A Cognitive Study of Excitebike, a Nintendo video game

Tiffany Clark and Elizabeth Holloway
Iowa State University
IE 681 / Fall 2018

Introduction

Excitebike was released in 1985 for the Nintendo Entertainment System (NES), and is a motocross racing game. It had widespread popularity and is considered one of the greatest racing games of any gaming system (Motosport, 2014).

Game Modes
Excitebike is a single-player game, in which the player, represented by a rider, completes a two-lap dirt bike race, attempting to achieve a qualifying time. There are five tracks available, each with a different track layout, level of difficulty, and qualifying time. Tracks have various obstacles, such as speed bumps and oil spills, which can delay player time. Encountering an obstacle will not end the race, only slow the bike or cause the rider to dismount from the bike.

Players are able to adjust speed by using game controls to accelerate, decelerate, and temporarily "boost" the bike to higher speeds. In order to avoid obstacles, the position and pitch of the bike must be adjusted with directional controls. Players can adjust the pitch of the bike in order to clear speed bumps and land jumps properly.

Figure 1: Excitebike in solo-mode

Engine temperature, displayed by a gauge at the bottom of the screen (Figure 1), is also a factor players must monitor. If the engine overheats, the bike is immobilized and the player must wait until the temperature decreases. However, players can maintain optimal engine temperature by decelerating or riding over track “cooling arrows.” The player may elect to ride solo (Figure 1) or with other CPU riders. There is also an additional mode which allows the player to design his own track. For the purposes of this study, only solo mode will be used.

Similar Games

Similar racing games include Nintendo’s MachRider (1985) and more modern games such as THQ’s MX vs. ATV series (2009 – 2011), EA’s Supercross 2000 (1998), and Microsoft’s Motorcross Madness (1998). Dirt bike racing games have also been adapted for iOS, like Mad Skills Motocross, where the only game control is the user’s thumbs, controlling direction on the X- and Y-axis.

MachRider, released the same year as Excitebike, is very similar in terms of game structure. Players must complete timed courses and avoid track obstacles. Some differences exist between the two games. In MachRider, the visual display of the game is in 3D (Figure 2), which changes the player perspective of the game. Also, the player must shift the gears of the bike, as opposed to just controlling speed. In addition to track obstacles, there are enemies chasing the rider that must be eliminated with weapons. While MachRider may have different attentional challenges, it lacks the difficult jumps of Excitebike (Motosport, 2014).

Figure 2: MachRider course

More modern motocross games include obvious updates such as better quality graphics, enhanced music, and user options like customization of rider and bike. They also include additional game options for enhanced challenges, like jump tricks and different terrains.

Existing Game Research

Excitebike has been used by researchers in studying the effect of violent vs nonviolent video games on the behavior of children. A lag effect of aggressive tendencies has been observed after exposure to certain video games. In one study, two groups of children engaged in a short period of video game play; their free-play behaviors afterwards were observed. One group played a nonviolent video game, Excitebike, while the other group played a violent video game, Double Dragon. Although both video games seemed to cause similar heart rate elevations, the children that played Double Dragon had twice as many aggressive behaviors during play as those children that played Excitebike (Anderson and Gentile, 2007).

Game Analysis

Game Considerations

Time is the most important metric of this game, as it will determine if a player moves to the next round. There are a number of factors that may cause the player a delay in time and some can be avoided with player skill, which may come with experience. The table below (Figure 5) lists all of the game factors that may affect overall race time. Players can adjust speed, direction, and pitch to avoid obstacles. Because of the time sensitive nature of the game, both speed and navigation demand concurrent attention and skill in order to reach a qualifying time. Novice players may not be able to handle more than one game attentional task demand at a time. Game errors include hitting speed bumps, driving over a non-track areas (grass), landing improperly off jumps, dismounting from the bike, hitting an oil slick, and overheating the engine.

