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The Effect of Music Familiarity on Driving: A Simulated Study of the Impact of Music Familiarity Under Different Driving Conditions

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THE EFFECT OF MUSIC FAMILIARITY ON DRIVING: A SIMULATED STUDY OF THE IMPACT OF MUSIC FAMILIARITY UNDER DIFFERENT DRIVING CONDITIONS

by

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Abstract

Music is one of the most popular activities while driving. Previous research on music while driving has been mixed, with some researchers finding music to be a distractor and some research finding music to be facilitative to driving performance. The current study was designed to determine if familiarity with the music might explain the difference found between self-selected and experimenter-selected music, and whether the difficulty of the driving conditions affected music's relationship to driving performance. One hundred and sixty-five University students participated in a driving simulation both with music and without music. Under the "with music" condition, participants were randomly assigned to three music conditions: self-selected music, experimenter-selected familiar music, and experimenter-selected unfamiliar music. In the simulation drive, participants first drove under a simple, low-mental workload condition (car following task in a simulated suburban road) and then drove under a complex, high-mental workload condition (city/urban road). The results showed that whether music was self- or experimenter-selected did not affect driving performance. Whether the music was familiar or unfamiliar did not affect performance either. However, self-selected music appeared to improve driving performance under low-workload conditions, leading to less car-following delay and less standard deviation in steering, but also caused participants to drive faster, leading to faster mean speed and higher car-following modulus, but not more speed limit violations. Self-selected music did not have any significant effect in high-mental workload conditions.

The Effect of Music Familiarity on Driving: A Simulated Study of the Impact of Music Familiarity under Different Driving Conditions

The majority of drivers listen to music while driving (Dibben & Williamson, 2007; Stutts, Feaganes, Rodgman, Hamlett, & Reinfurt, 2003). Given the general propensity in the population for listening to music while driving, how this music affects driving behavior is of wide interest and application. However, results regarding the effect of listening to music while driving have been varied enough that two different recent studies on this subject were able to assert both that "Previous studies suggest that listening to music… had either no-effects or positive effects on driving performance" (Ünal, Platteel, Steg, & Epstude, 2013) and that "…other studies have wrongly declared that music is 'not at all associated with negative driving performance'… both traffic researchers and drivers underestimate in-car distractions from activities… such as *simply listening to music.*" (Brodsky & Slor, 2013, emphasis in original document). A recent review of the literature highlighted the presence of varying results in regards to music and driving, mentioning that the distracting nature of music may diminish both stress/anger and attentional resources, that music of too high tempo or volume seem to decrease performance, and that the variables of arousal and cognitive capacity play a role in music's effects on driving (Dalton and Behm, 2007). It is difficult to determine the effect of music on driving task because the music effect can be influenced by many of variables, such as music characteristics (e.g., tempo, see Brodsky, 2002; loudness, see Dalton, Behm, & Kibele, 2007), music selection (e.g., self- vs. experimenter-selected, see Cassidy & MacDonald, 2009; 2010), mental workload, (see Ünal, Steg, & Epstude, 2012) and arousal (see Cassidy & MacDonald, 2010; Ünal, de Waard, Epstude, & Steg, 2013). However, it is important to determine under what circumstances music was likely to have a facilitative effect and under what circumstances music was likely to have a detrimental effect. The primary purpose of the current study is to investigate how music selection and music familiarity influence task performance under different driving situations.

Choice and Familiarity of Music

In previous research on the effect of music on driving task participants were often either assigned music to listen to (e.g., Beh & Hirst, 1999; Brodsky, 2002; Dalton, Behm, & Kibele, 2007; North & Hargreaves, 1999; Pêcher, Lemercier, & Cellier, 2009) or asked to choose their own music to listen to (e.g., Oron-Gilad, Ronen, & Shinar, 2008; Ünal, Steg, & Epstude, 2012). Cassidy & MacDonald (2009; 2010), in a task that involved driving through a video game simulation of Edinburgh (with no other traffic in the game) and avoiding randomly distributed traffic cones, found that when participants brought their own music, they performed better—driving faster and with fewer inaccuracies—than when they listened to experimenter-selected music (unreleased music) or when they listened to no music at all. Mizoguchi & Tsugawa (2012) found similar results that preferred music was associated with better driving performance. It appears that preferred self-selected music leads to better driving performance than non-preferred experimenter-selected music.

These studies all used a similar task: driving through a simulation while avoiding stationary obstacles (either the edges of the track or traffic cones). While participants were asked to drive "normally" in at least one of the Cassidy & MacDonald studies (2009), all studies used speed as a dependent variable, with better performance being interpreted as achieving faster speeds and fewer inaccuracies. As such, it is difficult to compare these studies to other studies which have included speed limitations, used mobile obstacles which began in peripheral vision, or given participants tasks such as car-following or maneuvering an intersection. All three studies cite the nature of the task used as one limitation of the study. Cassidy & MacDonald (2009; 2010) briefly discuss both cognitive capacity and induced arousal in the context of their findings and posit that familiar music should reduce the subjective complexity of music, but do not test how familiarity effects driving performance beyond ensuring that the experimenter-selected music was unreleased and had therefore not been heard by participants.

Although familiarity has been controlled for in previous music studies by either attempting to ensure lack of familiarity (e.g., Brodsky, 2002; North & Hargreaves, 1999) or by allowing participants choose their own music (e.g., Ünal, 2013), to the best of our knowledge, music familiarity itself has never been directly manipulated in a driving study. However, on a vigilance task in which participants had to detect a light bulb flash of a certain duration, familiar music, as compared to either no music or unfamiliar music, improved performance, but there was no significant difference on this task based on whether the music was rock or easy listening (Fontaine & Schwalm, 1979). Familiar music should maximize the benefits of music—arousal and engagement—while minimizing its downside—cognitive load—since both the melodic and lyrical content will have previously been processed. Indeed, familiarity with music seems to be related both to heightened pleasure/enjoyment and to higher physiological arousal as measured by skin conductance level (van den Bosch, Salimpoor, & Zatorre, 2013) and by heart rate (Fontaine & Schwalm, 1979). Furthermore, participants under induced cognitive load exhibit increased preference for familiar music (Ward, Goodman, Irwin, 2013), more complex tasks are related to increased preference for simple rather than complex music (Arkes, Rettig, & Scougale Jr., 1986), and familiar background music is associated with better reading comprehension when compared to unfamiliar background music (Hilliard & Tolin, 1979).

Other possible explanations for better performance with self-selected music include lack of internal motivation when given no music choice—that is, viewing these results through the lens of self-determination theory (e.g., Gagné & Deci, 2005; Langfred & Moye, 2004)—and mere enjoyment of, or preference for, the music in question. However, preference for music and familiarity with music tend to be confounded. Long before Zajonc coined the term "mere exposure effect" in 1968 to describe the tendency for people to develop preference for stimuli they encounter multiple times, it had been observed that enjoyment for music tends to increase with repetition (Meyer, 1903; Verveer, Barry, & Bousfield, 1933). More recent studies have confirmed this finding, although with the caveat that too much focused exposure to the same music may decrease liking (e.g., Szpunar, Schellenberg, & Pliner, 2004; van den Bosch, Salimpoor, & Zatorre, 2013). Furthermore, it seems that people are likely to replay music they find enjoyable. They are not likely to purposefully listen to music they do not find enjoyable multiple times. Therefore, it is expected that self-reported exposure to the music heard in the present experiment and self-reported enjoyment of the music heard will be highly correlated.

Arousal and Mental Workload

Both arousal, "the degree of physiological activation or…intensity of emotional response" (Husain, Thompson, and Schellenberg, 2002), and mental workload, "the ratio between task demands and the capacity of the operator" (Veltman & Gaillard, 1996), are related to driving performance (Husain et al., 2002; Turner, Fernandez, & Nelson, 1996). Mental workload—as measured both by self-report and physiological indicators—is higher when listening to music while driving as compared to driving with no music (Brodsky, 2002; Hughes, Rudin-Brown, & Young, 2012; Oron-Gilad, Ronen, & Shinar, 2008; Ünal, Steg, & Epstude, 2012). Furthermore, high mental workload induced by a cognitive task has been associated with poorer driving performance (Cantin, Lavallière, Simoneau, & Teasdale, 2009; Makishita & Matsunaga, 2008; Ross et al., 2014). However, Ünal, Steg, & Epstude, 2012 reported that driving with musically-induced mental workload is associated with similar or better performance on some driving tasks as compared to driving with no music, suggesting that drivers can and do regulate their cognitive load to increase performance on some driving tasks.

Human beings have a limited cognitive capacity (Day, Lin, Huang, & Chuang, 2009; Ross et al., 2014; Thompson, Schellenberg, & Letnic, 2011). As such, a task that optimally utilizes mental effort will neither overreach this mental threshold nor underutilize mental resources (Solovey, Zec, Garcia Perez, Reimer, & Mehler, 2014). Performance on simple (low workload) versus complex tasks (high workload) seems to be affected differentially by possible distractors (Avila, Furnham, & McClelland, 2011; Cassidy & MacDonald, 2007; Day, et al., 2009; Furnham & Bradley, 1997; Speier, Valacich, & Vessey, 1999). Indeed, for simple braking or vigilance tasks, performance with optimal music is comparable to or better with music as compared to without music when the brake cue is located centrally in one's vision (Consiglio, Driscoll, Witte, & Berg, 2003; Turner, Fernandez, & Nelson, 1996). However, when the cue is located in the periphery of one's vision, complicating the task, music often has a negative effect on response time (Hughes, Rudin-Brown, & Young, 2012). Beh and Hirst (1999) found this exact relationship, but only when music was high-intensity (i.e., high-volume) and the task was high-demand (i.e. multiple tasks), a finding which helps to underscore the importance of both arousal and mental workload.

