) is there a correlation between listening to music with varied tempos and flight performance, and (b) is there a correlation between the specific type of music and perceived flight performance.

**Methodology**

Participants for this study were six students enrolled in the Professional Flight Program at Purdue University. They each held a private pilot license, a current FAA medical certificate, and were non-instrument rated.

This study used Purdue University Cirrus SR20 flight simulators (visual, no motion system). Headphones and an IPod were used to play the songs for each segment. The flight maneuver directions were given to the participants verbally while they listened to the selected music. An information sheet was kept for each participant and a survey was given to each participant at the end (see Appendices A & B).
Participants each flew three flight segments - one without music and two with music. Segments were randomized for each participant and the flight maneuvers remained the same. During each segment, a qualified flight simulator instructor was there to operate the simulator and help properly record data. During one segment with music, the participants listened to three songs with slow tempos - “Stranger on the Shore” by Kenny G, “Being With You” by George Benson, and “Like A Lover” by Earl Klugh, with 56, 65 and 63 BPM, respectively. These songs were selected from Brodsky’s (2002) study, where the audio tracks were subjected to tempo criterion ratings in accordance with a “Swiss-made analog Cadenzia pocket Metronome to measure the felt pulsation of the main beat of each track”. During the other segment with music, the participants listened to a mix of songs, titled “Skyline,” with fast tempos - “Crazy Sonic” by Hold Me, “Mistol Team” by Princess Salavina, and “Cuervo, Dezibelio” by Overdrive (an MDK Remix), with a range of 155 to 165 BPM. Each song’s BPM was also verified by the researcher using Traktor, disc jockey music software.

In each segment, each participant completed two maneuvers under visual meteorological conditions (VMC): a steep turn and slow flight. The successful completion of each segment was based upon the Federal Aviation Administration’s (FAA) Private Pilot Practical Test Standards (PTS) for Airplane - Single-Engine Land (ASEL) in regards to altitude, heading, coordination and airspeed. For the steep turn maneuver, participant success was evaluated on their ability to:

- establish the manufacturer’s recommended airspeed or if one is not stated, a safe airspeed not to exceed VA [(120 knots)]
- roll into a coordinated 360° turn; maintain a 45° bank
- perform the task in the opposite direction, as specified by the flight instructor
- maintain the entry altitude, ±100 feet, airspeed, ±10 knots, bank, ±5°; and roll out on the entry heading, ±10° (FAA, 2011, p. 52)
For the slow flight maneuver, participant success was evaluated on their ability to:

- select an entry altitude that will allow the task to be completed no lower than 1,500 feet AGL
- establish and maintain an airspeed ($V_{so} = 56$ knots) at which any further increase in angle of attack, increase in load factor, or reduction in power, would result in an immediate stall
- accomplish coordinated straight-and-level flight, turns, climbs, and descents with landing gear and flap configurations specified by the flight instructor
- maintain the specified altitude, ±100 feet; specified heading, ±10°; airspeed, +10/−0 knots; and specified angle of bank, ±10° (FAA, 2011, p. 57)

For both maneuvers, coordination was measured by either a ¼, ½ or full deflection, as displayed by the inclinometer. Successful coordination was accepted up to ¼ deflection. For recording purposes, coordination was marked as “yes” it was -, or “no” it was not a coordinated maneuver.

Each information sheet was used to manually record deviations made during the flight maneuvers for each participant for each song. The four dependent variables were: (1) altitude, (2) airspeed, (3) coordination, and (4) heading. The two independent variables were: (1) the music played during the simulated flight, and (2) commands given for each selected maneuver.

**Results**

From the data gathered during the flight simulations, the One-Way Repeated Measures Analysis of Variance (ANOVA) statistical test was chosen, to compare the differences in the mean scores from deviations under the three musical conditions within the same group of participants. Six, One-Way Repeated Measures ANOVAs were conducted through SPSS. The six tests ran were for: altitude deviations while listening to no music, slow music, and fast music during steep turns, airspeed deviations while listening to no music, slow music, and fast music during steep turns, heading deviations made while listening to no music, slow music, fast music during steep turns, and three more identical tests for the slow flight maneuver. Participants’ flight
experience ranged from 56 to 205 flight hours. The null hypothesis was that there were no differences between the deviation means, or \( H_0: \mu_1 = \mu_2 = \mu_3 \), and the alternative hypothesis was that at least one mean was different to another mean, or \( H_a: \text{at least two means are significantly different} \). With the significance level at \( p = .05 \), results show there were no statistically significant differences found between any maneuver deviations and music conditions, as shown in the following:

- **steep turn, altitude**: \( F(1.32, 6.62) = .43, p = .60 \)
- **steep turn, airspeed**: \( F(1.42, 7.11) = .80, p = .45 \)
- **steep turn, heading**: \( F(1.80, 9.01) = .34, p = .70 \)
- **slow flight, altitude**: \( F(1.12, 5.60) = .78, p = .43 \)
- **slow flight, airspeed**: \( F(1.84, 9.20) = 1.60, p = .25 \)
- **slow flight, heading**: \( F(1.95, 9.74) = .59, p = .57 \)

Therefore, the null hypothesis was not rejected.

