Impacts of Game Responsiveness on Game Usability and Player Enjoyment

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Abstract

The state of concentration, motivation, and immersion in a task is often referred to as the psychological phenomenon of flow. Activities such as playing video games are well suited to evoking a flow state in players, although this state can become undone by flaws in the game's implementation such as including poor responsiveness. Games that respond poorly to player input or suffer from low frame rates interfere with players' game experiences.

This research aims to examine the impacts of reduced game responsiveness on game usability and elements of flow. These goals are accomplished by having participants play through a game and experience varying levels of additional input latency and reduced frame rate. Players complete a brief questionnaire throughout the process, answering questions about the usability of the game and comparing elements of the responsive and less responsive games.

The findings suggest that reduced game responsiveness negatively impacts game usability as well as player concentration, control, sense of feedback, and immersion. When the responsiveness variables were modified independently, the greatest number of players noticed changes in game feel with approximately 150ms and 250ms of combined input and display latency and when playing at a reduced frame rate of 12 FPS.

1 Introduction

The interactive nature of video games is one of the key features that sets the medium apart from similar types of media. For players to effectively interact with games, it is reasonable to expect responsive products where the player can interact with games in a timely manner and receive quality feedback from the games.

Unfortunately, this is not always the case. Occasionally, games on the market exhibit poor responsiveness and result in customer dissatisfaction (Bierton 2014). This research investigates some of the ways that poor game responsiveness impacts players and their experiences with the games they play. This research hopes to highlight specific ways that player experiences can be affected by poor responsiveness.

Poor game responsiveness is expected to have a negative effect on players' ability to experience the psychological phenomenon of flow. Flow is a state of heightened focus on a task that is facilitated by a balance of the task's challenge and the person's skill (Nakamura and Csikszentmihalyi 2002). Games are especially suited for enabling flow states in players, facilitating the development of a model of flow specifically for games (Sweetser and Wyeth 2005).

To explore the effects of game responsiveness on players, a short game was developed that artificially modifies the game's responsiveness in a controlled manner, using input latency and frame rate as variable for changing responsiveness. Players play through the game, indicating at what times they notice a change in how the game feels to them. Players also complete a questionnaire comparing their experiences with the game when it was fully responsive and less responsive. Through this questionnaire, players provide their views on how the usability of the game is affected and if changes in responsiveness affect various elements of the GameFlow model.

GameFlow contains eight elements (Sweetser and Wyeth 2005), seven of which will be examined through this research (one element is excluded for scope purposes). Changes in game responsiveness are expected to have the following impacts on the elements of Concentration, Challenge, Player Skills, Control, Clear Goals, Feedback, and Immersion:

- Lowered responsiveness is expected to make it more difficult for the player to concentrate on the game.
- Lowered responsiveness is expected to provide additional challenge for the player that they may lack the skills or desire to overcome.
- Lowered responsiveness is expected to interfere with the player's ability to develop and master the skills they will use in the game.
- Increased input latency is expected to give the player a worse sense of control over their actions.
- Game responsiveness is not expected to affect the clarity of the player's goals.
- Increased input latency and lowered frame rate are expected to give the player weaker feedback on their actions.
- Increased input latency and lowered frame rate are expected to challenge the player's ability to become immersed in the game.

The literature review provides an examination of the role of flow in game enjoyment and flow's role in the development of a model of enjoyment for games, GameFlow. Works on the current impacts of various sources of poor game responsiveness are detailed in-depth. The methodology section details the design and development of the game and questionnaire used in this research, including challenges and considerations as well as modifications made to produce higher quality results. The results and discussion section delivers the results of the player responses and interprets their significance in the context of the project goals. The dissertation closes with a conclusion and future work section, summarising the goals and accomplishments of the project as well as outlining opportunities for expanding and refining the results in future projects.

2 Literature Review

2.1 Flow

Games research that focuses on topics relating to enjoyment and immersion will often build upon seminal works by Csikszentmihalyi on his theory of flow (Plotnikov 2012; Birk and Mandryk 2013). Flow is the "phenomenon of intrinsically motivated … activity [that is] rewarding in and of itself … quite apart from its end product or any extrinsic good that might result from the activity" (Nakamura and Csikszentmihalyi 2002, p.89). Flow manifests itself in several ways, including: intense and focused concentration on the task being attempted, the sense of time passing faster than usual, and the experience of the task being performed being intrinsically rewarding (Nakamura and Csikszentmihalyi 2002).

Flow is an equilibrium between action opportunities (challenges) and action capabilities (skills) as seen in Figure 2.1. In addition to providing intrinsic reward from performing an activity, flow fosters creativity, focus, and engagement. When challenges exceed one's skills, people experience anxiety. Likewise, boredom is experienced when skills exceed challenges (Nakamura and Csikszentmihalyi 2002).

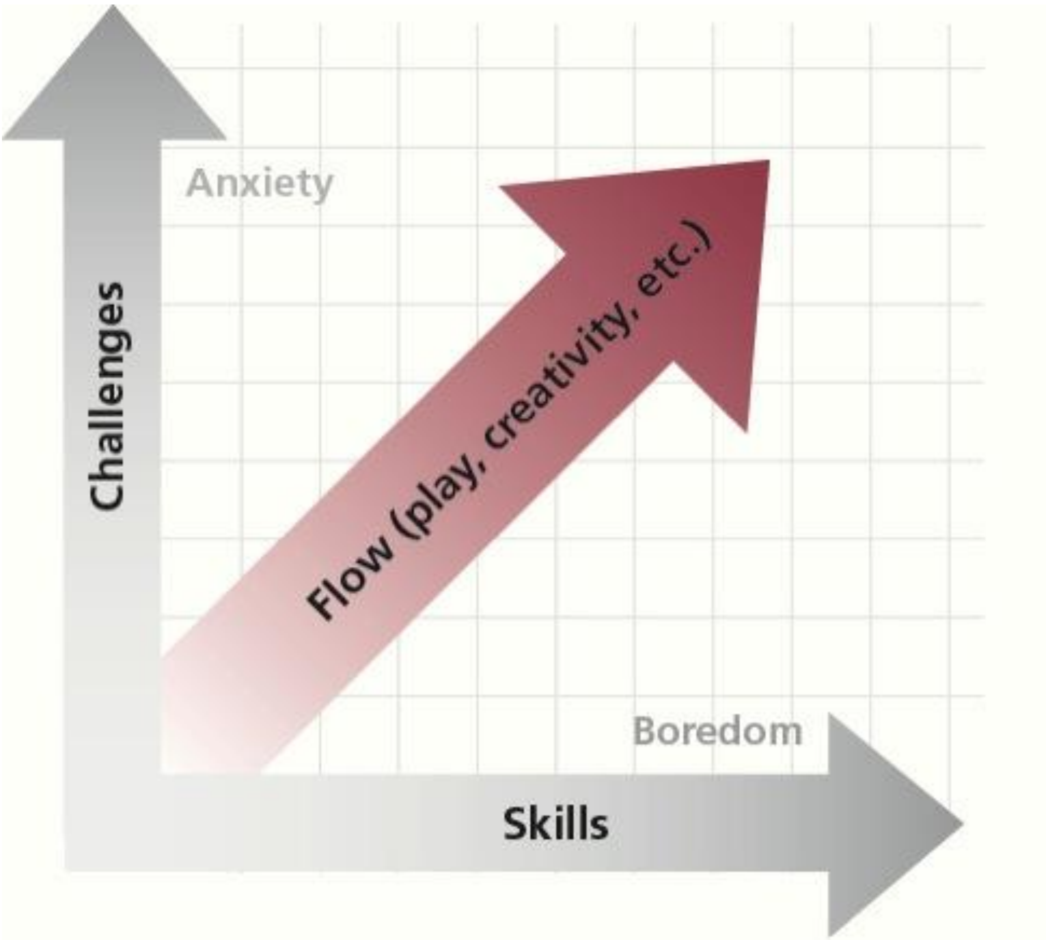

Figure 2.1: Flow is attained through a balance of challenges and skills (Phillips 2013).