Mental workload and arousal are not, however, entirely separate entities. Mental workload is related to physiological characteristics of arousal during driving tasks (Mehler, Reimer, Coughlin, & Dusek, 2009). Music induces arousal, but mental workload itself also induces arousal. The tradeoff of music is that it induces arousal at the expense of added mental workload. The best situation would be one in which both arousal and mental workload are kept at optimal levels—i.e., not too much and not too little. What constitutes an optimal level of arousal and mental workload may vary depending on the characteristics of the music, the demand of the situation, and the characteristics of the individual performing the task (Dalton and Behm, 2007), with an inverted U-shaped curve characterizing performance as either arousal or mental workload increase.

Driving workload can be different under different situations, such as response to an expected or unexpected event (Young, Lenne, Archer, & Williamson, 2013), how visually complex the driving environment is (Cantin et al., 2009), and whether the visual cue is presented centrally or peripherally (Beh & Hirst, 1999; Engen, 2008). In visually complex simulated environments for unexpected tasks, such as braking for a car or a pedestrian, music often seems to be detrimental to driving performance as compared to without music (Brodsky, 2002; Hughes, Rudin-Brown, & Young, 2012). However, on monotonous driving tasks such as maintaining lane position (Hughes, Rudin-Brown, & Young, 2012), matching speeds with a lead car (Ünal, de Waard, Epstude, Steg, 2013) or maintaining alertness while driving along a road for long periods of time (Oron-Gilad, Ronen, & Shinar, 2008), music appears to aid driving performance. Unexpected tasks in peripheral vision may be of special concern, because visual search patterns are affected by mental workload while driving (Recarte & Nunes, 2003). Therefore, music's effects on driving may be dependent on contextual factors.

Ünal, Steg, & Epstude (2012), who measured mental workload as a possible mediator of the effect of music on driving, found only positive effects or no effects of music on driving. This includes beneficial effects of music for braking when a car unexpectedly pulled out (a higher-workload task), although it was found that mental workload muted the positive effects of music on this task. This contrasts with the results of Jancke and Musial (1994), who found that listening to a radio broadcast through headphones increased steering variance ("the absolute deviation… from the midline of the road") with increased number of simulated curves. Hatfield and Chamberlain (2008), on the other hand, find very little effect of listening to a movie soundtrack or talk radio on a simulated city environment which includes pedestrians crossing the street, but do find that listening to a talk radio program increases number of collisions with cars. Because there is an inconsistency in previous results, and because of the seeming pattern of some differing studies based on the complexity of the driving task, the current simulation was designed to provide both high- and low-mental workload conditions. The expectation is that drivers will perform better with music under low-workload driving conditions (e.g., less traffic, more rehearsal) and worse with music under high-workload driving conditions (e.g., unexpected events, less rehearsal).

Purpose of Current Study

The purpose of the current study is to investigate how music selection and familiarity of music influence the effect of music on driving under different diving conditions. Many previous studies which have found negative effects of music have assigned participants music to listen to (e.g., Brodsky, 2002), and many of the studies which have found a positive effect of music have allowed participants to bring their own music to listen to (e.g., Ünal, 2013). As such, the finding that participants drive better with self-selected or preferred music seems promising. However, all studies of this nature so far have asked participants to complete driving games in which there was no traffic, although Cassidy and MacDonald included randomly-strewn traffic cones. The current study is in part an attempt to replicate these results in regard to self-selected music, but do so with a different workload condition and with driving performance measured by a different set of tasks (e.g., car-following, following a speed limit, braking for pedestrians, stopping at traffic lights, etc…).

Hypothesis 1: Those driving while listening to self-selected music will exhibit better driving performance than those listening to experimenter-selected music.

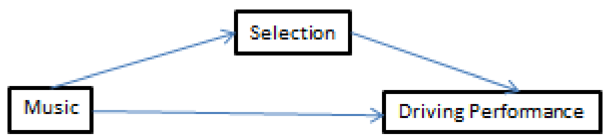

Figure 1. Model for Hypothesis 1

Participants' familiarity with music was manipulated in the current study. The expectation is that exposure to and enjoyment of music will explain the difference found between self-selected and experimenter-selected music by better optimizing levels of arousal and mental workload. Though previous studies attributed better performance with self-selected music to familiarity with the music (e.g., Cassidy & MacDonald, 2010), familiarity has never been tested as a possible predictor of music's effect on driving.

Hypothesis 2: Those driving while listening to familiar music will exhibit better driving performance than those listening to unfamiliar music.

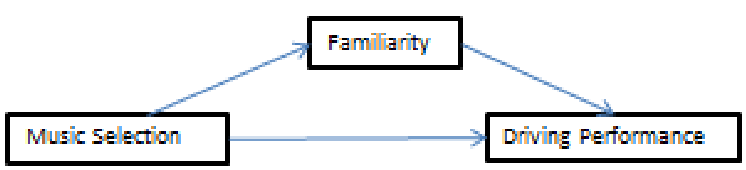

Figure 2. Model for Hypothesis 2.

While mental workload induced by music and driving has previously been tested, to our knowledge no study has attempted to manipulate the driving situation to either minimize or maximize task complexity and the expectedness of the task, thereby affecting mental workload. Like experimental- or participant- selection of music, this distinction in task type seems to explain many of the contradictory results of previous studies, with studies that have included high-workload conditions finding negative results and studies that have included low-workload conditions finding positive results.

Hypothesis 3: Drivers will perform better with music under low-workload driving conditions and worse with music under high-workload driving conditions.

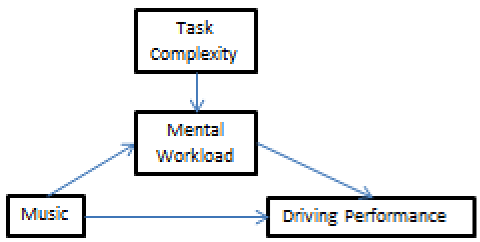

Figure 3. Model for Hypothesis 3.

Method

Participants

One hundred and sixty-five University of North Florida undergraduate students volunteered to participate in the study, often for course extra credit. The median age of participants was 21. Teen and young adult drivers are of special interest in regards to music and driving, because they seem to listen to music more often (Dibben & Williamson, 2007), and are more likely to be hospitalized due to vehicle crashes than the rest of the United States driving population (Bergen et al., 2014). Of these participants, 47 (27.5%) were male and 118 (71.5%) were female. 102 participants (61.8%) reported their race as “white,” 27 (16.4%) reported their race as “black,” 14 (8.5%) reported their race as “Asian,” 15 (9.1%) reported their race as “Hispanic,” and 6 (3.6%) reported their race as “other.” One participant’s data was entirely excluded from analysis due to extreme number of driving errors.

Procedure

All participants were asked to bring music with them that they would normally listen to while driving. Upon arriving and signing the informed consent, participants alternated between filling out a digitally administered survey (see Appendix A for a list of questions on the survey) and completing driving simulations. The experiment consisted of three simulations: a ten-minute training run to acclimate participants to the tasks and two approximately twelve-minute test runs. The difference between these two test runs was whether participants drove while listening to music or drove without music. Participants were randomly assigned to one of the three music conditions: self-selected familiar music, experimenter-selected familiar music, or experimenter-selected unfamiliar music. An SPER digital sound level meter (model no. 840028) was used to measure sound volume and keep it near or below 70 dB.

Because both practice and fatigue effects were a concern despite the ten-minute training run and the approximate forty-five minute duration of data collection, the order in which music was presented was counterbalanced based on experimental condition. Table 1 shows the number of participants in the final dataset in each condition.

Table 1

Number of participants in each experimental condition

Self-Selected/Familiar	Experimenter-Selected/Familiar	Experimenter-Selected/Unfamiliar
55	54	52

Simulation

The driving simulation was run using STISIM (Build 2.06.00) driving simulation software (see Figure 4 on page 13) with a steering wheel and brake/gas pedal attachment. The two test simulations were identical other than the order of braking tasks and the presentation of the unanticipated event, which will be explained later.

The driving simulation consisted of two parts, each approximately six minutes long: a car-following task and a drive through a city environment. The car-following task was designed to minimize mental workload—a monotonous, easily-anticipated task that has previously shown benefits with music (Ünal, de Waard, et al., 2013) in a visually simple environment. The drive through the city environment was designed to maximize mental workload—a rapid-fire, difficult-to-anticipate series of tasks in a visually complex environment.

For the car-following task, participants were asked to match the speed of a lead car, which accelerated and decelerated at intervals, as closely as possible while remaining a safe distance behind. For the city environment, participants were asked to obey traffic laws and avoid collisions while driving through a cityscape lined with cars and pedestrians, with stop lights at various intervals. Participants were confronted with at least 1 red light, 4 pedestrians, and 3 cars pulling out in front of them for each test run. They were further confronted with at least one unanticipated task in each run—either a car running a red light or a dog crossing the street. For the car-following half of the simulation, there was no speed limit, although participants were limited in speed by having to follow the lead car. However, in the city area of the simulation, there was a posted speed limit of 40 mph. Participants were informed of this beforehand and if they drove more than three miles over the speed limit would hear a police siren to remind them to drive slower.