Time Delay Factors

Time Delay Factor	**Expert Player Scenarios**	**Novice Player Scenarios**
Fell off bike	Adjust speed and pitch of bike to land correctly off jumps and go over speed bumps.	Do not adjust speed and pitch. Fall of bike. Must wait to remount.
Hit oil slick	Navigate around oil slick.	Drive directly through oil slick. Bike slows down.
Landed in grass	Adjust speed and pitch of bike to minimize time delay.	Drive directly through grass. Bike slows down.
Hit turbo	Use turbo appropriately to better time.	Too much turbo. High speed causes poor navigation of obstacle. Causes engine overheating. Too little turbo. Causes a slower overall time
Engine overheating	Navigate to pass bike over cooling arrows on track	Misses cooling arrows. Bike is temporarily immobilized as engine cools
Hit speed bump	Adjusts pitch of bike to bring front end up in order to clear speed bump	Do not adjust speed and pitch. Crashes on speed bump. Falls of bike and must wait to remount.

Figure 5: Expert player vs Novice player time delay scenarios

Game Timing

Each track lap has approximately three sets of obstacles followed by a "break". A break is defined as open straightaway track with that can be completed with minimal effort; the only goal is to maintain speed without error. When looking at an expert-completed round with very few errors, the approximate frequency of breaks and obstacles is:

1. Break: 5 seconds
2. Obstacles (13): 10 seconds
3. Break: 3 seconds
4. Obstacles (10): 10 seconds
5. Break: 5 seconds

6. Obstacles (5): 5 seconds
7. End of Round

A 38 second track lap is primarily spent navigating obstacles, which takes up 66% of overall race time. Additionally, the least amount of break time is between the two largest sets of obstacles, giving the player little time to recover.

Attentional demands

There are three attentional zones players experience during gameplay, shown in Figure 5a. The primary attentional zone, outlined in red, includes roughly two-thirds of the screen width and is where track obstacles appear. The bike always resides about one-third of the width of the screen from the left, regardless of speed or obstacles encountered. The engine temperature gauge (highlighted in green) and the timeclock (highlighted in yellow) offered additional attentional zones, though the time clock was primarily observed by the expert players who were looking to improve upon their previous trial times.