**Discussion**

As previously discussed, many private pilots listen to music on a personal music player, such as when they are making long cross-country flights (Brunghart & Simpson, 2008). Only half of the participants of this study supported this in their survey, indicating they do listen to music during all flights, and the tempo is varied. Additionally, opinions about listening to slow and fast music while flying varied amongst the participants, and no overarching assertion was made. Two participants indicated listening to both the slow and fast music was distracting to them and their thinking; one indicated the slow music seemed to calm him/her down more and allowed for more errors; and another indicated the faster music made it difficult to focus on successfully completing their maneuvers.
One limitation to this study was due to the use of simulators. One category of recorded deviations included “coordination.” Within the simulators, coordination occurred with every maneuver each participant was given, and was not included among the graphed deviations in Appendix D. This might not have been the case in a real aircraft, due to unpredictable variables.

Overall, according to the results of this study, it appears that listening to no music, slow tempo music or fast tempo music had no significant correlation with actual flight performance with regards to either maneuver. Additionally, perceived performance, as reported by participants on their surveys (Appendix B) was very closely linked to actual performance, as shown by the data in italics in Appendix C, thereby also having no significant correlation with the different music tempos.

**Recommendations and Conclusion**

For a further study, some changes are recommended. First, utilizing the simulator’s technology to record and print participant performance is advised in order to obtain more accurate information. Second, even though this study did not show significant results, a further study with a bigger sample with a greater variance of pilot experience may yield different results. Overall, this experiment was an interesting one and if in a future study significant results are found, safety measures can be taken to prevent cognitive overload and decreases in pilot performance.
References


Appendix A: Participant Information Sheet

Participant #: _____

Segment 1- Music Type: _________________________

Steep Turn  Slow Flight
Altitude:  Altitude:
Airspeed:  Airspeed:
Heading:  Heading:
Coordination: Y/N  Coordination: Y/N

Segment 2- Music Type: _________________________

Steep Turn  Slow Flight
Altitude:  Altitude:
Airspeed:  Airspeed:
Heading:  Heading:
Coordination: Y/N  Coordination: Y/N

Segment 3- Music Type: _________________________

Steep Turn  Slow Flight
Altitude:  Altitude:
Airspeed:  Airspeed:
Heading:  Heading:
Coordination: Y/N  Coordination: Y/N
Appendix B: Post-Flight Participant Survey

Participant #: _____

1. Do you listen to music while you fly (ex: cross-country flights)?
   If yes, how often?
   If yes, do you listen to high or low tempo music?

2. Which musical tempo segment did you like best?
   least?

3. How do you think you performed?

   **Segment 1**- Music Type: _________________________
   Steep Turn                                      Slow Flight
   Altitude:                                       Altitude:
   Airspeed:                                       Airspeed:
   Heading:                                        Heading:
   Coordination: Y/N                               Coordination: Y/N

   **Segment 2**- Music Type: _________________________
   Steep Turn                                      Slow Flight
   Altitude:                                       Altitude:
   Airspeed:                                       Airspeed:
   Heading:                                        Heading:
   Coordination: Y/N                               Coordination: Y/N
Segment 3- Music Type: _________________________

Steep Turn                               Slow Flight
Altitude:
Airspeed:
Heading:
Coordination:  Y/N                       Coordination:  Y/N

4. What were the most difficult parts of this exercise?
   the least difficult/easiest?

5. Was there any part of this exercise you found unclear?
   If so, please explain:

6. Do you have any recommendations for a future, similar study?
### Appendix C: Data Tables

#### Table 1: No Music

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<th>Heading (degrees)</th>
<th>Coordination (Yes/No)</th>
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#### Table 2: Slow Tempo Music

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*Italicized entries in parentheses indicate the participants’ perceived performance.
Appendix D: Graphed Figures of Recorded Deviations

Figure 1- Altitude Deviations (feet) – Steep Turn

Figure 2- Altitude Deviations (feet) – Slow Flight

Figure 3- Airspeed Deviations (knots) – Steep Turn
**Figure 4** - Airspeed Deviations (knots) – Slow Flight

**Figure 5** - Heading Deviations (degrees) – Steep Turn

**Figure 6** - Heading Deviations (degrees) – Slow Flight