For each event, surrounding vehicles were designed to change in appearance—so that participants were not cued by particular patterns of vehicles—but not to change substantially in size, so that vehicles did not randomly occlude vision of the relevant vehicle or pedestrian movement. The city element of the simulation was designed so that an intermittent stream of traffic continued in the opposite lane and cars were parked in the adjacent lane, making it difficult to swerve to avoid obstacles. In case this strategy was used, the number of times the center line or road edge was crossed was recorded.

For each pedestrian event, the initial time to contact (T2C) with the pedestrian was determined by the participant's car speed and distance from the relevant objects. The T2C was designed so that pedestrians began moving when, if the driver's vehicle continued on its current speed and direction, it would collide with the pedestrian. For vehicle events, each participant had the same initial T2C with the vehicle pulling out based on the participant's current speed and distance from the obstacle. In other words, the initial time-to-contact for pedestrians was variable based on the driver's speed while the initial time-to-contact for cars was invariable. Initial times-to-contact of 2.2 seconds for cars were decided upon so that participants driving at speed (30-40 mph) would be forced to brake to avoid a collision but also had the ability to avoid a collision through braking alone. The traffic light switched from green to yellow at a simulated distance of 1000 feet away and stayed that color for 2 seconds before turning red. The initial start time method for the unexpected events (the dog and the car running the red light) was the same as that for pedestrians.

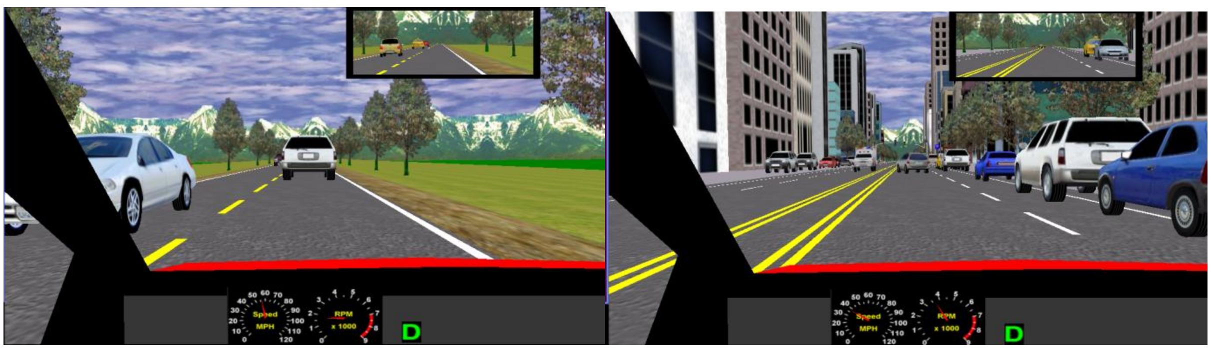

Figure 4. Screen captures of the car-following task (on right) and city environment (on left).

For each run, the following variables were measured: number of traffic violations (e.g., speeding, crossing the center line, running a red light), number of collisions, gas and brake response time for each city event, steering variance from the center line for the duration of the car-following task and at intervals in the city portion of the run, average speed, and—for the car following task—coherence with the lead vehicle, modulus, and delay in response to the lead vehicle. See Table 2 for a summary of variables by load condition. The order of events, the variables recorded, and what portion of the simulation they were recorded for, can be found in Appendix B.

Table 2

Dependent variables by load condition

	Overall	Low-load	High-load
Performance Variables	Mean Speed (↓)	Car-Foll. Steer. std. dev. (↓)	# Collisions (Cars, ↓)
		Car-Following Delay (↓)	# Collisions (Pedestrians, ↓)
		Car-Following Coherence (↑)	City Steering std. dev (↓)
		Car-Following Modulus (↓)	Lane Excursions (↓)
			Minimum T2C (↑)
			Pedestrian Brake Time (↓)
			Amber Light (↓)
			UE #1 (Car) Brake Time (↓)
			UE #2 (Dog) Brake Time (↓)
			# Speed Exceedances (↓)

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. UE = "Unexpected Event" (An event that occurred in only one test simulation run)

Music Selection

Music for the experimenter-selected familiar music condition was chosen to maximize artist and song familiarity for the familiar music condition and ensure unfamiliarity for the unfamiliar music condition, while attempting keeping other attributes (e.g., musical style, length of song, tempo) similar. Appendix C fully explains this process.

Table 3

List of titles and artists used in experimenter-selected music conditions

Familiar Music			
Order	Song	Artist	Length (min:sec)
1	Here Comes the Sun	The Beatles	3:05
2	Thriller	Michael Jackson	5:14
3	Let It Be	The Beatles	4:03
4	Billie Jean	Michael Jackson	4:52
5	Come Together	The Beatles	4:19
Unfamiliar Music			
Order	Song	Artist	Length (min:sec)
1	Fresh As a Daisy	Emitt Rhodes	2:52
2	I Wanna Be Rich	Calloway	5:15
3	Painted Dayglow Smile	Chad and Jeremy	3:27
4	Jump to the Beat	Stacy Lattislaw	5:20
5	Seaside Woman	Linda McCartney	3:55

Music Presentation

Music was played via an adjacent computer on a pair of speakers positioned on either side of the monitor used for the simulation. Music was started at the beginning of each test run with music and continued until the end of the simulation, when it was stopped—thus, no participants ever heard song #5 on either experimenter-selected playlist. The experimenter-selected playlist was played in the same order each time. Participants brought in their own music on CDs, flash drives, and smart phones or music devices. Smart phones or music devices that could not be connected to the computer were connected directly to the speakers and the volume level re-adjusted. Participants were asked what their preferred order was for self-selected music and were accommodated if they expressed a preference. Participants who chose to do so were allowed to use web-based services such as Spotify or Pandora for self-selected music.

Questionnaire

Items on the questionnaire can be found in Appendix A. Items to assess extroversion were taken from the Eysenck Personality Questionnaire-Brief Version, as analyzed by Sato (2005). Only items that loaded on the factor of extraversion in Sato's analysis were included in the questionnaire.

Experimental Design

In this study, we manipulated 2 within-subject variables, music condition (with music vs. without music), and driving complexity/workload (car-following/low-workload vs. city-driving/high-workload) and one nested between-subject variables, music familiarity (self-selected, experimenter-selected familiar, experimenter-selected unfamiliar). Run-order (whether music was presented first or second) was treated as a between-subject variable. Other between-subject variables were collected through the questionnaire.

Results

Limiting Data

Almost all measurements of driving performance were automatically recorded by the STISIM simulator. However, brake response times were coded by taking the first instance after an event began that there was an input from the brake pedal. The same method was used to code brake response times for the unexpected events (the dog and the car passing the light). Mean brake response time for the four pedestrian events and minimum time-to-contact for the three car-pulling-out events were each combined into one variable by taking the mean value. Outliers for continuous dependent variables were excluded on a case-by-case basis, with outliers being defined as values more than 2.5 standard deviations from the mean. Five participants whose partial data were included in between-subjects analysis did not complete the full experiment and were not included in within-subjects analysis.

Manipulation Check

Using the survey to compare the data to experimental conditions, the experimental manipulation appears to have been successful. Because self-reported familiarity and enjoyment were non-normally distributed, Kruskal-Wallis H Test was used. There was a significant difference in self-reported times heard, $\chi^2 = 97.29$, $p < .0005$, with a mean rank score of 110.66 for self-selected/familiar music, 99.02 for experimenter-selected/familiar music, and 29.35 for experimenter-selected/unfamiliar music. A significant difference was also found for self-reported enjoyment, $\chi^2 = 78.85$, $p < .0005$, with a mean rank score of 116.23 for self-selected/familiar music, 81.94 for experimenter-selected/familiar music, and 37.36 for experimenter-selected/unfamiliar music.

Both familiarity with and enjoyment of the music heard were highest when participants selected their own music, similar but lower when participants listened to experimenter-selected familiar music, and drastically lower when participants listened to experimenter-selected unfamiliar music. Follow-up pairwise comparisons using Mann-Whitney tests and Bonferroni corrections found that the difference between self-selected familiar and experimenter-selected familiar music approached, but did not reach, significance, and that all other differences were statistically significant. See Appendix E for a listing of comparison statistics and mean and median values.

Hypothesis 1: Self-Selected vs. Experimenter-Selected

The first hypothesis was that self-selected music would be more beneficial than experimenter-selected music. In order to control for familiarity of music, only self-selected familiar and experimenter-selected familiar music were compared in this analysis. For continuous dependent measures, an independent samples-*t*-test compared driving performance based on whether participants were listening to self-selected familiar or experimenter-selected familiar music. No significant difference was found (see Table 4 for means and standard deviations, and Cohen's d for each test).

Because passing the amber light was a dichotomous variable, binary logistic regression using self-selected familiar vs. experimenter-selected familiar as a predictor was used to determine whether participants were more likely to pass the amber light. Test of the full model did not reach statistical significance [χ^2 (1, N = 108) = .38, p = .54]. When familiarity was controlled, no statistically significant evidence supported the hypothesis that listening to self-selected music leads to better performance while driving than listening to experimenter-selected music.