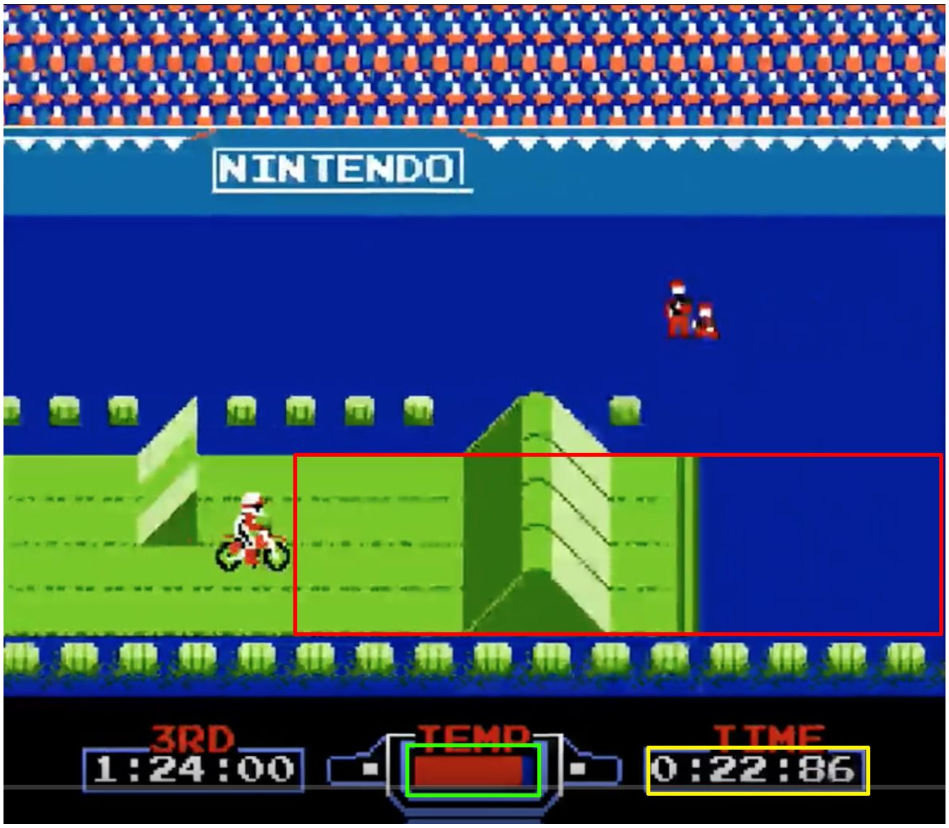

Figure 5a: Attentional Zones

Gameplay includes several attentional tasks. Within the track (the primary attentional zone), players identify obstacles, determine how approach an obstacle, and then navigate the bike and/or alter the speed of the bike accordingly. Players must also periodically check the temperature of their engine (secondary attentional zone) and may choose to check the time of their round (secondary attentional zone).

Player Study

Control Game Play

We conducted our study with two expert and two novice player groups. In total, three novices and three self-described experts were used. One group, consisting of two experts and two novices, used the original NES game console with a GamePad controller. A second group, including one novice and one expert, used an online emulator with keyboard input.

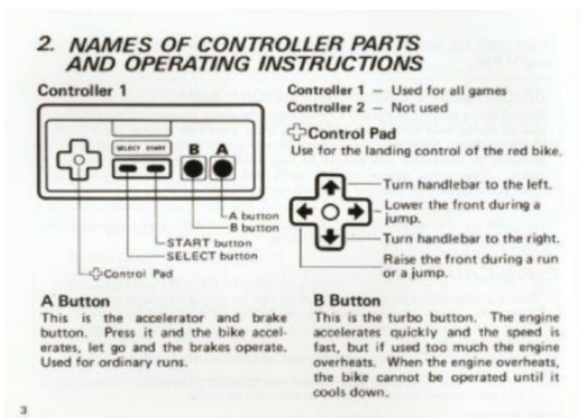

Figure 6a: Excitebike GamePad controller options

On the GamePad controller, the “A” (throttle/brake) and “B” (turbo) buttons control the speed of the bike, while the Control Pad options dictate the Y-axis position of the bike on the track and pitch of the bike in the air (Figure 6a). The emulator follows a mapping of the original NES GamePad (Figure 6b). Bike position and pitch are controlled with the keyboard’s up and down keys, while the acceleration of the bike is controlled with the X (throttle/brake) and Z (turbo) keys.

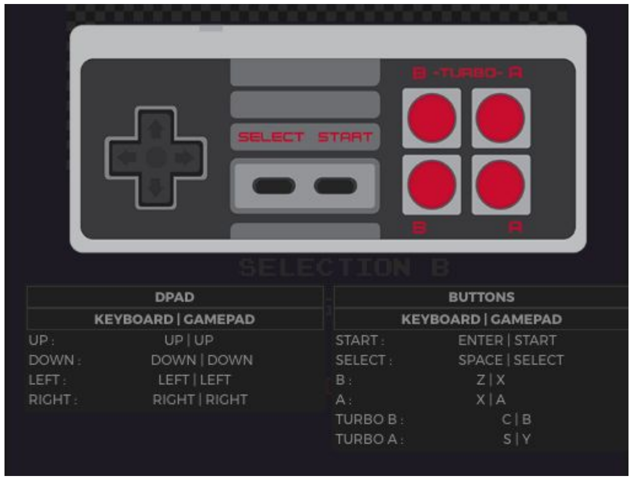

Figure 6b: Web-based emulator game controls

In order to create comparable data, all players conducted their races in solo-mode on Track 3 of 5. In preliminary studies, it was found that on Tracks 1 and 2, novice race times and number of errors were close to those of experts. However, at Track 3, obstacles and time challenges increase enough to distinguish between expert and novice game play. Players conducted a few test runs before races were recorded in order to regain familiarity of the game, in the case of experts, or learn the controls, in the case of novices.