2.1.1 Flow and Games

Csikszentmihalyi's works on flow have provided a foundation for explaining why people enjoy consuming media, particularly games. Aside from providing entertainment, media consumption exhibits characteristics very similar to those who have entered a flow state, such as providing arousal, helping pass time, and relaxing the consumer (Sherry 2004).

Games however, are particularly well-suited for fostering flow compared to other types of media. Sherry (2004) made a strong case for this, noting the following characteristics of games:

1) They have clear and defined goals and use manageable rules that are normally well communicated.

2) They provide action that can be adjusted to the player’s capabilities, whether manually or automatically.
3) They provide clear feedback such as score, player health, and progress indicators.
4) They facilitate concentration through the use of graphical and audio information.

Despite the qualities that consuming non-interactive media has for presenting a flow state in consumers (Sherry 2004), the interactive nature of games suggest that they present a more fertile environment for flow to take place.

2.1.2 GameFlow

The compatibility of flow and games has, in part, led to the development of a model of enjoyment in games that is based on flow (Sweetser and Wyeth 2005). This model, named GameFlow, consists of eight elements, almost all of which can be mapped directly to various elements of flow: Concentration, Challenge, Player Skills, Control, Clear Goals, Feedback, Immersion, and Social Interaction. The mappings between the elements of GameFlow and their corresponding elements in flow are presented in Table 1.

GameFlow element	**Flow element**
Concentration	Ability to concentrate on the task
Challenge and Player Skills	Perceived skills should match challenges and both must exceed a certain threshold
Control	Allowed to exercise a sense of control over actions
Clear Goals	The task has clear goals
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement, reduced concern for self and sense

	of time
Social Interaction	n/a

Table 1: Mappings between GameFlow elements and flow elements (Sweetser and Wyeth 2005).

Although the Social Interaction element does not map directly to an element of flow, it has been shown that social interactions, whether the other players have a virtual or co-located presence, are significant elements of player enjoyment (De Kort and Ijsselsteijn 2008) and that players will play games that they would not otherwise play when a social element is involved (Sweetser and Wyeth 2005). Despite the argument that the Social Interaction element is not necessarily a desirable element in all games (Cowley et al. 2008), the Social Interaction element remains a part of GameFlow (Sweetser, Johnson, and Wyeth 2012). Although social interaction is present in only a subset of all games, its inclusion in GameFlow is wise considering the likelihood that the widespread appeal of multiplayer gaming, including games on social media websites and massively-multiplayer online games, is due in part to the enjoyment of playing with other people.

GameFlow was validated as an evaluation tool by successfully being used to distinguish between two games receiving high and low scores in professional reviews, and was used to determine why one game succeeded and the other did not (Sweetser and Wyeth 2005). In this research, the elements of GameFlow will be used to compare playthroughs of a game that manipulate different variables that change the game's responsiveness in an attempt to compare player's enjoyment of the different playthroughs.

2.2 Responsiveness in Games

As established, flow has been used in games to model an ideal balance between challenge and skills that results in enjoyment, whereby anxiety or boredom become present when they become out of balance. Poor game responsiveness impacts this system as an additional challenge. In contrast to typical challenges in games where challenge elements are deliberately designed for the player's enjoyment, poor responsiveness hinders the player's ability to interact with the game, such as by reducing their ability to provide meaningful input to the game or by having reduced ability to receive useful feedback from the game. Whereas deliberately designed challenges are often built with the player's ability to overcome them in mind, players may not have the skills or desire to adapt to the challenge introduced by poor game responsiveness.

This research attempts to explore relationships between player enjoyment and game responsiveness, relationships that have not been covered by modern games research to a large degree. The research goal is supported by limited existing work: a paper by Jörg, Normoyle, and Safonova (2012) that examines the connection between input latency and player performance and satisfaction, and a paper by Claypool and Claypool (2007) that illustrates the importance of adequate frame rate for good player performance in a first-person shooter. This research builds upon the work Jörg, Normoyle, and Safonova (2012) by using various levels of input latency as opposed to a single value. The work by Claypool and Claypool (2007) is also expanded on by evaluating players' satisfaction with low-frame rate games.

Two variables that impact game responsiveness are investigated in this research. Input latency, the time between a player entering an input and the input's effect in the game, is tested as a variable that affects the game's responsiveness in terms of receiving input. Frame rate, the frequency of screen updates measured in frames per second (FPS), is tested as a variable that affects the game's responsiveness in terms of delivering output. By modifying these variables to change a game's responsiveness, it is expected that the less responsive game will feel slower and more sluggish, and thus will be less enjoyable to play than the more responsive game. Players will be asked which game they feel more strongly supports each of the relevant elements of the GameFlow. The particular application used for this research does not involve social elements, so the Social Interaction element cannot be tested directly.

2.2.1 Input Latency

It is a reasonable expectation of modern games to be responsive. Latency of all kinds has been an obstacle for quality real-time gaming experiences. Perhaps most prominently, multiplayer games played over a network must solve the challenge of reducing network latency for smooth game experiences. In networked games, sources indicate that delays greater than 100ms impact user enjoyment (Beznosyk et al. 2011) although results are conflicting with regards to decreases in performance due to network latency. Work by Dick, Wellnitz, and Wolf (2005) notes that the highest performances on average in their experiment were achieved using the greatest of four delays used in their study (500ms), while Beznosyk et al. (2011) identify performance decreases at over 100ms of delay.

The impact of network latency on player performance has also been shown to vary based on the perspective that the player plays from in the game (Claypool and Claypool 2006). A game where the player plays from an omnipresent perspective, such as in a real-time strategy or simulation game, is resilient to high levels of network latency. Games where a player controls an in-game avatar from a third-person perspective are more susceptible to the effects of latency, and games played from a first-person perspective are highly sensitive (Claypool and Claypool 2006). These differences in latency sensitivity may be useful for developers to use as guidelines to maximise players' performance potential when networking latency is a concern. They also suggest that for games played from omnipresent and third-person perspectives, the need to fix poor responsiveness issues is less crucial than for those played from a first person perspective.

Among the solutions to mitigate network latency was the lockstep model which kept client states in a peer-to-peer configuration in sync by registering client inputs only after all other player inputs had also been received. This introduced input latency, producing a far inferior game experience compared to games that responded immediately using client-side prediction (Bonham et al. 2000). Even in offline gaming environments, high levels of input latency are a concern (West 2008) demonstrating that input latency can come from sources other than network connections, including the available processing power of the hardware and added latency from display devices (DisplayLag 2014).