Table 4

Means of driving variables based on familiarity condition

Part of Simulation	Variable	Self-Selected			Experimenter-Selected			*d*
		N	Mean	SD	N	Mean	SD	
Overall	Mean Speed (↓)	54	35.34	1.28	54	35.50	1.58	+.11
Part One: Low-Load (Car-following)	Car-Foll. Steer. std. dev. (↓)	55	.85	.21	54	.92	.26	+.30
	Car-Following Delay (↓)	53	1.76	.90	54	1.74	.91	-.02
	Car-Following Coherence (↑)	54	.81	.09	54	.82	.09	-.11
	Car-Following Modulus (↓)	53	1.09	.08	54	1.10	.08	+.13
Part Two: High-load (City)	# Collisions (Cars, ↓)	54	.37	.76	54	.37	.56	.00
	# Collisions (Pedestrians, ↓)	54	.67	.82	54	.63	.81	-.05
	# Speed Exceedances (↓)	54	1.19	1.33	52	1.65	1.64	+.31
	City Steering std. dev. (↓)	55	.84	.20	53	.84	.20	.00
	Lane Excursions (↓)	54	1.41	1.55	54	1.67	2.15	+.14
	Minimum T2C (↑)	55	.67	.26	54	.72	.28	-.18
	Pedestrian Brake Time (↓)	48	1.07	.23	48	1.09	.26	+.08
	Amber Light (↓)	54	.09	.29	54	.13	.34	+.13
	UE #1 (Car) Brake Time (↓)	27	2.54	.34	26	2.62	.31	+.25
	UE #1 (Dog) Brake Time(↓)	28	1.47	.21	25	1.48	.20	+.05

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. *d* = Cohen's *d* for comparison. Positive Cohen's *d* indicates a more desirable effect for self-selected music. Negative Cohen's s *d* indicates a more desirable effect for experimenter-selected music.

Hypothesis 2: Familiar vs. Unfamiliar

Because music selection—whether the experimenter or the participant selected the music—appeared to have no effect on driving performance, to clarify why previous studies found that self-selected music resulted in better driving performance than experimenter-selected music, the next step in the analysis tested the second hypothesis that listening to familiar music, as opposed to unfamiliar music, would improve driving performance was tested. In order to control for selection, only experimenter-selected familiar and unfamiliar music were contrasted in this analysis. For continuous dependent measures, an independent samples-*t*-test compared driving performance based on whether participants were listening to experimenter-selected familiar or unfamiliar music. Only one significant difference was found: participants were more likely to exceed the speed limit in the familiar music condition than in the unfamiliar music condition, $t(90.23) = 2.50$, $p = .014$ (see Table 5 for means and standard deviations, and Cohen's *d* for each test).

Because passing the amber light was a dichotomous variable, binary logistic regression using self-selected familiar vs. experimenter-selected familiar as a predictor was used to determine whether participants were more likely to pass the amber light. Test of the full model did not reach statistical significance [χ^2 (1, N = 106) = .30, $p = .59$].

Table 5

Means of driving variables based on familiarity condition

Part of Simulation	Variable	Unfamiliar			Familiar			*d*
		N	Mean	SD	N	Mean	SD	
Overall	Mean Speed (↓)	49	35.51	1.50	54	35.50	1.58	+.01
Part One: Low-Load (Car-following)	Car-Foll. Steer. std. dev. (↓)	50	.91	.25	54	.92	.26	-.04
	Car-Following Delay (↓)	50	1.78	1.01	54	1.74	.91	+.04
	Car-Following Coherence (↑)	50	.81	.08	54	.82	.09	+.12
	Car-Following Modulus (↓)	53	1.09	.08	54	1.10	.08	-.13
Part Two: High-load (City)	# Collisions (Cars, ↓)	52	.50	.92	54	.37	.56	+.17
	# Collisions (Pedestrians, ↓)	52	.73	1.05	54	.63	.81	+.11
	# Speed Exceedances (↓)	49	.96	1.33	52	1.65	1.64	-.46
	City Steering std. dev. (↓)	49	.85	.23	53	.84	.20	+.05
	Lane Excursions (↓)	51	1.88	2.45	54	1.67	2.15	+.09
	Minimum T2C (↑)	52	.64	.27	54	.72	.28	+.29
	Pedestrian Brake Time (↓)	42	1.08	.25	48	1.09	.26	-.04
	Amber Light (↓)	52	.10	.30	54	.13	.34	-.09
	UE #1 (Car) Brake Time (↓)	25	2.63	.36	26	2.62	.31	+.03
	UE #1 (Dog) Brake Time(↓)	22	1.46	.24	25	1.48	.20	-.09

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. *d* = Cohen's *d* for comparison. Positive Cohen's *d* indicates a more desirable effect for familiar music. Negative Cohen's s *d* indicates a more desirable effect for unfamiliar music.

When selection choice was controlled for, the hypothesis that listening to familiar music leads to better performance while driving than listening to unfamiliar music did not appear to be supported either. Although number of speed exceedances was higher with familiar music, this was the only effect found. Furthermore, examining the means for other values, there does not appear to be a consistent pattern of familiar music leading to worse outcomes. In fact, those who drove listening to familiar music had fewer collisions both with pedestrians and with cars, although not significantly so.

Hypothesis 3: Task Complexity and Music

The next important question is whether driving with music produces better driving performance than driving with no music at all. Since most drivers choose their own music to listen to, only self-selected music was used in this analysis (for the same analyses for all conditions, see Appendix F). The hypothesis that the complexity of the driving task would change music's effect on music was tested by comparing the low-load (car-following) and high-load (city) elements of the simulation.

Driving performance was compared when participants listened to self-selected familiar music to when the same participants drove while listening to no music. For continuous dependent measures, a paired-samples *t*-test compared driving performance for participants who listened to music to the same driving performance measures without music (See Table 6 for means and standard deviations for all paired-samples t-tests based on with music vs. without music). Participants exhibited better driving indicators with music in the low-load condition (car-following) but also exhibited less caution (car-following modulus, mean speed).

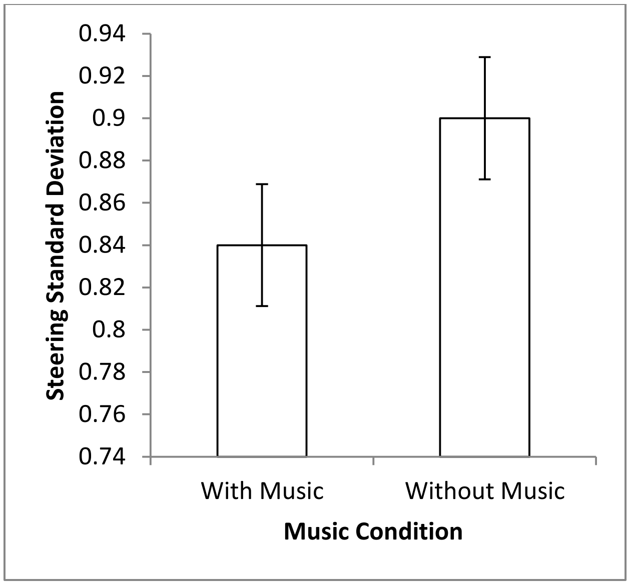

Figure 5. Comparison of car-following steering standard deviation with music/without music for drivers with self-selected familiar music. Error bars represent standard error of the mean.

Paired samples *t*-tests comparing with music vs. without music were conducted on driving performance variables. Participants showed significantly less standard deviation from the center line in steering while listening to music, $t(52) = 2.43$, $p = .019$, indicating safer driving with music (See Figure 4). Participants had a significantly higher mean delay without music than with music, indicating unsafe driving while driving without music, $t(52) = 4.62$, $p < .0005$ (See Figure 5). Paired samples *t*-tests of several variables with and without music for the self-selected familiar music condition also indicated that participants drove faster while listening to music, with participants have both a higher mean speed while driving with music, $t(53) = 2.13$, $p = .038$, and exhibiting a higher car-following modulus while driving with music, $t(52) = 2.06$, $p = .044$ (See Figures 6 and 7). Both of these variables indicate that participants tend to drive faster, exhibiting a less cautious driving strategy, with music.

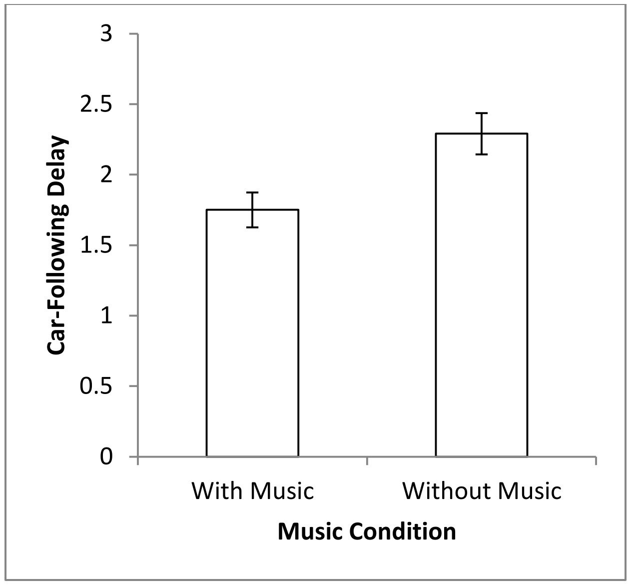

Figure 5. Comparison of values of car-following delay with music/without music for drivers with self-selected familiar music. Error bars represent standard error of the mean.