Five races for each experts and novices were recorded in private and without interruption. Races were rewatched to tally the number of times the player:

- Fell off bike
- Hit oil slick
- Landed in grass
- Overheated engine
- Hit speed bump
- Hit cooling arrow

Total race time, place finished and strategic features used were also recorded. Time spent completing obstacles was not recorded. The reason for this was because for the majority of the race, players chose to only use the throttle, and not the turbo, when encountering obstacles. This creates a mean fixed speed during obstacle challenges. In most observed gameplay, the turbo feature was only used strategically to approach obstacles, so variations in time between all participants is too small to detect accurately (milliseconds). Furthermore, usage of the turbo feature is not indicative of expert behavior as using it can also have a negative outcome when it causes the engine to overheat.

Interviews

At the end of the control gameplay, we asked all players a series of questions in a semi-structured interview format:

1. What would you say to a novice that would make this game easier?
2. What piece of strategy do you think took you the longest to learn?
3. What, if anything, "throws you off" when it happens during gameplay?
4. What's the biggest challenge for you with this game?
5. What "roadblock" or challenge took you the longest to "figure out"?
6. Is there any part of the game where you feel most tense or physically engaged?
7. What is the most exciting part of the gameplay?
8. What skill do you think is most useful to get better at (what would you suggest novices work to improve on)?
9. What skill do you think holds you back from being even better at this game? (What would you practice to improve further?)

Questions were chosen to elicit information on various pieces of gameplay. The goal was to understand what types of strategy experts used that novices did not, what parts of the game were deemed most difficult and how they were approached, as well as what parts of the game have the highest number of attentional demands.

Attentional Demand Task Gameplay

Expert players participated in an additional attentional demand task during game play. The novice group did not participate in this task. Experts were given a few warm-up races to regain familiarity of game controls and track obstacles. During game play, experts were asked to listen to a list of randomly generated numbers and indicate when two odd numbers appeared consecutively by saying the word “odd.” The expert game control players and the expert emulator players completed two races with the attentional demand task. The same data was measured as in the control gameplay. This type of listening task has been used by cognitive psychologist to study divided-attention. In other research that uses similar number listening tasks, participants either failed to identify the odd number target or failed to respond correctly to the attentional control task (Schacter, 1999).

Hypothesis

It was hypothesized that experts would have faster race times, with fewer obstacle errors, than novices. Initial analysis of the game, also led to the assumption that experts would use better strategies than novices. For the purpose of this study, *strategy* can be defined as player skill based on the number of game features used. It was also thought that expert play could be reduced to novice play when an additional attentional demand task is introduced. This can be measured in terms of time and errors.

Results

As anticipated, during control game play, expert players made fewer errors than novices and finished with faster times and higher place finish (Figure 7a). The largest difference was in the number of times players fell off the bike due to obstacle encounters. Novices fell off the bike approximately three times more than experts. It was observed that this was either due to struck speed bumps or landing jumps incorrectly.

Errors, Total Time and Place for Expert vs. Novice Players

	Novice Mean	Expert Mean
Number times player fell off bike	6.23	1.9
Number of times player hit oil slick	1.2	1.1
Number of times player landed in grass	2	2
Number of times player engine overheated	0.2	0.1
Number of times player hit speed bump	2.95	0.4
Number of times player hit cooling arrow	2.3	2
Overall race time (minutes)	1:49	1:16
Place finish	13.88	2.7

Figure 7a: Average Errors, Total Time and Place Finish for Expert vs. Novice Players

During the attentional demand task, experts surprisingly performed better on physical obstacles: speed bumps, oil slicks, etc. Race time increased, but not drastically, and place finished slightly improved. The largest area of difference was found on errors related to engine temperature. During control gameplay, engine temperature did not seem to be a factor. Experts neither used the track cooling arrows, nor did they let engines overheat. However, during attentional demand task gameplay, these occurrences roughly doubled.