Poor input latency has been shown to negatively affect players' performance and game experience, with the detrimental effect of the latency being greater during more difficult challenges (Jörg, Normoyle, and Safonova 2012). Players are able to adapt to input delays after a few minutes of playing (Jörg, Normoyle, and Safonova 2012). No research was found supporting the notion that increased input latency is a desired characteristic in games.

An article by Neversoft co-founder Mick West (2008) explored input latencies on console games. He suggested that games with frame rates of 60 FPS typically have an excellent input response time of 66ms and games running at 30 FPS have between 133ms and 166ms. Furthermore, he suggests that 200ms or more is an unacceptable input response time (West 2008). West's limited explanation of arriving at these values make his suggestions seem highly subjective, but Jörg, Normoyle, and Safonova (2012) determined that 150ms provided a noticeable yet mostly tolerable input response time. This supports West's recommendations as being reasonable.

2.2.2 Frame Rate

Frame rate, the number of screen refreshes per second, is important not only for providing a satisfying visual experience, but also for delivering visual feedback to the player. Modern games are typically capable of running at 60 FPS but frame rates of 30 FPS have long been acceptable for game releases, especially those for console platforms (Leadbetter 2014). At half the rate of 60 FPS, motion blur is often added to games running at 30 FPS to smooth the game’s visual presentation (Leadbetter 2014).

To the researcher’s knowledge, no work has explored the connection between player satisfaction and game frame rate, although players have certainly criticised poor frame rates in games, such as at the launch of Assassin’s Creed: Unity (Bierton 2014). Research by Claypool and Claypool (2007) has determined that, in general, first-person shooter games that require precise actions such as shooting are greatly impacted by lower frame rates. In these same games, lower precision and response requirements such as movement are not as deeply impacted. It is reasonable to expect that as a player’s performance drops due to reduced frame rate, their satisfaction with their performance and the game will also be lower.

2.3 GameFlow and Changes in Responsiveness

By using the elements of GameFlow and deciding on variables for changing game responsiveness, tests can be run between games that differ only in their responsiveness. By surveying players on their experiences playing a responsive and less responsive game, it can be determined what elements of GameFlow are affected by reduction in responsiveness.

Although GameFlow has eight testable elements, the Social Interaction element is not used in this research because the game does not involve a social element. Of the remaining elements, it is expected that changes in game responsiveness will impact all but the Clear Goals element, leaving expected changes in the elements Concentration, Challenge, Player Skills, Control, Feedback, and Immersion:

- Lowered responsiveness is expected to make it more difficult for the player to concentrate on the game.
- Lowered responsiveness is expected to provide additional challenge for the player that they may lack the skills or desire to overcome.
- Lowered responsiveness is expected to interfere with the player's ability to develop and master the skills they will use in the game.
- Increased input latency is expected to give the player a worse sense of control over their actions.
- Increased input latency and lowered frame rate are expected to give the player weaker feedback on their actions.
- Increased input latency and lowered frame rate are expected to challenge the player's ability to become immersed in the game.

3 Methodology

3.1 Application Design

To maintain focus on the research objectives, the game was to be built purely as a means for obtaining data from participants with little focus given to other factors such as designing a memorable game experience or monetisation, among many other possible considerations.

A simple platformer game was developed for the experiment. In the game, the player is tasked with walking through several areas obtaining collectibles. Although simple, the game provided the player with a goal to concentrate on and a simple challenge. The game is demonstrated in Figure 3.1.

Figure 3.1: The game developed for the experiment, with the game's controls displayed at the bottom of the screen.

The choice to make a platformer for the research was made in order to make a game of an accessible genre. The popularity of platformer games such as the Super Mario Bros. series indicate that simple platformer games are easy for many participants to pick up and learn to play with little instruction. The work by Claypool and Claypool (2006) describing first-person games being most susceptible to latency was not found until late in the application's development. If this literature had been found sooner, a game played from a first person perspective may have been a more appropriate choice for this research where latency susceptibility is of importance.

In the game, the player walks across five short, unique areas where they are tasked with collecting floating cherries while performing simple platforming tasks such as climbing onto terrain and jumping across gaps. Each area has a different layout of platforms and cherries and is of similar difficulty to each other area. To create a scenario where a responsive and less responsive game can be play and compared, the player plays the game once with no modified responsiveness, and several times using varying levels of input latency and various frame rates. For the player's convenience, the game's controls are displayed at the bottom of the screen at all times.

Over the course of the game, the player experiences increases in input latency and decreases in frame rate separately, then together. These variables are initially tested independently to obtain an approximate indication of the player's susceptibility to changes in these variables independent of one another.

3.1.1 Game Walkthrough

To familiarise the player with the game, they are greeted with instructions for the game as seen in Figure 3.2. The instructions emphasise that the player should pay attention to how the game feels to them, that the game is not competitive, and that they will be periodically completing parts of the accompanying questionnaire. The choice to make the player know that the game is not competitive was made to reduce any possible gender bias in the results (Greenberg et al. 2010). Originally, the player was intended to destroy targets, but this was changed to collecting cherries instead as a non-violent alternative.

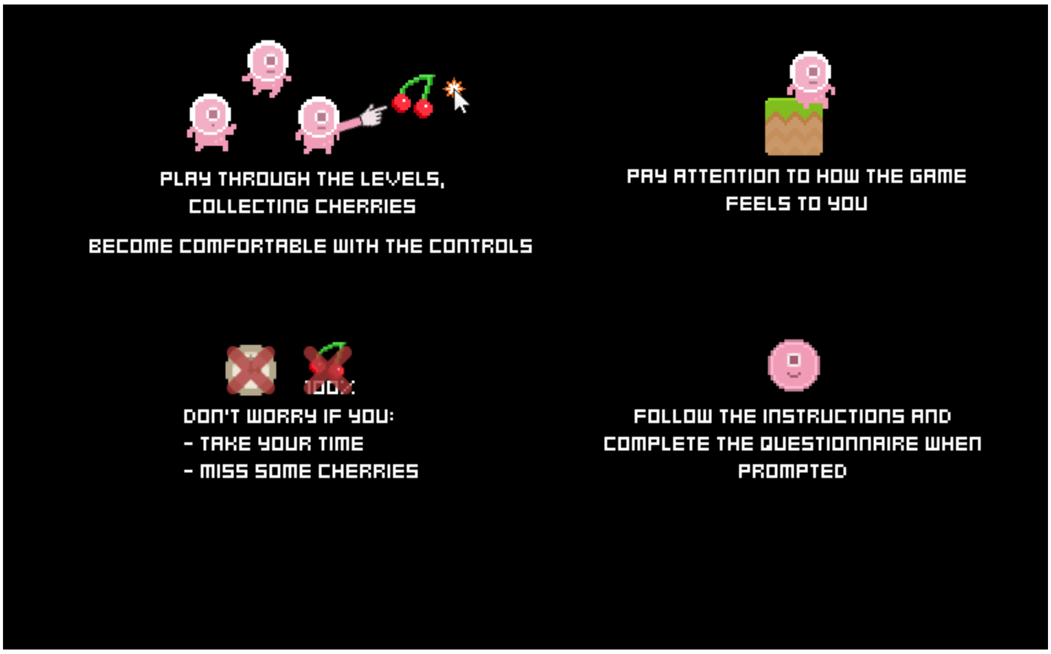

Figure 3.2: Game instructions displayed to players when beginning the game.

