The Effect of Sound on Player Performance in Mario Kart 8 Deluxe

Group 6

Austin Hadamuscin, Olusegun Omotunde, Daniel Sasu

Goal or objective: Our goal is to see if the sound and music of Mario Kart 8 Deluxe influence the performance of a player.

Response: Time (seconds) to complete a seven-lap race on the Baby Park track.

Factor	Levels	Description
Difficulty	3 Levels - 50cc - 100cc - 150cc	These levels reference engine displacement in cubic centimeters of real-life engines. Generally, the larger the displacement of a vehicle's engine is, the faster the vehicle can go. In Mario Kart, as a player increases the difficulty, the racing becomes faster and the CPUs (A.K.A. Computers) become more competent competitors. We believe that as the speeds increases, it may be harder to detect obstacles or items that are thrown due to the increased concentration it takes to race at faster speeds.
Sound	3 Levels - Game Sound On - Game Sound Off - Player's Own Music	This is the focus of our study. Mario Kart has excellent sound design that allows players to detect when other players are near, when obstacles on the course will spin them out, or when an item is about to hit them. We suspect that the absence of sound may affect how a player reacts to objects being used on them or their in-game environment. We are including a player's own music as a level because if there is a change in race times from when the game sound is on versus when it is off, we wanted to see whether that change was due to the absence of game music, or sound in general.
Number of Players	2 Levels - One Player against all CPUs - One Player against another player and CPUs on local split-screen	This factor was chosen because playing against all CPUs vs playing against CPUs and one other person may change the way players choose to use their items. Instead of targeting a CPU with a red shell, one may choose to save it until they can hit their friend/real-life opponent. Additionally, when playing locally with another player, the screen is split vertically. This dramatically reduces the amount of track the players can see, making it harder to detect incoming obstacles or items, especially with the sound turned off.
Participants	Blocking Factor	Each participant will have a different skill level that we are not trying to detect; therefore, we will be blocking by the participants to account for this source of variance.

Narrative:

Nintendo are masters of sound design when it comes to their own intellectual property and Mario Kart 8 Deluxe is no exception. The race used in this experiment, Baby Park, is a hectic, seven-lap, short oval race accompanied by a soundtrack that becomes incrementally more frantic as each lap is complete. Due to these characteristics, we suspect that the absence of sound while racing on this track will affect players' race times. We included three levels of sound: game sound on, game sound off, and player's choice of music. For the first two levels, we will be turning the speaker amplifier on and off, respectively to control the sound. For the third level of sound, a player's choice of music, participants will be instructed to play music from their personal headphones in both ears, at a level of their choosing. The genre of music will be determined by each participant, but the genre must stay consistent throughout the entire experiment. General conversation among participants and spectators will be permitted while any level of sound is being conducted.

The complications that arise when measuring a continuous response variable, race time in seconds, are compounded by the fact that Mario Kart 8 Deluxe does not provide race times for races other than time trials; therefore, will be using the stopwatches on our phones to time our races. Time will start at *GO!* (see image 1 in the index) and stop at *FINISH!* (see image 2 in the index). We are blocking by the participants, so the individual operating the stopwatch does not have to be consistent throughout the entire experiment but will need to be consistent throughout an entire block. If there is an error in the measurement caused by the stopwatch operator forgetting to start or stop the stopwatch, a glitch in the game or stopwatch, or any other unforeseen circumstance, the observation for that treatment be aborted and redone if found immediately after, or during the observation. If the error is caught after one or several treatments have been complete, we will assess the severity of the error and weigh if it is worth redoing the entire block.

There will be two levels for the number of players: one- and two-player. Each block must have a consistent opponent for the two-player level and local multiplayer must be used, not online multiplayer. The online multiplayer is not free so this choice will make the expected budget of the experiment $0 since Austin already owns the console, game, and tv. Also, when playing online, participants will be able to see the entire screen, as opposed to sharing half the screen when playing local multiplayer. An opponent may be another participant in the experiment or someone from outside the experiment. We decided on this because, due to the nature of the game, we believe that the skill of a player does not impact the performance of his or her opponent nearly as much as the performance lost from missing half of the screen, as mentioned in the table on the previous page.

Mario Kart 8 Deluxe, comes with 41 characters, 23 karts, 18 wheels, and 12 gliders, each with a unique set of stats that can drastically affect gameplay so, we have decided to keep these choices consistent for the entire experiment. Each participant will need to use the character Mario, the kart Streetle, the wheel Roller, and the glider Waddle Wing (see images 3-6 in the index respectively). This combination was chosen because of its high traction and acceleration (see image 7 in the index), which will make the tight corners of Baby Park easier for newcomers. Also as a way to help newcomers get used to the game, every participant, regardless of skill level or experience, will complete three single-player, 50cc, practice races, with the game sound on, on any track(s) to get used to the controls and mechanics of the game. No in-game assists, such as Smart Steering and Auto Acceleration will be used. These settings are found by pressing + or – on the Joy-Con controller during kart selection. If a participant decides to use tilt steering rather than joy-stick steering, they may do so, but they cannot switch between the two. Participants will be using one

Joy-Con controller (either the red or the blue) rather than both and they must remain with one color as the button layout for each Joy-Con is slightly different. The race mode we will be using is called VS Race. This mode will allow us to race on Baby Park, with both one and two players, and with CPUs without having to play through an entire four circuit cup like we would in Grand Prix mode. Both the order of blocks and the order of treatments have been randomized. The code that accomplished the random ordering, as well as the randomized data table itself can be found at the end of this section.