Attentional Demand Task Gameplay

	Expert Control Gameplay Mean	Expert Attentional Demand Task Gameplay Mean
Number of times player fell off bike	1.9	1.75
Number of times player hit oil slick	1.1	0.5
Number of times player landed in grass	2	2
Number of times engine overheated	0.4	2
Number of times player hit speed bump	2	1.25
Number of times player hit cooling arrow	0.1	1.5
Time for round (minutes)	1:16	1:19
Place finish	2.7	2.5

Figure 7b: Average Errors, Total Time and Place Finish for Control Gameplay vs. Attentional Demand Task Gameplay

Discussion

Experts vs Novices

Overall, skill and experience were a factor in successful gameplay. As observed in video playback, experts frequently used the arrow keys to adjust the pitch of the bike when approaching a speed bump or going over a jump. Adjusting pitch allowed expert players to go over speed bumps, rather than around them, which resulted in better track times. This also allowed them to land jumps successfully. As far as advantages from experience, experts were able to remember and anticipate upcoming obstacles from repeated gameplay, which helped them position the bike for upcoming obstacles and avoid errors. They also strategically used the turbo feature both when the bike was on the track and in the air, which led to a faster track time and better clearance on jumps.

Typically, novices did not try to use game controls outside of those that preformed basic actions. Bike speed is an example of this. Novices used the throttle but not the turbo feature. They also admitted to not having a good understanding of how the feature worked. The turbo feature requires toggling to a different button than the one that is used for control throttling. Novices focused primarily on track navigation and maintaining constant speed, which was less attentional load sporadically using turbo.

During attentional demand task gameplay, experts had difficulty monitoring all attentional zones while completing the listening task. The attentional zone that suffered was a secondary zone: engine temperature. Data showed that expert players overheated engines more frequently and missed opportunities to hit cooling arrows. And although tasks in the primary attentional zone were completed correctly, they were done so with less skill. Players failed to use game features relied on for speed. For example, experts that commonly adjusted the pitch of the bike to clear speed bumps, instead chose to navigate around them. This caused only a slight increase increase in race time, but a large decrease in the number of times game features could be used.

During interviews, experts also admitted to added feelings of stress around certain obstacles such as oil slicks. Still, their level of game play was not reduced to that of the novices. This indicates that either the attentional demand task was not difficult enough, or that some expert behaviors were benefiting from muscle memory. Research has shown that moderately playing video games allows some players to gain individualized habits that result in bursts of in-game improvement (Huang et al, 2015). Furthermore, in time-sensitive situations, these habits serve as muscle memory, giving these players an advantage over novices. All of our expert players had past experience playing Excitebike, primarily in adolescence, which may have given them an added advantage during the attentional demand task.

As was previously mentioned, Excitebike has been used in research, categorized as a non-violent video game. Gentil et. al. found that violent video games had a much stronger impact on players' cortisol levels, showing only small, but significant, increases for non-violent gaming. Higher levels of cortisol have been shown to increase the number of risky choices made (Putman et. al. 2010), so one might hypothesize that with lower cortisol levels, players were more likely to be conservative with their choices. This supports our findings that expert players during the attentional task were more likely to slow down and avoid obstacles rather than attempting to speed through and make quicker, riskier decisions that might result in errors.

Interviews

To summarize the answers, the novices stated that they had problems sharing attentional resources during control game play. They said it was difficult trying to simultaneously maintain optimal speed of the bike and navigate obstacles. Additionally, even though novices understood game controls, some did not have a thorough understanding of when they could use them. For example, one novice used the turbo feature to accelerate the bike while it was on the ground. No novices realized you could also use this when the bike was in the air. They also did not realize that not only could adjusting pitch land jumps, but also speed bumps.