The player proceeds to play through the game's five areas until they reach an endpoint that displays a message, instructing the player to complete the Baseline Survey section of the questionnaire to determine how they felt about the game that they just played through. At this stage of the experiment, the game runs at 60 FPS with no additional input latency in order to determine how the player feels about the game with no changes to the input latency or frame rate. After completing the Baseline Survey, the player is instructed to continue playing through the game.

The player is then asked to play through the same five areas, paying attention to how the game feels to them. As they continue the game, the player character experiences increasing levels of input latency on their actions. The first area has no added input latency, and every area following the first adds 50ms of additional latency, up to a maximum of

200ms in the fifth area. An informal experiment by West (2008) determined that 200ms of latency was very noticeable and made player movements feel sluggish. 150ms has been identified as being noticeable while keeping the game playable (Jörg, Normoyle, and Safonova 2012). By using a variety of latency values, a sizable window for players to notice changes in the game feel is provided. The finding that immersion in games is subjective (Jennett et al. 2008) suggests that susceptibility to input latency may also be subjective, so this possibility is supported for various levels of input latency.

Once the player indicates that they have noticed a difference in how the game feels to them, they continue to the next section of the game where they are given the same instructions to pay attention to how the game feels to them and to indicate when they notice a change. During this third playthrough, the player experiences no additional input latency, but the game’s frame rate decreases over the span of the five areas. Beginning with the first area that runs at 60 FPS, each subsequent area decreases in frame rate by 12 FPS, reaching a minimum of 12 FPS in the fifth area. No particular criteria other than intuition were used for determining a suitable minimum frame rate that should be noticeable to most players.

The player is asked to play through the game a fourth and final time, again being asked to pay attention to how the game feels to them. During this final playthrough, the player experiences both additional input latency and reduced frame rate simultaneously. The fifth area in this playthrough has the game run using the input latency and frame rate that the player had indicated changed the game feel in the previous two playthroughs. From the fifth area, each preceding area runs using 16ms second less input latency and 3 FPS faster frame rate. This final section was included as an experiment to see if there are any indications that a combination of increased input latency and lowered frame rate have a compounding effect on how noticeable reduced responsiveness is for the player.

After playing through the final areas of the game, the player is provided with a code to be entered into the questionnaire. The code primarily contains data relating to the input latencies or frame rates used when the player noticed a change in how the game felt to them. The code contains five positive integers, representing in order:

- The input latency that resulted in a change in game feel, independent of frame rate.
- The frame rate that resulted in a change in game feel, independent of input latency.
- The input latency that resulted in a change in game feel when combined with reduced frame rate.
- The frame rate that resulted in a change in game feel when combined with increased input latency.
- The average update speed of the game in frames per second.

Rather than have the player enter these values in the questionnaire after the appropriate sections, they are provided at the end of the game in bulk. This way, the player does not have to repeatedly alternate between playing the game and entering values in the questionnaire, which they may find confusing. The fifth and final value provides an indication of how well the game performed on the player’s computer. This is necessary to know because the method used to modify the game’s frame rate requires a sufficiently high update rate. If the value is not above 300, it is possible that the frame rate could not be artificially manipulated properly and the player’s questionnaire answers would be inaccurate.

3.1.2 Implementation

The application was developed using the Unity game engine which allowed for rapid prototyping and easy implementation of new features. Unity also allowed the application to be easily deployed on Windows, Mac, and Linux platforms so potential test players would not be deterred from not being able to play on their preferred operating system. While Unity also allows projects to be played in-browser using the Unity Web

Player browser plug-in, the web versions are not playable at high frame rates for performance reasons (Unity Answers 2011). Because the method for modifying the perceived frame rate requires a high operating frame rate, the web versions of the game could not accurately run at the desired frame rates, and thus and were not released for players to use.

3.1.2.1 Input Latency Modification

To artificially modify the input latency in the game, all inputs that would cause the player character to react in some way (i.e walking, jumping, or grabbing) were wrapped by a coroutine method that would wait a specified time before running.

3.1.2.2 Frame Rate Modification

Although Unity has built-in functionality for changing the game's frame rate by modifying the global value Application.targetFrameRate (Unity Documentation 2014a), early tests indicated that using this method to modify frame rate was an insufficient solution for this research when the amount of input latency used would also need to be changed.

The problem is illustrated in Figure 3.3 and resides in the method that Unity uses for processing input. For each key or button that is pressed by the player, a flag is set inside Unity indicating that that input was provided. At the beginning of every frame, all marked input flags are processed and cleared (Unity Documentation 2014b). The issue with this process is that it is affected by the value of Application.targetFrameRate. As an example, setting the frame rate to 10 FPS using this method reduces the input sampling rate to 10 Hz. When using no additional input latency, the player would still feel lag on their inputs due to their inputs being processed once every .1s. The player could experience up to .1s of unintended additional latency in this case, depending on when the player provided their input in between frames.

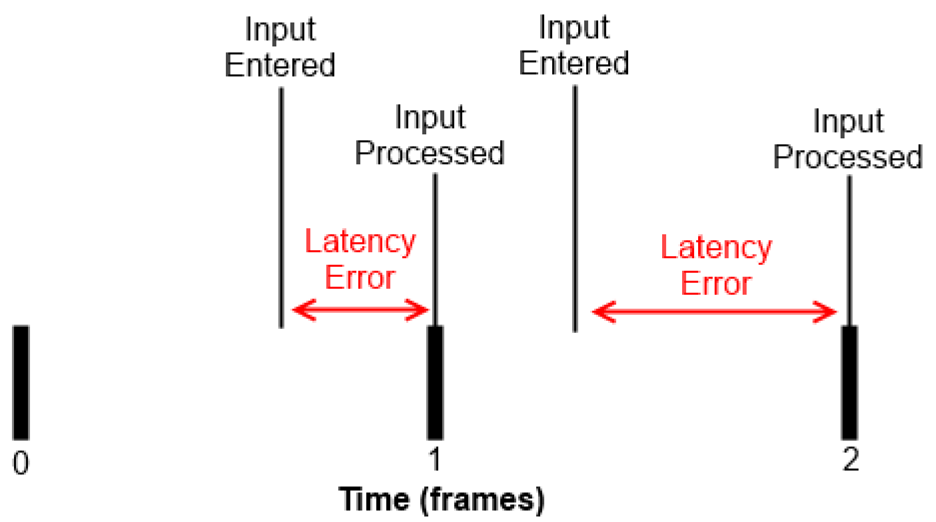

Figure 3.3: Demonstration of erroneous added input latency caused by lowering application frame rate.

The solution to this problem involved not modifying Application.targetFrameRate. This approach would allow inputs to be sampled at full speed. Although there would always be some additional latency regardless of frame rate, using the highest possible application frame rate ensures that the additional latency is negligible. An alternate way of modifying the player's perceived frame rate would be required which was achieved by rendering the game scene to texture, presenting it to the player, and updating it at a specified interval using Unity's InvokeRepeating method (Unity Documentation 2014c).

Testing revealed that using this method of changing the player's perceived frame rate functioned poorly when the game ran on slower hardware and ran much smoother on more modern hardware. For this reason, it became necessary to know how well game ran on players' computers. If the frame rate was low, the players' answers would be treated with caution since the frame rate modifications would not be accurate and the players would not be able to provide accurate answers to many questionnaire items. The hardware used to develop the game was capable of running the game at 300 FPS with no issues. Since this performance value was achieved using a 2011 laptop with no discrete graphics hardware, this was used as a rough performance minimum for users. Results that were achieved at frame rates below this value would be treated with caution. One test indicated that that frame rates of below 70 FPS produced unacceptable results.