Because passing the amber light was a dichotomous variable, binary logistic regression using with music/without music as a predictor to determine whether participants in the self-selected familiar music condition were more likely to pass the amber light. Test of the full model did not reach statistical significance, χ^2 (1, N = 110) = .63, p = .43.

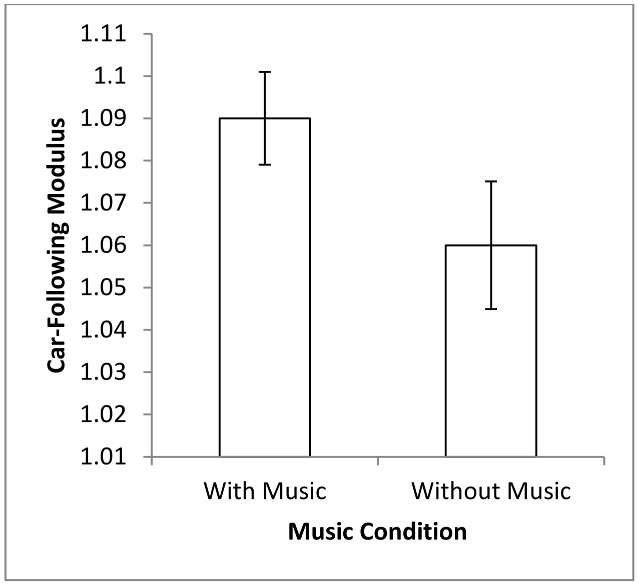

Figure 6. Comparison of values of car-following modulus with music/without music for drivers with self-selected familiar music. Error bars represent standard error of the mean.

Table 6

Means of driving variables for self-selected music based on with music/without music

Part of Simulation	Variable	With Music			Without Music		*d*	Better Cond.
		N	Mean	SD	Mean	SD		
Overall	Mean Speed (↓)	54	35.34	1.28	34.99	1.33	-.27	NM**
Part One: Low-Load (Car-following)	Car-Foll. Steer. std. dev. (↓)	53	.84	.21	.90	.21	+.29	M**
	Car-Following Delay (↓)	53	1.75	.90	2.29	1.07	+.55	M***
	Car-Following Coherence (↑)	53	.82	.09	.80	.09	+.22	-
	Car-Following Modulus (↓)	53	1.09	.08	1.06	.11	-.31	NM**
Part Two: High-load (City)	# Collisions (Cars, ↓)	54	.37	.76	.35	.65	-.03	-
	# Collisions (Pedestrians, ↓)	52	.67	.82	.69	.86	+.02	-
	# Speed Exceedances (↓)	54	1.19	1.33	.87	1.24	+.25	-
	City Steering std. dev. (↓)	55	.84	.20	.87	.20	+.15	-
	Lane Excursions (↓)	53	1.64	2.13	1.41	1.56	-.12	-
	Minimum T2C (↑)	53	.67	.26	.65	.25	+.08	-
	Pedestrian Brake Time (↓)	41	1.08	.24	1.09	.21	+.04	-
	Amber Light (↓)	54	.09	.29	.06	.23	-.11	-

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. M = "Music." NM = "No Music." Differences significant at the .1 level are indicated with one asterisk (*). Differences significant at the .05 level are indicated with two asterisks (**). Differences significant at the .01 level are indicated with three asterisks (***). *d* = Cohen's *d* for comparison. Positive Cohen's *d* indicates a more desirable effect with music. Negative Cohen's s *d* indicates a more desirable effect without music.

Overall, these findings suggest that participants drive faster with self-selected familiar music: they have a higher mean speed and car-following modulus, indicating a tendency to overcorrect their speed to catch up with the lead car. However, participants also perform better in the low-load condition: they exhibit less car-following delay and less standard deviation in steering, indicating quicker response to the lead car's change in speeds and more control of the vehicle. Participants do not significantly differ on any variable in the high-workload condition.

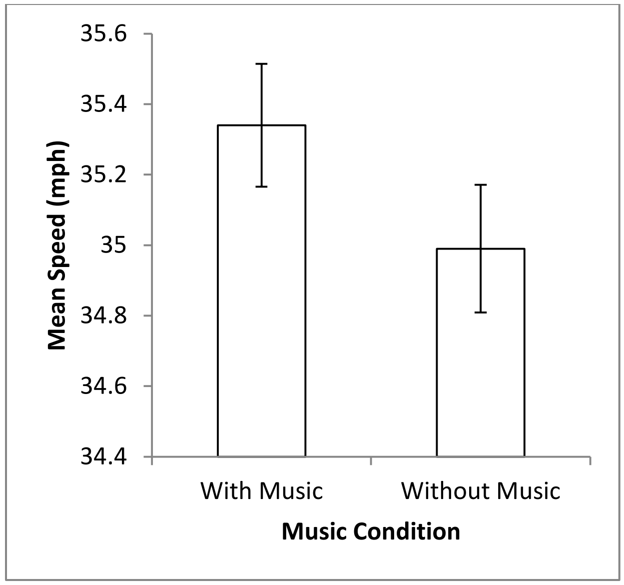

Figure 7. Comparison of values of mean speed with music/without music for drivers with self-selected familiar music. Error bars represent standard error of the mean.

Discussion

In this study, three hypotheses were examined to determine music's effect on driving via the mechanisms of arousal and mental workload: how experimenter- or participant-selection of music affects the relationship, how familiarity of music affects the relationship, and how task complexity affects the relationship. Results showed that there was no effect for music selection when familiarity was controlled. The only effect for familiarity when selection was controlled was greater speed exceedances with familiar music, although this was not part of a pattern in the data. The effect of music on task type when music selection was controlled was better car-following variables—lower delay in car-following and less standard deviation in steering during car-following—but also a tendency to drive faster. The tendency to drive faster was shown in higher car-following modulus and higher mean speed, although a higher number of speed exceedances was not found.

Selection of Music

The result indicated that there was no significant difference between self- and experimenter-selected music effect on driving performance when the music were equally familiar to participants.. This does not parallel previous research (Cassidy and MacDonald, 2009; 2010; Mizoguchi and Tsugawa, 2012). One explanation for the inability to replicate these studies may be the difference in the types of driving tasks used in each study. Previous researchers contrasting self-selected and experimenter-selected music used video games in which participants attempted to avoid stationary obstacles such as traffic cones or the edges of the course while around a circuit. The tasks in the current study, while asking participants to avoid obstacles in the high-workload condition, limited participants' speed and used pedestrians and cars—mobile rather than stationary elements—as obstacles. As such, the obstacles may have been in participants' peripheral vision. When targets are in peripheral vision and mental workload is high, there is some evidence to suggest that music may be detrimental to performance (Beh and Hirst, 1999; Hughes, Rudin-Brown, & Young, 2012; Recarte & Nunes, 2003).

Familiarity of Music

Another possible reason for the inability to replicate previous results in the current study is the effects of music familiarity and preference. Cassidy and MacDonald's (2009; 2010) assigned music was unreleased and therefore would be unfamiliar to participants. We failed to find a significant difference between familiar and unfamiliar music, except regarding familiar music leading to more speed exceedances. Preference may also be a factor, since Mizoguchi and Tsugawa (2012) used preferred music out of a set of choices rather than participant-selected music. Self-reported enjoyment and exposure to music—used as a manipulation check—were positively related to several indicators of driving performance (See Appendix D). This suggests that familiarity and enjoyment may play a role in the relationship between music and driving, but the current study did not adequately tap into this feature, possibly due to too much extraneous variance from the number, type, and complexity of tasks, the way in which the simulation was designed and run, practice effects for the tasks, or carryover effects of music.

Task Complexity

When listening to self-selected familiar music, participants evinced better driving performance under low cognitive load but not high cognitive load. This effect becomes even more pronounced when all music conditions are included (See Appendix F), with participants performing worse in high-workload conditions. It is possible that analysis using only participants in the self-selected familiar condition did not provide enough statistical power. For most variables for participants in each selection condition, about 50 data for each music/without music condition were available after outliers were removed. It is also possible that this difference between music and without music for the high-workload condition is driven by the experimenter-selected conditions. If the latter explanation was the case, it would explain the differing effects of music on driving in different studies that were noted in the introduction.

When listening to self-select familiar music, participants also tend to drive faster. This might partly be an effect of music's arousing effects. Brodsky (2002) found that participants drive faster with faster tempos, and that faster mean speed explained the increased number of errors from music in the dataset. Adolescents and young adults tend to prefer more "intense" music (Bonneville-Roussy, Rentfrow, Xu, & Potter, 2013) and are more sensation-seeking (Dahl, 2008), so it is plausible that they would choose more arousing music to listen to. However, participants in the self-selected familiar dataset did not exhibit an increased number of errors with music, which also coincides with Cassidy and MacDonald's (2009; 2010) finding that participants driving with self-selected music drove faster with fewer or an equivalent number of driving errors.

The tradeoff of self-selected familiar music in this case seems to be that it causes drivers, on average, to drive faster, but it equips them via induced arousal to compensate by reacting more quickly. This may be a function of moving from the gas to the brake pedal faster, a compensatory strategy that has been found in both older drivers and for cell phone users—although in comparison to cell phone users, music listeners do not use this strategy (Berg & Dessecker, 2013; Summala, 2000). This may also be a function of faster initial reaction time.