The experts, on the other hand, had no issues with attention demands during control game play. Their issues seemed to lie in perfecting skill, such as landing jumps correctly in order to maintain speed. They also admitted to being privy to certain “cheat codes,” which were not known to the novices. For example, repeatedly pressing the “A” button while a rider is down allows them to mount back on the bike faster. Experts advised that novices should remain patient and try to avoid the urge to drive aggressively because falling off of the bike costs valuable time.

Additional Considerations

Input controls should also be taken into consideration. The expert group that used the GamePad had noticeably faster track times than the expert group that used the emulator with keyboard input (Figure 8). Both experts in the emulator group had past experience with the game, but with a game controller. Comments were made that the emulator mapping was reversed compared to the game functions on the NES controller (Figure 8).

Input Control Differences: Emulator vs Console Gamepad

	Emulator Expert Average	**Console Expert Average**
Number times player fell off bike	3.2	0.6
Number of times player hit oil slick	2	0.2
Number of times player landed in grass	2.2	1.8
Number of times player engine overheated	0.2	0
Number of times player hit speed bump	0.4	0.4
Number of times user hit cooling arrow	0.8	3.2
Time for round (minutes)	1.246	1.072
Place finish	4.4	1

Figure 8: Average Errors, Total Time and Place Finish for Experts using Emulators vs. Nintendo Console

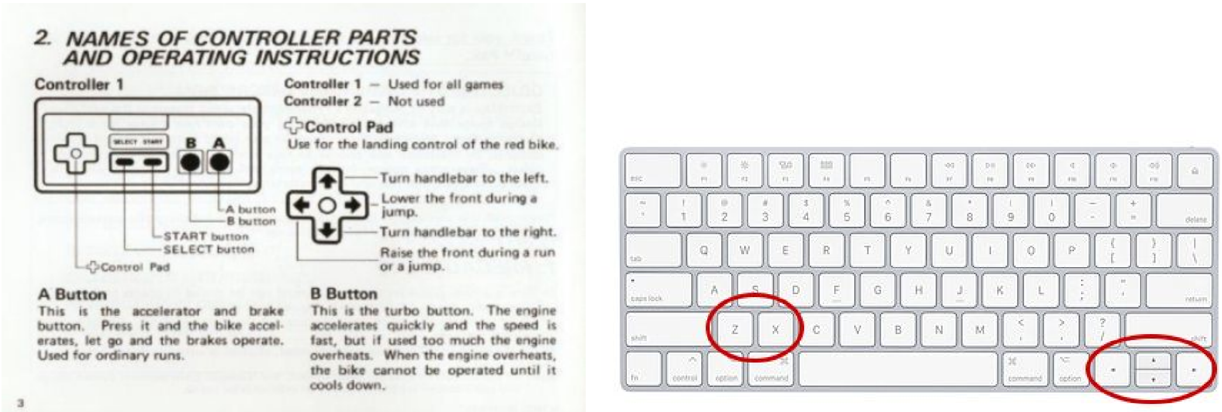

Figure 9: NES GamePad input options vs emulator keyboard input mapping

On the NES GamePad, speed of the bike is controlled by options on the right side of the controller, but on the keyboard this is controlled by the Z and X keys on the left side of the keyboard (Figure 9). This caused mapping issues with our console experts, which may have increased attentional demand, causing them slower times than the console experts. Future studies could focus on input controls and game feature mapping.

Possible mathematical performance predictor

In addition to total number of errors, it was found that game strategy was a strong predictor of finish time. Results from the attentional demand task were an indication that prior knowledge of successful strategies, or skill, decreased total race time. And expert performance was decreased significantly by added attentional demands.