3.1.3 Other Sources of Latency

In addition to the latency provided by the game, other sources of latency, such as display devices, also need to be considered. Due to the application running on players' personal computers which are likely to collectively use many different display devices, it is not feasible to be able to calculate the display latency added by these devices individually. However, online databases can be used to estimate that the amount of additional latency added by display devices is typically 10ms to 50ms (DisplayLag 2014).

3.2 Questionnaire Design

This research required players to complete a questionnaire that accompanied the game in order to determine how they perceived the game with good responsiveness compared to the game with poor responsiveness. The questionnaire questions can be found in Appendix A.

3.2.1 Demographical Survey

The player begins the experiment by completing a brief section of the questionnaire before beginning the game. The questions cover basic demographics such as the player's gender identity, age, level of education, and gaming experience. While this research doesn't aim to find correlations between this data and player enjoyment, it is included in the event that it has some significance.

3.2.2 Game Surveys

For ease of development, an existing, validated questionnaire was sought so it could be adapted for this experiment.

The questionnaire that was chosen is a modified version of the System Usability Survey (SUS), replacing the word “system” with “game”. The SUS is a technology-agnostic survey that is used to determine the usability of a system and can also be used to compare the usability of similar systems (Brooke 1996). The SUS is a series of ten questions that ask the user to answer each question on a 5-point Likert scale, ranging from Strongly Disagree to Strongly Agree. The values obtained from the survey are used to calculate a usability score out of 100, where 68 is an average score (Brooke 2013).

This modified SUS is included in the questionnaire twice: once for the playthrough with no modified input latency and frame rate (the Baseline Survey), and once for the playthrough with modified input latency and frame rate (the Modified Game Feel Survey). By asking the player to rate the usability of each game, the results of the survey can be expected to indicate that one game has higher usability than the other. It is important to note, however, that usability is not necessarily an indication of other properties of the game, such as enjoyability or overall quality.

An alternative questionnaire that was considered was the Game Engagement Questionnaire (GEQ), an attempt to quantify players’ engagement with games, and a questionnaire that was designed specifically for games (Brockmyer et al. 2009). The questions in the GEQ cover topics more related to flow than the modified SUS, but proper answers to the questions would require a greater amount of time spent with the games in this experiment. Items in the GEQ such as “Time seems to stand still or stop” and “I can’t tell I’m getting tired” are not able to be answered accurately within the approximate 15 minute duration of this experiment and are more suited for games with longer periods of exposure.

Following the completion of the Modified Game Feel Survey, the player is asked to enter the game code provided to them at the end of the game, and they are asked to describe how the game felt differently to them compared to when they completed the Baseline Survey.

3.2.3 Game Comparisons Using GameFlow Elements

The final part of the questionnaire asks the player to specify if either playthrough better supported each of the seven GameFlow elements being examined, or if there was no difference. The player is asked a question about all GameFlow elements except for the Social Interaction element. This is because the game does not contain a social element. This element could be tested in a similar experiment containing a social aspect, but would require a greater number of participants involved. The question used for each element is based on the element criteria developed by Sweetser and Wyeth (2005).

The player also has the opportunity to leave comments about the game, the questionnaire, or the research in general.

3.3 Modifications

While the majority of the results consisted of expected results, a couple of results obtained from the first wave of participants contained unexpected values. Specifically, some latency and frame rate values that players indicated presented a change in game feel had not yet been modified.

To remedy this, some instruction text in the game was modified. Originally, the player was asked to indicate when they noticed a change in how the game felt to them. While vague, it was considered important to not reveal what variable was being modified in the player's current playthrough in order to avoid the placebo effect influencing the player. The fact that some players noticed a change in the game's responsiveness when in fact there was none at the time indicated that it would be helpful if the player knew that a) the first section of the second and third playthroughs were intended to act as a point of reference for the player, and b) all sections after that point were valid sections in which the game's responsiveness had actually been modified. To accomplish these tasks, the instruction text preceding the second and third playthroughs included this information.

An additional measure to produce more reliable results was introduced into the questionnaire. After players had completed the Modified Game Feel Survey, they were asked to describe how the game felt differently to them compared to when the game's responsiveness was not modified. By examining the comments left by players, it would be easier to assess their interpretation of the concept of "game feel" and to identify possible cases where the player had a different, unexpected interpretation of the phrase.

After making these changes, the majority of new players identified that the responsiveness of the game had changed and no players indicated that they noticed a change in game feel when the game's responsiveness had not yet been modified.

A number of early participants also commented on a player control issue where the player character would stick to a wall if they jumped up against it. This issue was fixed to give the player better control when jumping up against walls.

4 Results and Discussion

Participants for the experiment were invited to take part through links posted to the Abertay Game Development Society Facebook page as well as both the Gaming and Gamedev boards of the social news website Reddit.

In total, 26 players completed the game and the questionnaire. Due to the players' ability to perform the experiment remotely on their own hardware, some results were submitted using hardware that was not powerful enough for this particular application. This resulted in the game not being able to properly control the frame rate at any time. As a result, these results were not included in the analysis.

The remaining results were provided by 19 respondents (15 male, 3 female, 1 non-binary). In general, participants played games on a wide range of hardware; Windows, Playstation 4, Android phones, Xbox 360, and Playstation 3 were among the more popular platforms with Windows being extremely popular. Windows was also shown to be the favourite platform of the vast majority of participants. Over half of the participants indicated that they had completed at least one form of post-secondary education. There did not appear to be any correlations between demographics data and any experiment results.

4.1 Impact of Responsiveness on Game Usability

Using the answers obtained in the Baseline Survey and Modified Game Feel Survey, a usability score was calculated for each game completed by each player. These scores are displayed in Figure 4.1.