Austin conducted a pre-trial at his home on Thursday, March 24, 2022. He gathered 20 observations from one treatment of our experiment (single player, 100cc, game sound on). Austin's girlfriend, Jill, timed his races. The gathered data can be seen in our R code located at the end of this section, where we calculated an estimate for our number of blocks.

From the pre-trial experiment, we expect each observation to take anywhere from 90-120 seconds, so we are planning for 30 to 45 minutes per block which includes setup time in between treatments. There will be 4 participants (Austin, Olusegun, Daniel, Jill), so we are planning on data collection to take anywhere from 2 to 3 hours. We plan to conduct all blocks of our experiment on Saturday, April 2nd, 2022 at 1:00 PM at Austin's apartment, given that our proposal has been approved. Otherwise, we will postpone the experiment until the next Saturday, April 9th, 2022 at 1:00 PM at the same location.

We want to be able to detect a difference in means, D, of 7 seconds over an entire race, or 1 second per lap. This is not to say that we expect participants to lose 1 second per lap, this is more to give context to our desired detectable difference. Using the data from our pre-trial, we estimated σ^2 as 33.1427. The factors "difficulty" and "sound" have 3 levels of treatment and the factor "number of players" has 2 levels of treatments. So, using this information, the non-centrality parameter for difficulty and sound will be $\lambda = \frac{nB(2)(3)(7^2)}{2(33.1427)} \approx 4.44nB$ and the non-centrality parameter for number of players will be $\lambda = \frac{nB(3)(3)(7^2)}{2(33.1427)} \approx 6.65nB$, where nB represents the number of blocks desired. We used the first non-centrality parameter, $\lambda \approx 4.44nB$, for block estimation because it will result in a lower power, giving us a conservative estimate of the number of blocks needed to reach our desired power for any test in question. With 4 blocks, our lambda is about 13.57, giving us a critical value of around 3.179 from an $F_{2,51}$ distribution. This F-value results in a power of about 0.964, showing that we have enough blocks to detect our desired difference. The R code for these calculations can be found below.

R Code that Randomizes the Experiment

```r
rand_dat <- list(4)
it = 1

for(i in sample(c("Austin", "Olusegun", "Daniel", "Jill"))){

  dat <- expand.grid(Participant = i,
            `Number of Players` = c("One Player","Two Players"),
            Difficulty = c("50cc","100cc","150cc"),
            Sound = c("Sound On", "Sound Off", "Player's Music"))

  rand_dat[[it]] <- dat[sample(1:nrow(dat)),]

  it <- it + 1

}

rand_dat <- do.call(rbind, rand_dat)
```

R Code that Calculates the Number of Blocks

```r
time_obs <- c(116.73,116.99,100.20,108.60,
              103.77,  97.55,110.00,107.92,
              107.79,108.19,110.96,102.94,
              116.48,109.17,108.16,105.30,
              109.99,  98.52,116.21,105.95)

#the following code is used to find the samples size needed for Two-Way ANOVA
alpha=.05
a=3     #number of levels of A
b=3     #number of levels of B
c=2     #number of levels of C
sigsq=var(time_obs) # our estimate of sigma^2 from the pretrial

n=4             #number of blocks
DA=7  #desired diff (in seconds) in means to detect with prob 1-beta
Fcrit=qf(1-alpha,a-1,(a*b*c-1)*(n-1))       #value at which we reject H0
lam=n*b*c*(DA^2)/(2*sigsq)        #non-centrality parameter (ncp)
beta=pf(Fcrit,a-1,(a*b*c-1)*(n-1),ncp=lam)
power=1-beta
nforA=cbind(n,Fcrit,beta,power)   #output for A
nforA
```

	n	Fcrit	beta	power
[1,]	4	3.178799	0.03597092	0.9640291

Data Table:

Participant	Number of Players	Difficulty	Sound	Time (seconds)
Jill	Two Players	150cc	Sound On	
Jill	Two Players	100cc	Sound On	
Jill	Two Players	150cc	Sound Off	
Jill	Two Players	50cc	Player's Music	
Jill	Two Players	100cc	Sound Off	
Jill	One Player	100cc	Sound On	
Jill	One Player	100cc	Sound Off	
Jill	One Player	150cc	Sound Off	
Jill	One Player	150cc	Sound On	
Jill	One Player	50cc	Sound Off	
Jill	One Player	100cc	Player's Music	
Jill	Two Players	100cc	Player's Music	
Jill	Two Players	150cc	Player's Music	
Jill	One Player	50cc	Player's Music	
Jill	One Player	150cc	Player's Music	
Jill	One Player	50cc	Sound On	
Jill	Two Players	50cc	Sound Off	
Jill	Two Players	50cc	Sound On	
Daniel	Two Players	100cc	Player's Music	
Daniel	One Player	50cc	Sound Off	
Daniel	Two Players	100cc	Sound On	
Daniel	One Player	150cc	Sound On	
Daniel	Two Players	50cc	Sound On	
Daniel	Two Players	150cc	Player's Music	
Daniel	One Player	100cc	Sound On	
Daniel	One Player	50cc	Sound On	
Daniel	Two Players	150cc	Sound Off	
Daniel	Two Players	150cc	Sound On	
Daniel	Two Players	50cc	Sound Off	
Daniel	Two Players	50cc	Player's Music	
Daniel	One Player	50cc	Player's Music	
Daniel	One Player	150cc	Sound Off	
Daniel	Two Players	100cc	Sound Off	
Daniel	One Player	100cc	Sound Off	
Daniel	One Player	150cc	Player's Music	
Daniel	One Player	100cc	Player's Music	
Olusegun	Two Players	150cc	Sound Off	
Olusegun	One Player	100cc	Sound On	
Olusegun	One Player	50cc	Player's Music	
Olusegun	Two Players	50cc	Player's Music	
Olusegun	Two Players	50cc	Sound On	
Olusegun	One Player	50cc	Sound Off	
Olusegun	Two Players	100cc	Player's Music	

Olusegun	Two Players	100cc	Sound On	
Olusegun	One Player	100cc	Player's Music	
Olusegun	Two Players	50cc	Sound Off	
Olusegun	Two Players	150cc	Player's Music	
Olusegun	One Player	50cc	Sound On	
Olusegun	One Player	150cc	Sound On	
Olusegun	One Player	150cc	Sound Off	
Olusegun	One Player	150cc	Player's Music	
Olusegun	Two Players	150cc	Sound On	
Olusegun	Two Players	100cc	Sound Off	
Olusegun	One Player	100cc	Sound Off	
Austin	Two Players	150cc	Sound On	
Austin	Two Players	150cc	Sound Off	
Austin	One Player	100cc	Sound On	
Austin	One Player	50cc	Player's Music	
Austin	Two Players	150cc	Player's Music	
Austin	One Player	150cc	Sound Off	
Austin	One Player	50cc	Sound On	
Austin	One Player	150cc	Sound On	
Austin	Two Players	100cc	Sound Off	
Austin	One Player	100cc	Player's Music	
Austin	Two Players	50cc	Sound Off	
Austin	Two Players	100cc	Sound On	
Austin	One Player	100cc	Sound Off	
Austin	Two Players	50cc	Player's Music	
Austin	One Player	50cc	Sound Off	
Austin	One Player	150cc	Player's Music	
Austin	Two Players	100cc	Player's Music	
Austin	Two Players	50cc	Sound On	

Index:

Image 1: The *GO!* that indicates when to start the stopwatch. (GamerJGB, 2017)

Image 2: The *FINISH!* that indicates when to stop the stopwatch. (GamerJGB, 2017)

Image 3: Mario ("Mario Kart 8 Deluxe in-game statistics", 2022)

Image 4: Streetle kart ("Mario Kart 8 Deluxe in-game statistics", 2022)
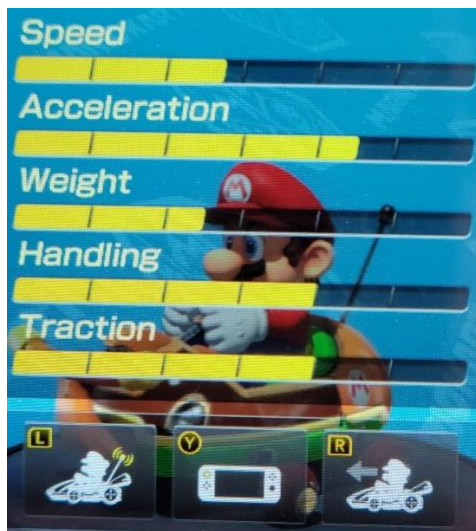

Image 5: Roller wheel ("Mario Kart 8 Deluxe in-game statistics", 2022)

Image 6: Waddle Wing glider ("Mario Kart 8 Deluxe in-game statistics", 2022)

Image 7: Kart Statistics

References:

GamerJGB. (2017, June 7). *Mario Kart 8 Deluxe: GCN Baby Park [1080 HD]* [Video].
      YouTube. https://www.youtube.com/watch?v=RgfGIju16M0

Mario Kart 8 Deluxe in-game statistics. (2022, March 30). In *Super Mario Wiki*.