Five successful game strategies were identified:

- Adjusting pitch of the bike over speed bumps
- Adjusting pitch of the bike while going over jumps
- Using the turbo feature without overheating the engine
- Pressing the “A” button repeatedly to quickly remount bike
- Clearing multiple jumps at once (required knowledge of the track and understanding of trajectory and appropriate speed)

The observed experts used more strategic game features than novices. However, frequency of feature usage was not a good predictive element, as novices often misused certain strategic features which caused time delays. For example, the turbo feature can been deemed as a positive game feature, but when used inappropriately, it is either negated by other game factors or can cause the engine to overheat quickly. When the relationship between number of strategic game features used and total time was observed, there appeared to be a moderately strong negative correlation (R=-.84; See Figure 10).

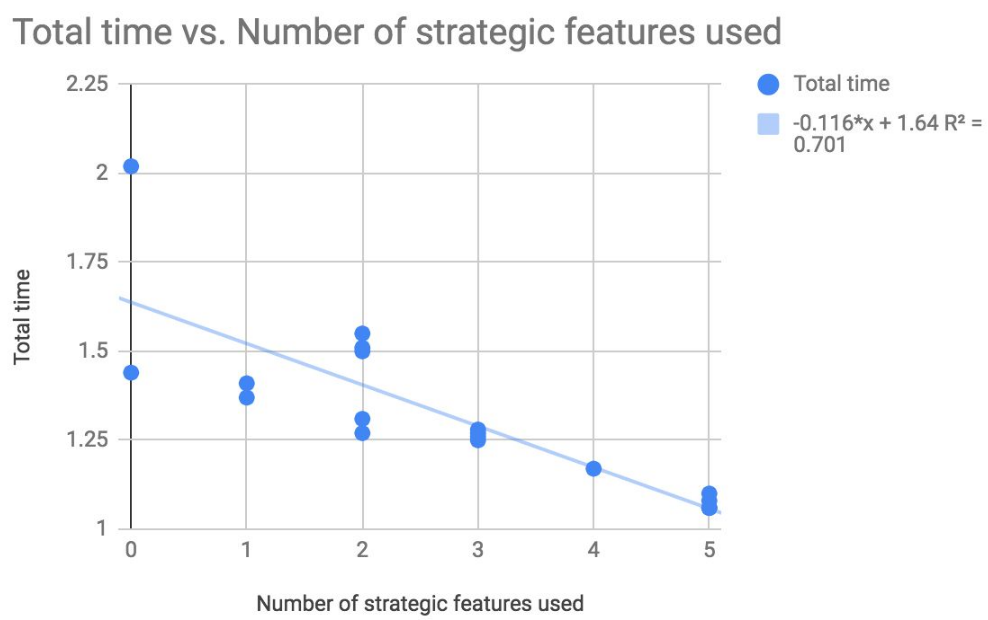

Figure 10: Total time vs. number of strategic features used in round

Using this model, we can predict the total time to complete Track 3, using the linear equation:

$$-0.116*(\text{Number of strategic features used}) + 1.64 = \text{Total time}$$

In other words, expert players of Excitebike use combinations of game features, which can be referred to as *skill*, to achieve faster race times. This model can predict overall race time from the number of game features used. For example, according to the model, players that use three game features will have a moderate race time of 1:29. This matches the data collected from players in this study. Because this model represents game skill, it can also be used to develop player personas. Spread of the data would dictate the range of the personas. Moderate skill, as shown at the mid point of X- and Y-axis, represents an intermediate player. Extreme beginners and novices would always appear at the highest point of the Y-axis, which represents the slowest race times. Player personas would be important in video game development and testing.

While the linear equation can be used to estimate race time for Track 3, additional trials are needed to verify whether the model can effectively predict race time on other tracks. Each track differs in the number and type of obstacles; thus, average race times for a given track would change accordingly. Similar linear models for other tracks could be developed provided there is enough data to determine player skill for each track. Additionally, it would be optimal to verify if teaching novices proper use of the strategic game features would result in consistent data points within the linear model. As some game features may have a learning curve, it is possible that simply using them is not a predictor. It may be the case that only achieving positive game outcomes from using strategic features truly predicts performance.