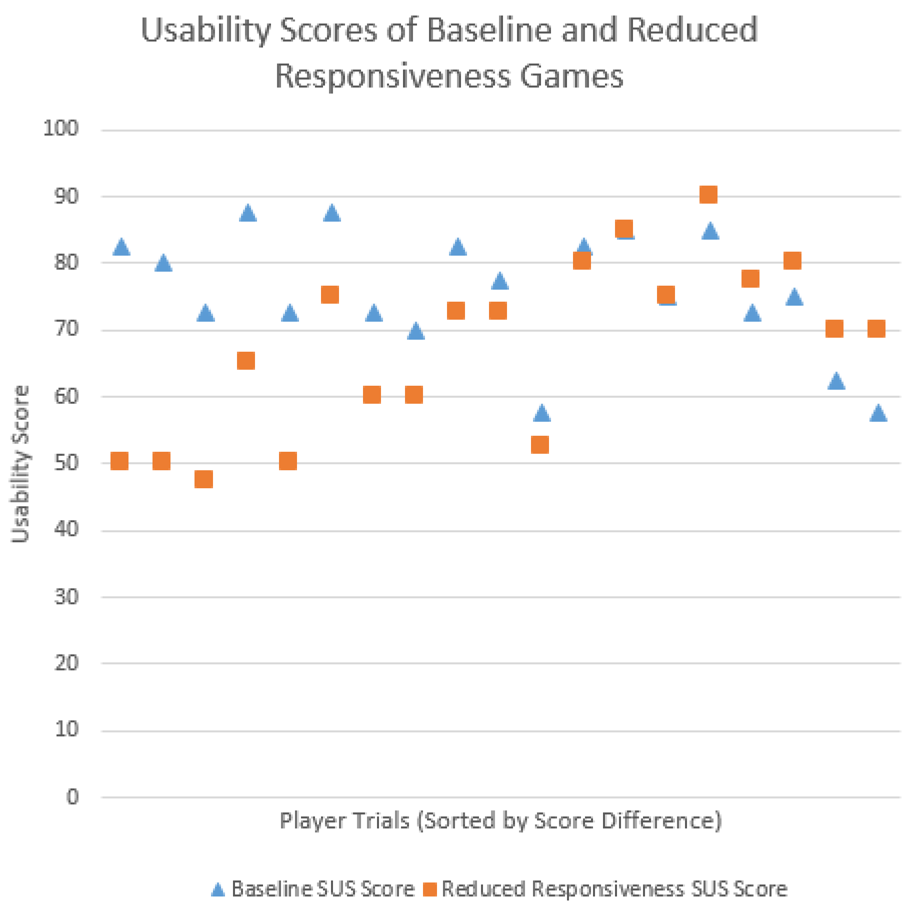

Figure 4.1: Usability scores of Baseline and Reduced Responsiveness games.

Overall, the Baseline game received higher scores than the Reduced Responsiveness game. The Baseline game scores had a median score of 75 with a mean of 75.7 while the Reduced Responsiveness game scores had a median of 70 with a mean of 67.7.

When the trials are sorted by the difference between the Baseline score and the Reduced Responsiveness scores, as in Figure 4.1, there is a clear indication that the majority of players thought that the Reduced Responsiveness game was less usable, and that the overall difference in score was greater for players indicating that the Baseline game was more usable.

It was not expected that just over 25% of participants would think that a game with reduced responsiveness would be preferable to an identical game playing at maximum speed. This could be an indication that some players simply do find games to be more usable with a small reduction in responsiveness. Because this game was played from a third-person perspective, the impact of the reduced responsiveness would be less than for a first-person perspective and more than for an omnipresent perspective (Claypool and Claypool 2006). For a similar experiment played from one of the other two perspectives, the differences in game usability could have a different impact. Players may not see a difference in usability for two games played from an omnipresent perspective, and players may see a clear and distinct difference if playing from a first-person perspective.

4.2 Impact of Responsiveness on GameFlow Elements

Players' responses to questions about which game better supported seven of the eight GameFlow elements are displayed in Figure 4.2.

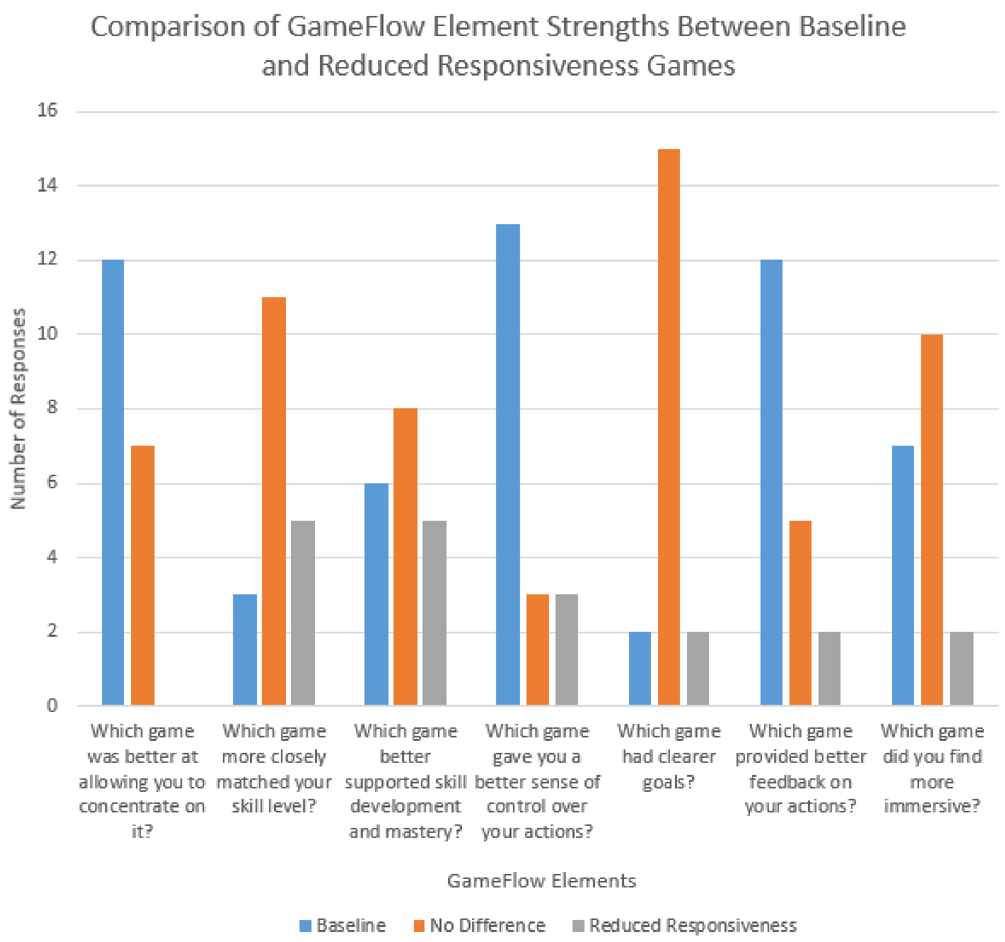

Figure 4.2: Comparison of GameFlow element strengths between Baseline and Reduced Responsiveness games.

It was hypothesised that the Reduced Responsiveness game would support all tested GameFlow elements worse with the exception of the Clear Goals element, which would not be affected.

Most players indicated that the Baseline game supported the Concentration element better, although a significant number of players also felt there was no difference between the games.

The results of the Challenge element question showed that most players didn’t feel that either game matched their skill level better than the other, with a slight skew toward preferring the less responsive game. The results of this question were likely highly dependent on the skill level of the player. The Baseline game was a very low difficulty game (with no challenging obstacles to overcome and no way to lose) and the Reduced Responsiveness game may have been slightly more challenging for players. It seems likely, however, that this difference in difficulty was not a major factor for most players who felt like both games had similar difficulty relative to their skill level.

The responses for the Player Skills element were fairly evenly distributed. Players’ choices for this question may indicate a preference for different types of environments that players prefer for developing their skills in a game. For example, players preferring the Baseline game may see more value in being able to build their skills in a highly responsive environment. On the other hand, players preferring the Reduced Responsiveness game may see the process of adapting to the game’s poor responsiveness (Jörg, Normoyle, and Safonova 2012) as a skill in itself.

Players felt that the Control element was much stronger for the Baseline game than the Responsiveness. This result was expected since the added input latency of the Reduced Responsiveness game was expected to interfere with players’ sense of control over their character.

The Clear Goals element was largely unaffected by a difference in responsiveness, as predicted.

The majority of players felt that the Baseline game provided better feedback on their actions. A small number of players noted that they felt there was no difference between the two games. This could be interpreted as the player not noticing a change in the game’s responsiveness specifically, but still noticing a change in how the game felt in a manner that was subtle enough to not affect their sense of the game’s feedback changing.