Summary and Conclusions

In the current study it was found that neither music selection nor music familiarity—with the exception of number of speed limit exceedances—influence driving performance, but rather it is the complexity of the task being performed that influences music's effect on driving performance, with low-complexity tasks leading to better performance. This result provides an explanation for previous inconsistent results of music on driving performance. In other words, when music effect was measured under in a low-complexity driving condition, there was a facilitative effect. However, this effect was not demonstrated in a high-complexity driving condition. Given that much research on the effect of music on driving performance has been conducted with a driving simulator, the complexity of the simulation is likely less complex than many real driving situations, especially during emergency or unexpected events.

Regarding the lack of music familiarity effect on driving, the design of the current study may have obscured the effects of familiarity and enjoyment while highlighting the effects of task complexity. As such, further research on the effects of both music choice and familiarity and type of driving task in relation to music would help clarify the relationships (or lack thereof) found in the current study. It seems, based on the results of the current study, that driving with music is not a major safety concern under most normal (low-complexity) driving conditions such as driving on the highway. However, in unfamiliar environment or high-traffic environment, the facilitation effect of music seems to disappear. The current study was conducted with a driving simulator. More research on real life driving situations will provide more conclusive evidence on effect of music under high-complexity situation.

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Appendix A. Questions on Survey

Depending on whether music was presented in the first or second run, questions 20-25 may have been presented before questions 7-19.

1. What is your (the participant's) gender? Male Female
2. Do you have a history of video-induced motion sickness? If so, you may not wish to participate in this experiment. Yes No
3. Do you have a history of photosensitive epilepsy? Yes No
4. Do you have any other condition that may make it difficult for you to use a computer-based driving simulation? Yes No
5. On a scale of 1-100, how tired do you feel right now?
6. What self-selected songs were brought in?
7. Questions that loaded on "extroversion" factor from Eysenck Personality Questionnaire-Brief Version (See Sato, 2005). Answered on a 1-5 Likert scale.
8. How often do you listen to music while driving?

   - All the time (About 90-100% of the time—every time I drive)

   - Often (About 60-90% of the time)

   -Sometimes (About 40-60% of the time)

   -Rarely (About 10-40% of the time)

   - Never (About 0-10% of the time—only when a passenger makes me listen to music)
9. What type of music do you listen to as you are driving? (Please circle all that apply)

   -Pop

   -Classical

   -Country

-Hip Hop

-Rap

-Jazz

-Blues

-Classic Rock

-Heavy Metal

-Indie Rock

-Reggae

-Latin

-Easy Listening

-Folk

-Other____

-Whatever's on the radio

10. What is your current grade level?

-Freshman (1st year)

-Sophomore (2nd year)

-Junior (3rd year)

-Senior(4 or more years)

-Post-grad/graduate student

-Other

11. What do you consider your race to be?

- White

- Black

- Asian

- Hispanic

- Native American

-Other

12. What is your age?

13. How many years of your childhood (0 to 20 years) did you spend in the United States?

-0

-1-5

-5-10

-10-19

-All of them (20—or however old you are if you are younger than 20)

14. What is the name of an artist/band or song that you listen to frequently?

15. Approximately how many hours per week do you spend driving?

16. What is your current major? (please type "not applicable" if you do not have a college major)

17. Approximately how many hours per week do you spend playing video games?

18. How many years have you been driving?

19. If you play video games, what kind of video game do you usually play?

-Action video game (such as *Call of Duty*)

-Puzzle Game (such as *Portal*)

-Strategy Game (such as *Civilization*)

-Other ____

Questions 20-22 were asked for each song played.

20. How familiar are you with the nth song you heard today? (Please ask the experimenter if you don't remember what the nth song was.) (1-100 sliding scale)
21. How many times before had you heard the nth song you heard today? (Please ask the experimenter if you don't remember what the nth song was.)
    - Never (0)
    - A few times (1-5)
    - Several times (6-10)
    - Many times (more than 10 times)
    - I am very familiar with this song.
22. How much did you enjoy listening to the nth song you heard today? (Please ask the experimenter if you don't remember what the nth song was.)
    - I hated it
    - I didn't like it
    - It was okay
    - I kind of liked it
    - I loved it
23. How familiar are you with the *style* (e.g., pop, classical, blues, country, etc...) of music you listened to today?
    - This is the only kind of music I listen to
    - I often listen to this kind of music
    - I sometimes listen to this kind of music
    - I do not actively seek out this kind of music, but I hear it often
    - I do not actively seek out this kind of music, but I hear it every once in awhile

-I actively avoid this kind of music

-I have never heard this kind of music before

24. How much did you enjoy the *style* (e.g., pop, classical, blues, country, etc...) of music you listened to today?

    -I usually enjoy listening to this style of music

    -I sometimes enjoy listening to this style of music

    -I have no feeling one way or the other about this style of music

    -I usually prefer not to listen to this style of music

    -I dislike this style of music

25. How similar is the music you listened today to the music you normally listen to while driving?

    - This is exactly the sort of music I listen to while driving.

    - This is somewhat similar to the music I listen to while driving

    - I would hardly ever listen to this type of music while driving.

26. On a scale of 1-100, how tired do you feel right now?

Appendix B. Table of Driving Performance Variables

Table 7

Description of dependent variables

Portion of Drive	Variable	Description
Overall Performance	Mean Speed (mph)	The distance of the simulated environment, in miles, divided by the amount of time it took to complete the simulation, in hours.
Car-Following	Coherence	How well the lead car was followed. Values can be from 0 to 1, with a value of 1 indicating perfect matching of the lead car's speed pattern. Interpreted similarly to a correlation coefficient. Values below .3 are typically discarded (Ward, Manser, de Waard, Kuge, & Boer, 2003).
	Modulus	How much faster or slower than the lead vehicle the participant drives. Values greater than 1 indicate driving too fast in an attempt to overtake the lead vehicle. Values less than 1 indicate driving too slow. Values of approximately 1 indicate driving at approximately the same speed as the lead vehicle.
	Delay	The average amount of time it takes the participant to respond when the lead vehicle speeds up or slows down.
	Steering Std. dev.	The amount of standard deviation in vehicular heading in comparison to the center line.
City	# Traffic Lights Passed	Whether the amber light was passed or not.
	# Collisions	The number of times that another vehicle was run into. The lead vehicle in the car-following portion of the scenario could not be collided with.
	# Pedestrians hit	The number of times a pedestrian was run into. This includes the dog in the unexpected event.
	# Speed Exceedances	The number of times participants drove over the speed limit. A speed limit was only in effect for the city portion of the simulation.
	# Lane Excursions	The number of times participants crossed either the center line or the edge of the road.
	Minimum Time to Contact (T2C)	A measure of how close to the vehicle ahead that the participant was. The least amount of time it would take the participant's vehicle, at current speed, to collide with the vehicle ahead. Lower values indicate less margin of speed and distance between the participant's vehicle and the vehicle ahead.
	Gas Pedal Response Time	The amount of time, after the incident begins (i.e., the vehicle or pedestrian begins moving, the traffic light switches color, etc…), that it takes the participant to remove pressure completely from the gas pedal.
	Brake Time	The amount of time, after the incident begins (i.e., the vehicle or pedestrian begins moving, the traffic light switches color, etc…), that it takes the participant to apply pressure to the brake pedal.

Table 8

Comparison of presentation of events by run

Task #	Training Run	Run #1	Run #2
1.	Car-Following Task (5 min.)	Car-Following Task (6 min.)	Car-Following Task (6 min.)
2.	Car #3	Car #3	Pedestrian #1
3.	Pedestrian #2	Pedestrian #3	Car #3
4.	Car #1	Amber Light	Unexpected Task (Dog)
5.	Pedestrian #1	Pedestrian #2	Car #2
6.	Pedestrian #3	Car #1	Car #1
7.	Car #2	Car #2	Pedestrian #4
8.		Pedestrian #4	Pedestrian #2
9.		Unexpected Task (Car runs light)	Amber Light
10.		Pedestrian #1	Pedestrian #3

Appendix C. Music Selection Process

Familiar music was chosen based on querying Echo Nest's (site: www.echonest.com) database for the most familiar songs of the most popular artists, as listed at various times between 1/1/14/ and 3/1/14. This method was chosen to generate songs that were familiar to most people (like Christmas songs), were familiar to most people in the format of the recording that was to be presented (like Disney songs), were songs that many participants would conceivably listen to while driving (like modern popular music), and were also quantifiable on familiarity in some way. A list of unfamiliar songs that were similar to each song were then generated in the following manner:

For each alternate song, a list of artists (e.g., The Merseybeats) similar to the popular artist in question (e.g., the Beatles) were generated. This list of artists was limited to those with a maximum familiarity rating of .5, which usually meant they had attained some level of popularity at one time, but were never iconic or definitive. Artists with low-to-moderate popularity were chosen for two reasons:

1) Artists with low popularity are not successful enough to have a large catalog of songs from which to choose. This would have made matching based on musical characteristics prohibitively difficult.
2) We did not want participants to do worse on a trial simply because the music they were listening to was very bad or very strange. Artists with at least some popularity were less likely to be amateurish.