Conclusion

It was hypothesized that experts would have faster race times, with fewer obstacle errors than novices, while also using more effective strategies than novices. It was also thought that expert play could be reduced to novice play when an additional attentional demand task is introduced. This can be measured in terms of time and errors. The first hypothesis was confirmed: experts did indeed have significantly faster races times, made fewer errors and used more game strategy features than novices. However the attentional demand task did not reduce expert total time or frequency of error to that of a novice.

It was surprising that there was little difference between control expert gameplay and attentional task gameplay. Experts were able to complete the attentional listening task fairly well, while continuing control gameplay at an advanced skill level. They seemed to be able to monitor all but one secondary attentional zone: the engine temperature gauge. There were many more incidents of the engine overheating and opportunities missed to hit the engine cooling arrow.

Obstacles, as the main visual targets, consumed the majority of player attentional resources because they were displayed in the primary visual attentional zone: the track. The engine temperature gauge was in a secondary attentional zone, and could be thought of as a peripheral distractor, and thus was neglected when the attentional demand task was introduced. Research has shown that experienced video game players (VGPs) have better selective attention than novice video game players (NVGPs). VGPs are able to distribute visual attention widely over the game screen while also monitoring peripheral information (Bavelier, et al, 2012). It is possible that experts were exercising selective attention based on past game experience and skill to continue to achieve much faster race time than novice.

Ultimately, aside from total number of errors, player strategy was a distinguishing factor between experts and novices. The number of strategy features used by the player predicted their total time to complete two laps on Track 3.

Brief

Tiffany Clark designed the original game concept and data analyzation structure. She provided both novice and expert players. Her background in user analysis was vital during observation in video playback, as she delineated many metrics from gameplay. She was responsible for the most important part of this research: she took the gameplay data and developed correlations between player metrics and game outcome, leading us to our final mathematical performance prediction model. Additionally, she shared equal responsibilities in writing the research paper, developing the slide presentation, and formatting the data.

Elizabeth provided both novice and expert players, analyzed data, and played a vital leadership role in constructing the final paper. She researched the game's background and other similar games and did considerable analysis on the player videos. Her analysis led us to our final mathematical predictor using strategic elements. She also led the charge with the presentation and was present during class to provide answers to student and professor questions.

Sources

Anderson, C. A., Gentile, D. A., & Buckley, K. E. (2007). *Violent video game effects on children and adolescents: Theory, research, and public policy*. Oxford: Oxford University Press. Bavelier, D., Achtman, R. L., Mani, M., & Föcker, J. (2012). Neural bases of selective attention in action video game players. *Vision Research,61*, 132-143. doi:10.1016/j.visres.2011.08.007

Gentile, D. A., Bender, P. K., & Anderson, C. A. (2017). Violent video game effects on salivary cortisol, arousal, and aggressive thoughts in children. *Computers in Human Behavior,70*, 39-43. doi:10.1016/j.chb.2016.12.045

Huang, J., Yan, E., Cheung, G., Nagappan, N., & Zimmermann, T. (2017). Master Maker: Understanding Gaming Skill Through Practice and Habit From Gameplay Behavior. *Topics in Cognitive Science,9*(2), 437-466. doi:10.1111/tops.12251

Putman, P., Antypa, N., Crysovergi, P., & Willem A. J. Van Der Does. (2009). Exogenous cortisol acutely influences motivated decision making in healthy young men. *Psychopharmacology,208*(2), 257-263. doi:10.1007/s00213-009-1725-y

Schacter, D. L., “The cognitive neuropsychology of false memories.” *Cognitive Neuropsychology*. Cambridge, MA: Harvard University; 1999.

The Top 10 Greatest Dirt Bike Games Ever Made. (2014, March 10). Retrieved from https://www.motosport.com/blog/the-top-10-greatest-dirt-bike-games-ever-made