Most players indicated that the Immersion element was not greatly affected by a change in game responsiveness. However, the remaining responses skewed largely in favour of the Baseline game being much more immersive than the Reduced Responsiveness game. While it is possible that game responsiveness does not affect a game's quality of being immersive, one interpretation of this data comes due to the fact that the players may have not had enough time with each game to become immersed. It is possible that a similar experiment where players had the opportunity to spend more time with a game would yield more definitive results for the Immersion element.

4.3 Player Susceptibility to Changes in Responsiveness

Examining the values of the Game Code provided to players at the end of the game indicated the amount of input latency and the frame rate in use when they noticed a change in how the game felt to them.

The various input latencies that caused changes in game feel with a frame rate of 60 FPS are displayed in Figure 4.3. Interestingly, these results have peaks at both 100ms and 200ms of additional latency. Taking into account the fact that 200ms was the maximum allowed amount of input latency (when tested independently of frame rate) used in the game, it is possible that some players who noticed a change at 200ms only did so because they reached the fifth and final level and could not continue experiencing greater levels of latency, being forced to choose 200ms to continue with the experiment.

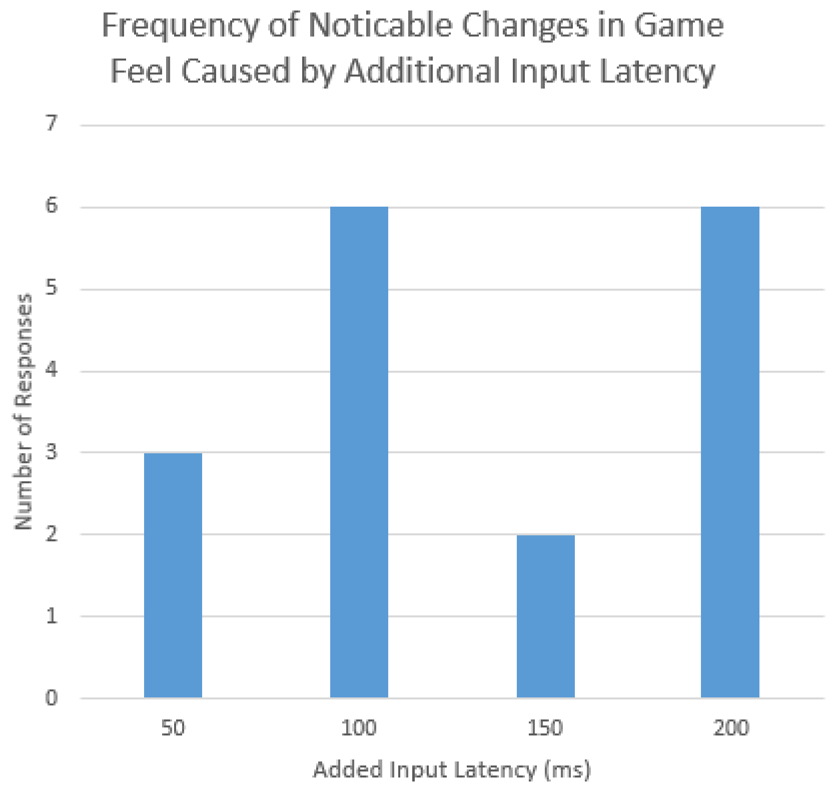

Figure 4.3: Frequency of noticeable changes in game feel caused by additional input latency.

Because the experiment was available online for players to complete, the amount of additional latency from each player's display device could not be accurately determined. However, many display devices have 10ms to 50ms of latency (DisplayLag 2014), providing a very loose estimate of the display latency added from players' hardware. Assuming display latency of 50ms (for simplicity's sake), the greatest number of players noticed changes in game feel with 150ms and 250ms of total latency. The result of 150ms is in line with Jörg, Normoyle, and Safonova's (2012) finding that 150ms of latency was noticeable yet mostly tolerable. For players experiencing 250ms of total latency, it is possible that they were not as receptive to changes in input latency as other players were. It may also be a possibility that changes in input latency had little impact in causing changes in game feel for those players, and those responses only exist because they needed to give a response in order to continue with the game. These speculations could be explored in a similar experiment with more granular increases in input latency.

The frame rates at which the players noticed a change in game feel (with no additional latency) are displayed in Figure 4.4. Most players noticed a change in game feel when the game's apparent frame rate dropped to 12 FPS with fewer players noticing changes at 36 FPS and 24 FPS. Since 12 FPS was the lowest allowed frame rate for this test, again, it is possible that some players only chose this value because they needed to choose a value to continue with the game. Player's susceptibility to frame rate could be explored in a similar experiment with more granular decreases in frame rate.

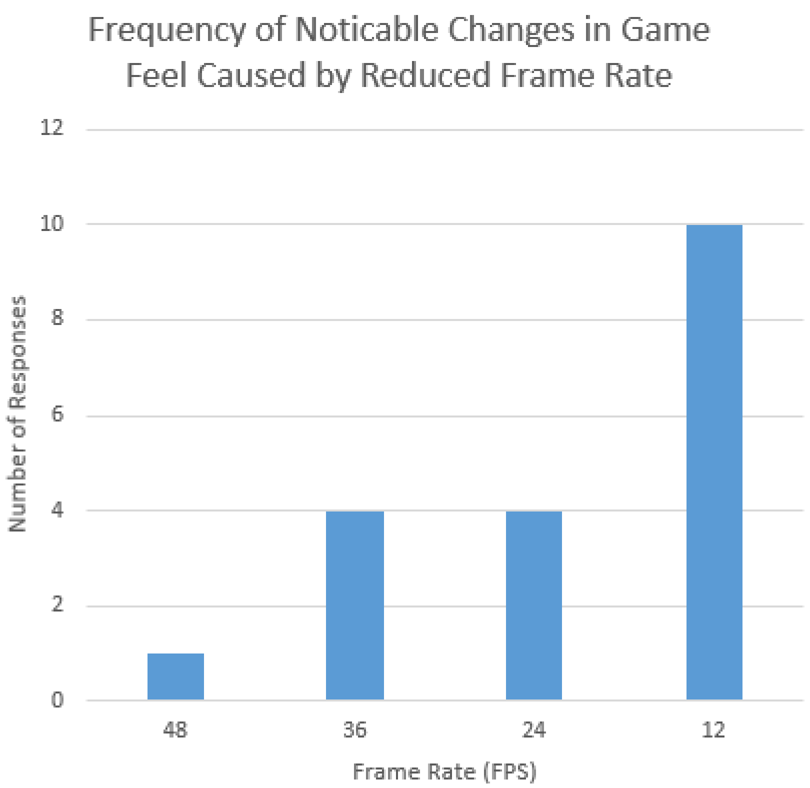

Figure 4.4: Frequency of noticeable changes in game feel caused by reduced frame rate.

The intention of the players' final playthrough of the game was to explore possible compounding effects of combining sources of poor responsiveness. This final section would combine the values for the additional input latency and reduced frame rate values that caused changes in game feel together and set the least responsive area to apply those values. Unfortunately due to a software bug, the player started their final playthrough using these values. While this error did not produce any meaningful results about compounding effects of combining sources of poor responsiveness, all but one player noticed a change in game feel within the first two areas of their final playthrough. This can be interpreted as validating the previous results as poor responsiveness being the cause of the changes in game feel.