After a list of artists were generated, each artist's Echo Nest song catalog was searched, matching the target song in question on tempo (within 20 bpm either way) and length (within 30 seconds either way). From this list, each song was additionally compared subjectively by the researcher on such characteristics (provided by Echo Nest's analysis) as energy, liveness, valence, danceability, speechiness, and acousticness. Snippets of songs subjectively thought to be similar enough were listened to by the researcher to determine their suitability. Some artists are known by more than one name or belong to more than one group and came up in the list of artists with a familiarity rating below .5 (e.g., The Plastic Ono Band and the Quarrymen were included despite containing members of the Beatles). Songs or artists that were deemed as possibly offensive to a general audience were omitted. To generate alternate unfamiliar songs for each target familiar song, approximately 50-75 artists were searched, approximately 100-150 songs compared, and approximately 20-35 songs listened to before the list of 5 songs was chosen. The songs chosen for the survey, while not in the same order, coincided 86% (6 out of 7) with the most downloaded songs for those artists on Last.Fm (accessed 3/3/2014)

These 5 songs were provided to a small group of raters (N = 8, 5 males and 3 females) who each chose the song that they believed was most similar to the target song and indicated how familiar they were with the target song. Based on the raters' responses, a list of 5 familiar and 5 unfamiliar songs were generated. The titles and artists of these songs can be found in Table 2.

Appendix D: Self-Reported Enjoyment and Exposure to Music

If enjoyment and familiarity do diverge, it is expected that enjoyment will be a more important variable than familiarity because lack of enjoyment is expected to decrease participants' motivation to complete the driving task well. Partial support for this hypothesis may be found in Perham and Withey's (2012) finding that liked music as compared to disliked music, regardless of tempo, increases performance on a spatial rotation task.

As part of the questionnaire, participants self-reported both how many times they had heard each song and how much they enjoyed listening to each song. The mean of each of these variables for all songs heard was taken and recoded into a four-point variable for familiarity and a three-point variable for enjoyment to create approximately normal distribution. In addition, a median split was performed on each variable. Dependent variables were analyzed for those runs for which music may have had an influence using ANCOVAs with run order as the covariate. The effects of enjoyment and familiarity appear to be dependent upon the variable (see Table 9). Enjoyment appears to mediate the effects of times heard on minimum time-to-contact (see Figure 8). Number of times heard also significantly decreases the mean speed of participants, and this effect becomes greater when mean enjoyment is included as a covariate.

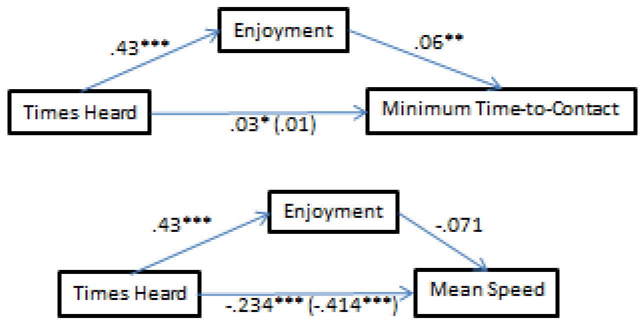

Figure 8. Mediation models for minimum time-to-contact and mean speed. One asterisk (*) indicates significance at the .1 level, two asterisks (**) indicate significance at the .05 level, and three asterisks (***) indicate significance at the .01 level.

There was a main effect of mean times heard on mean speed, $F(1, 231) = 6.86$, $p < .01$, car-following modulus, $F(1, 230) = 3.88$, $p < .05$, and a trend towards an effect for minimum time-to-contact, $F(1, 235) = 3.50$, $p < .1$. Participants drove slower, had lower car-following modulus, and left more time-to-contact the more they reported having heard a song. There is a main effect of enjoyment on number of car collisions, $F(1, 232) = 6.24$, $p < .05$, and minimum time-to-contact, $F(1, 231) = 6.25$, $p < .05$, and a trend towards an effect for number of pedestrian collisions, $F(1, 232) = 3.62$, $p < .1$. Participants collided with fewer obstacles, both cars and pedestrians, and left more time-to-contact with cars when they self-reported more enjoyment of the music they listened to.

There is an interaction between enjoyment and times heard for car-following modulus, $F(1, 230) = 5.77$, $p < .05$, car-following coherence, $F(1, 225) = 5.56$, $p < .05$, and for brake time for the car passing the light, $F(1, 72) = 4.63$, $p < .05$, and a trend for both car-following delay,

$F(1, 225) = 3.36$, $p < .1$, and brake time for the dog, $F(1, 142) = 2.97$, $p < .1$. When enjoyment and times heard did not match—that is, when participants either enjoyed the music and had not heard it often or had heard the music often and did not enjoy the music—participants had lower car-following modulus, more delay in car-following, less car-following coherence, slower brake time for the car passing the light, and faster brake time for the dog.

Having heard a song appeared to be related to more cautious driving—slower speed, less overcorrection in car-following, more time-to-contact—and enjoying a song appeared to be related to being less likely to collide with pedestrians or cars. Frequently, an interaction was found between familiarity and enjoyment, with congruity between familiarity and enjoyment (having heard a song many times before and enjoying it or not having heard a song before and not enjoying it) being related—with one exception—to better driving indices (e.g., higher car-following coherence, less car-following delay, faster reaction time for the first unexpected event). One possible explanation for this pattern of interaction is that those with incongruity between familiarity and enjoyment—those who had heard a song many times before and did not like it or had not heard a song before and enjoyed it—spent more mental effort processing the music or found it annoying, while those who did not like the music and had not heard it before or who like the music and had heard it many times before could either ignore the music or had already processed it. One alternative explanation for these results is that mean enjoyment may be acting as a surrogate for engagement with the task or commitment to the study and that familiarity is the sole variable affecting cognitive processing.

Table 9

Means and standard deviations for dependent variables by enjoyment and times heard

Part of Simulation	Variable	LE/LF	LE/HF	HE/LF	HE/HF
Overall	Mean Speed (↓)	35.66 (.14)	35.66 (.26)	35.47 (.32)	35.19 (.15)
Part One	Car-Following Variance (↓)	.92 (.02)	.87 (.04)	.87 (.06)	.89 (.03)
(low-load)	Car-Following Modulus (↓)	1.11 (.01)	1.03 (.02)	1.10 (.02)	1.09 (.01)
	Car-Following Delay (↓)	1.86 (.10)	2.14 (.20)	2.13 (.23)	1.81 (.11)
	Car-Following Coherence (↑)	.82 (.01)	.80 (.02)	.77 (.02)	.82 (.01)
Part Two (high-load)	# Collisions (Cars, ↓)	.39 (.06)	.28 (.12)	.21 (.14)	.31 (.07)
	# Collisions (Pedestrians, ↓)	.83 (.09)	.65 (.18)	.31 (.22)	.65 (.11)
	City Variance (↓)	.86 (.02)	.78 (.04)	.82 (.05)	.85 (.02)
	Lane Excursions (↓)	1.76 (.19)	1.29 (.37)	1.31 (.48)	1.61 (.22)
	Minimum T2C (↑)	.65 (.03)	.68 (.05)	.72 (.07)	.72 (.03)
	Pedestrian Brake Time (↓)	1.10 (.03)	1.08 (.05)	1.17 (.06)	1.08 (.03)
	Amber Light (↓)	.06 (.03)	.15 (.05)	.04 (.06)	.10 (.03)
	UE #1 (Car) Brake Time (↓)	2.52 (.05)	2.80 (.11)	2.70 (.11)	2.60 (.06)
	UE #2 (Dog) Brake Time (↓)	1.52 (.03)	1.46 (.05)	1.40 (.07)	1.51 (.03)

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. LE = “Low Enjoyment,” LF = “Low Familiarity,” HE = “High Enjoyment,” HF = “High Familiarity.” One asterisk (*) indicates significance at the .1 level. Two asterisks (**) indicates significance at the .05 level. Three asterisks (***) indicates significance at the .01 level. Standard error of the mean is in parentheses.

Appendix E: Pairwise Comparisons for Manipulation Check

Table 10

Comparison of medians for familiarity and enjoyment by experimental condition

	Self-Selected Familiar	Exp.-Selected Familiar	Exp.-Selected Unfamiliar
Times Heard	4.25 (4.06)	4 (3.77)	1 (1.21)
Enjoyment	4.75 (4.59)	4 (4)	3.25 (3.21)

Mean values are included in parentheses.

Table 11

Results of Mann-Whitney pairwise tests

	Self-ESF	Self-ESU	ESF-ESU
Times Heard	$U(108) = 1143$, $Z = 2.23$, $p = .026$	$U(105) = 61.5$, $Z = 8.70$, $p < .0005$	$U(103) = 86$, $Z = 8.44$, $p < .0005$
Enjoyment	$U(107) = 682$, $Z = 2.94$ $p < .0005$	$U(104) = 173$, $Z = 7.86$, $p < .0005$	$U(101) = 420$, $Z = 6.01$, $p < .0005$

"Self" = Self-selected familiar, "ESF" = Experimenter-Selected Familiar, "ESU" = Experimenter-Selected Unfamiliar. Using Bonferroni corrections, significance is at $p = .016$.

Appendix F: Music vs. No Music for All Conditions

To test the hypothesis that the complexity of the driving task would change music's effect on music was tested by comparing the low-load (car-following) and high-load (city) elements of the simulation. It was further tested by comparing results for run 1 and run 2, since there seemed to be practice effects on many variables. With more practice, less mental processing would be required to process the task, creating less mental workload.

Driving performance was compared when participants listened to music to when the same participants drove while listening to no music. For continuous dependent measures, a paired-samples *t*-test compared driving performance for participants who listened to music to the same driving performance measures without music (See Table 12 for means and standard deviations for all paired-samples t-tests based on with music vs. without music). Participants exhibited better driving indicators with music in the low-load condition (car-following) and worse driving indicators in the high-load condition (city).

Table 12

Means of driving variables based on with music/without music

Part of Simulation	Variable		With Music		Without Music		Better Condition
		N	Mean	SD	Mean	SD	
Overall	Mean Speed (↓)	153	35.46	1.44	35.22	1.45	Without**
Part One: Low-Load (Car-following)	Car-Following Variance (↓)	155	.90	.24	.92	.23	Music
	Car-Following Delay (↓)	154	1.74	.92	2.22	1.04	Music***
	Car-Following Coherence (↑)	152	.82	.09	.81	.10	Music*
	Car-Following Modulus (↓)	151	1.10	.10	1.08	.10	Without**
Part Two: High-load (City)	# Collisions (Cars) (↓)	158	.42	.76	.35	.69	Without
	# Collisions (Pedestrians) (↓)	158	.68	.90	.65	.92	Without
	# Speed Exceedances (↓)	149	1.30	1.41	.81	1.13	Without***
	City Variance (↓)	152	.85	.21	.85	.20	Without
	Lane Excursions (↓)	153	1.65	1.95	1.55	1.92	Music
	Minimum T2C (↑)	155	.68	.27	.67	.26	Music
	Pedestrian Brake Time (↓)	117	1.09	.26	1.09	.21	Without
	Amber Light (↓)	158	.11	.31	.04	.19	Without**

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance. Asterisks indicate significant t-tests with music/without music. One asterisk (*) indicates significance at the .1 level. Two asterisks (**) indicates significance at the .05 level. Three asterisks (***) indicates significance at the .01 level.

For the overall speed, participants drove significantly faster with music, $t(152) = 2.58$, $p = .011$. For the car following (low-load) task, Participants exhibited significantly less car-following delay, $t(157) = 2.47$, $p = .011$, greater car-following modulus, $t(150) = 2.50$, $p = .013$, and a trend for greater car-following coherence, $t(151) = 1.80$, $p = .075$. With the exception of car-following modulus, participants in the low-load condition performed better, exhibiting quicker response (car-following delay) to and closer approximation of the pattern (car-following coherence) of the lead car. However, they also tended to overcorrect by driving faster than the lead car to catch up (car-following modulus).

For the city run (high-load condition), participants exhibited more speed exceedances, $t(157) = 3.42$, $p = .001$, and were 3.07 times more likely to pass the traffic light, $\chi^2(1, N = 321) = 5.96$, $p = .015$, with music. Participants in the high-load condition performed worse, driving past the speed limit and attempting to pass the traffic light more often, with music than without music.

An analysis was also run to determine if participants performed better with music with practice. A 2 x 2 (with music/without music x run 1/run 2) between-subjects ANOVA was run on continuous variables to determine if run order and music condition significantly interacted. It was found that on many driving indices they did, with participants driving better with music on the second run than the first run.

Drivers perform worse with music on the first run but not the second run for car-following modulus, $F(1, 308) = 4.73$, $p = .03$, $\eta = .12$ and show a trend for this in regards to number of collisions with cars, $F(1, 317) = 3.34$, $p = .069$, $\eta = .10$. Drivers perform worse with music on the first run and better with music on the second run for number of lane excursions, $F(1, 311) = 5.11$, $p = .025$, $\eta = .13$, number of collisions with pedestrians, $F(1, 317) = 4.01$, $p = .027$, $\eta = .12$, and pedestrian brake time, $F(1, 267) = .9.54$, $p = .002$, $\eta = .19$. There is also a trend for an interaction for car-following coherence, $F(1, 309) = 3.12$, $p = .08$, $\eta = .10$, with participants exhibiting more coherence with music in the second run but not the first run. Both mental workload condition and run order appear to be related to music's effects on driving, with music becoming beneficial as mental workload is decreased.

Table 13

Means of driving variables as a function of music/without music and run order

Part of Simulation	Variable	Run 1		Run 2	
		With Music	Without Music	With Music	Without Music
Overall	Mean Speed (↓)	35.24	34.90	35.67	35.55
Part One: Low-load (Car-following)	Car-Following Variance (↓)	.94	.93	.86	.92
	Car-Following Delay (↓)	1.11	1.07	1.08	1.09
	Car-Following Coherence (↑)	1.70	2.28	1.81	2.19
	Car-Following Modulus (↓)	.81	.81	.83	.80
Part Two: High- load (City)	# Collisions (Cars) (↓)	.71	.5	.11	.19
	# Collisions (Pedestrians) (↓)	.77	.51	.57	.76
	# Speed Exceedances (↓)	1.26	1.81	.92	1.15
	City Variance (↓)	.85	.86	.84	.85
	Lane Excursions (↓)	2.15	1.68	1.15	1.71
	Minimum T2C (↑)	.64	.65	.72	.69
	Pedestrian Brake Time (↓)	1.14	1.07	1.02	1.13
	Traffic Light (↓)	.15	.05	.06	.03

Upward pointing arrows indicate that greater values are desired for positive performance. Downward arrows indicate that smaller values are desired for positive performance.

The findings of Ünal Steg and Epstude (2012) are duplicated with all music in the current study, with improvements shown for car-following delay and (when run order is included as an interaction term) time-to-contact for cars pulling out with music. However, additional variables also replicate Brodsky's (2002) finding that music leads to more passed traffic lights, faster speeds, and (when run order is included as an interaction term) more automobile collisions (see Appendix D for more analysis in relation to Brodsky's study on tempo). Furthermore, with one exception, either no effect or positive main effects of music were found for the low mental workload (car-following) condition, while either no effect or negative main effects of music were found for the high mental workload (city) condition. This suggests that part of the differences found in previous research may be due to the situation—that is, whether the scenario presented tended to impose high- or low-mental workload. The effect of music on driving performance is a function of the complexity of the current driving situation. This may help explain the differences between previous results.

These results are advanced in the current study by finding that, with practice, participants performed better with music. Uniformly, when an interaction between music and run order was found, if music appeared to be detrimental in the first run its effects became either facilitative or negligible in the second run, and if music appeared to have no effect in the first run, its effects appeared facilitative in the second run. At least a trend for this sort of interaction was found for all dependent variables for which music appeared to have a detrimental effect except attempts to pass the traffic light. An alternative explanation for the interactions found might be that they are the result of a carryover effect of mood induced by music—that is, participants drive worse with no music in the second run because music was played in the first run. However, this seems unlikely to be the entire explanation, since it does not explain the interactions in which positive effects for music are found in the second run.

One problem with the current study is that the high-workload condition was somewhat unrealistic. In most metropolitan areas, one would not be confronted by multiple cars and pedestrians suddenly moving in front of the driver with extremely little time to react in a very short amount of time. As such, temporary arousal, mental workload, and ability to practice and anticipate the next task were all maximized.

In their study, Ünal Steg and Epstude (2012) found that mental effort mediated music's positive effects on the standard deviation of speed in their car-following task but masked music's positive effects on time-to-contact with a parked car pulling out (that is, the results became more significant when mental effort was controlled for). The current study contained a series of obstacles for the high-load condition, requiring more effortful vigilance, and found overall negative effects of music for this condition. Ünal Steg and Epstude's overall finding in regards to music increasing time-to-contact was also found, but this was due entirely to music's effects in the second run, when participants had more practice. As such, it seems that under circumstances of very high external mental workload, the costs of music while driving may outweigh its benefits.

The finding that the unexpected event drove most of the difference in number of collisions between music listening and non-listening is similar to Beh and Hirst's (1999) finding that participants performed worse with music only when the music was high-intensity, high demand, and the cue was in peripheral vision. It also seems related to North and Hargreaves' (1999) finding that, when given no cognitively demanding task, participants differentiate between "low arousal" and "high arousal" (i.e., louder, faster tempo) music by driving slower and rating the driving task as more difficult in "high arousal" music. However, when given a cognitively taxing task to do at the same time (counting backwards), participants drive slower and rate the task as more difficult than when driving without the task, but make no differentiation between types of music.

The practice effect found may have some implications in regards to newly-licensed and less experienced drivers. As previously mentioned, Brodsky and Slor (2013), in an in-car study, found negative effects of self-selected music for newly-licensed drivers, and young adults report listening to music while driving more than other age groups (Dibben & Williamson, 2007).

Although age and driving experience were recorded for the current study, not enough of an inexperienced population was available to provide a suitable contrast. Further research might address whether there is indeed a practice effect, or whether what was found was instead an expectation effect—a conjecture that might be supported by the tendency of the unexpected event to evince differences with or without music. It might also address how much this hypothesized practice effect might be task specific or whether it is a result of general driving skills. Future research might also try to determine if there is a threshold for driving behaviors to become automated, and therefore less likely to be unduly burdened by background music. Some driving skills may not be well learned for at least several months past licensing (Sagberg & Bjørnskau, 2006).

Curriculum Vitae

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Education

University of North Florida, Jacksonville, Florida
Master of Arts in Psychology, December 2014
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Bachelor of Science in Psychology; Minor in English, May 2010
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Honors and Awards

Scholarships

2005-2009 UNF Presidential Scholarship

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Work Experience

University of North Florida, Jacksonville Florida
Research Assistant, Office of Faculty Enhancement, August 2013-December 2014

Jacksonville Public Library, Jacksonville, Florida, Pablo Creek Branch
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