5 Conclusion and Future Work

This research conducted an investigation into the effects of reduced game responsiveness on game usability and effect on flow. By having players compare games that differ in their responsiveness and answer a modified System Usability Survey about each game, the effect of the change in responsiveness on the game's usability can be measured. Additionally, players indicated their susceptibility to changes in game feel caused independently by changes in input latency and frame rate by indicating the first instance that they noticed a consistent change in game feel.

To measure the effects of responsiveness on flow, players were asked to answer questions concerning the games on the elements of a model of flow called GameFlow. These questions asked the player to indicate which game was stronger or if there was no difference for seven of the eight elements of GameFlow: Concentration, Challenge, Player Skills, Control, Clear Goals, Feedback, and Immersion. It was hypothesised that these elements, with the exception of Clear Goals, would be weaker in a game with reduced responsiveness compared to the same game with full responsiveness. The Social Interaction element was not tested because the scope of the project was not large enough to be able to meaningfully engage participants in a social manner.

The results of 19 player responses suggested that a reduction in responsiveness resulted in a decrease in usability compared to a game without modified responsiveness. Not all players agreed that reduced responsiveness made the game less usable. In fact, a number of players indicated that the change in responsiveness actually increased the usability of the game. Future work should make efforts to verify if some players actually find games with reduced responsiveness to be more usable or if these findings were simply anomalies.

Player responses suggest that a fully responsive game is preferable to a game with reduced responsiveness for the elements of Concentration, Control, and Feedback. The players generally saw no difference for the Challenge and Clear Goals elements, and they indicated a slight preference for the more responsive game for the Immersion element. The results for the Player Skills were fairly evenly distributed. This could be an indication that some players have different environmental preferences for developing skills. Some players may prefer a game where they have full control over their actions as in the Baseline game, and some may prefer a game with an immediate obstacle to overcome as in the Reduced Responsiveness game. In any case, the impact of responsiveness can be further explored by more thoroughly examining each of the GameFlow elements with a longer questionnaire that asks a broader range of questions about each element, based on the criteria developed by Sweetser and Wyeth (2005) in order to better understand the effects of responsiveness on each element. Future projects with larger scope will also want to consider involving a social aspect to their game in order to evaluate the impact of responsiveness on the Social Interaction element. Furthermore, other impacts of lowered game responsiveness can be explored, including being a source of possible frustration in players.

For future work, it is recommended to compare the results of this experiment, obtained by playing a game viewed from a third-person perspective, with a similar experiment where the game is played from a first-person or omnipresent perspective (Claypool and Claypool 2006).

Players indicated that the levels of input latency that caused a change in game feel were most common at 100ms and 200ms (approximately 150ms and 250ms total latency when accounting for display latency), although players noticed changes at 50ms and 150ms (approximately 100ms and 200ms with display latency) as well. Changes to game feel that were caused by reduced frame rate occurred most often at 12 FPS, with most remaining players noticing changes at 24 FPS and 36 FPS. For researchers wishing to explore the relationship between changes in game feel and game responsiveness it greater detail, it is recommended that changes to input latency and frame rate be made in smaller steps than 50ms and 12 FPS, respectively, to obtain more granular observations.

While the Unity game engine allowed for rapid prototyping and easy deployment of the game used in the experiment, the limitation of being unable to modify the game's frame rate without also introducing additional and unintended input latency proved to be an obstacle. While the workaround to this issue did provide a solution, the solution required the game to run at a sufficiently high frame rate on players' computers in order for the frame rate to be modified properly. Any future research where the game's frame rate needs to be modified without the introduction of unintended extra input latency will want to consider developing a custom engine to give the developers more control over the inner workings of their game. Alternatively, players could play the game at a common physical location to remove any impact that different hardware configurations would have on the results. This may result in lower participation numbers, so this approach may not be suitable unless an appropriate level of participation is expected.

In conclusion, the results of this research suggest that poor responsiveness in games negatively impacts usability and is detrimental to player concentration, control, feedback, and immersion. Further work should investigate these claims in greater detail to verify them and to quantify the degree of the impact caused by a loss of responsiveness.

Appendices

Appendix A: Research Questionnaire

Respondents anonymously completed and submitted the following questionnaire online via Google Forms.

Section 1: Introduction

What gender do you identify as?

One of:

- Male
- Female
- Rather not say
- Other (user-specified)

What is your age?

How many hours per week do you typically play video games?

What video game platforms do you normally play on?

Any number of:

- Windows
- Mac
- Linux
- Xbox One
- Playstation 4
- Wii U
- Android phones
- Android tablets
- iPhone
- iPad
- Xbox 360

- Playstation 3
- Wii
- Other (user specified)

What game platform do you play on most often?

One of:

- Windows
- Mac
- Linux
- Xbox One
- Playstation 4
- Wii U
- Android phones
- Android tablets
- iPhone
- iPad
- Xbox 360
- Playstation 3
- Wii
- Other (user specified)

What levels of education have you COMPLETED?

Any number of:

- Secondary school
- Associate/college degree
- Bachelor’s degree
- Master’s degree
- Doctorate degree
- Other (user specified)

End of Section 1: Introduction

Please leave this page open and begin the game. Follow the instructions and play until prompted to return to this questionnaire.

Section 2: Baseline Survey

Answer the next ten questions about how the game felt during the five areas you just played through.

Rated one out of [strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree]:

- I think that I would like to play this game frequently.
- I found the game unnecessarily complex.
- I thought the game was easy to play.
- I think that I would need the support of a technical person to be able to play this game.
- I found the various game mechanics to be well integrated.
- I thought there was too much inconsistency in this game.
- I would imagine that most people would learn to play this game very quickly.
- I found the game very awkward to play.
- I felt very confident playing the game.
- I needed to learn a lot of things before I could play the game.

End of Section 2: Baseline Survey

Please leave this page open and play the game through to the end. Follow the instructions and play until prompted to return to this questionnaire.

Modified Game Feel Survey

Answer the next ten questions about how the game felt during the last area you pressed P in.

Each answered as one out of [Strongly disagree, Somewhat disagree, Neither disagree nor agree, Somewhat agree, Strongly agree]:

- I think that I would like to play this game frequently.
- I found the game unnecessarily complex.
- I thought the game was easy to play.

- I think that I would need the support of a technical person to be able to play this game.
- I found the various game mechanics to be well integrated.
- I thought there was too much inconsistency in this game.
- I would imagine that most people would learn to play this game very quickly.
- I found the game very awkward to play.
- I felt very confident playing the game.
- I needed to learn a lot of things before I could play the game.

Enter your Game Code.

This is a code of five numbers that was provided to you at the end of the game. This code contains only information about what sections felt differently to you and how well the game performed on your computer.

Describe HOW the game felt differently to you here compared to the very first time you played.

Describe in as much detail as you can.

Section 4: Post-Game Survey

Answer the following questions about the game when you answered the Baseline Survey (the first set of ten questions) compared to when you answered the Modified Game Feel Survey (the second set of ten questions).

Each answered as one out of [Baseline, No difference, Modified Game Feel]:

- Which game was better at allowing you to concentrate on it?
- Which game more closely matched your skill level?
- Which game better supported skill development and mastery?
- Which game gave you a better sense of control over your actions?
- Which game had clearer goals?
- Which game provided better feedback on your actions?

- Which game did you find more immersive?

Do you have any comments to add about the game, the questionnaire, or the research in general?

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