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How Responsiveness Affects Players' Perception in Digital Games

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Digital games with realistic virtual characters have become very popular. The ability for players to promptly control their character is a crucial feature of these types of games, be it platform games, first-person shooters, or role-playing games. Controller latencies, meaning delays in the responsiveness of a player's character, for example due to extensive computations or to network latencies, can considerably reduce the player's enjoyment of a game. In this paper, we present a thorough analysis of the consequences of such delays on the player's experience across three parts of a game with different levels of difficulty. We investigate the effects of responsiveness on the player's enjoyment, performance, and perception of the game, as well as the player's adaptability to delays. We find that responsiveness is very important for the player as delays affect the player's enjoyment of the game as well as the player's performance. A quick responsiveness becomes essential for more challenging tasks.

Disciplines

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Comments

At the time of publication, author Alla Safonova was affiliated with Disney Research, Philadelphia. Currently, she is a faculty member at the School of Engineering and Applied Science at the University of Pennsylvania.

How Responsiveness Affects Players' Perception in Digital Games

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Abstract

Digital games with realistic virtual characters have become very popular. The ability for players to promptly control their character is a crucial feature of these types of games, be it platform games, first-person shooters, or role-playing games. Controller latencies, meaning delays in the responsiveness of a player's character, for example due to extensive computations or to network latencies, can considerably reduce the player's enjoyment of a game. In this paper, we present a thorough analysis of the consequences of such delays on the player's experience across three parts of a game with different levels of difficulty. We investigate the effects of responsiveness on the player's enjoyment, performance, and perception of the game, as well as the player's adaptability to delays. We find that responsiveness is very important for the player as delays affect the player's enjoyment of the game as well as the player's performance. A quick responsiveness becomes essential for more challenging tasks.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation; K.8.0 [Personal Computing]: General—Games

Keywords: virtual characters, digital games, responsiveness, controller latency, control lag

1 Introduction

How we experience a game depends on many factors: the type of game, the challenge, the task, design, and story, and of course on our own preferences. Many of the best selling digital games of the past years, such as Call of Duty: Black Ops, Madden NFL, or World of Warcraft, rely on player controlled characters [ESA 2011]. As character behaviors become more complex and online games become more popular, the consequences of controller latency and network delay becomes a large concern.

The responsiveness of a character is the amount of time between an input from the user or player and the associated response, which might be visual, auditive, or tactile. It is also called response lag, controller latency/lag, or input lag. Delays in the responsiveness of a character are common in games, for example, due to network latencies or to computations on motion transitions [McCann and Pollard 2007]. It has been shown repeatedly that people are very sensitive to temporal effects in animations or to small delays between different modalities [McDonnell et al. 2009; Carter et al. 2010]. Mania et al. show that head tracking latencies in virtual environments of about 15ms can already be detected by trained ob-

servers [Mania et al. 2004]. Jörg et al. demonstrate that a 0.5s delay in the finger motions of a virtual character can alter the interpretation of a whole scene. [Jörg et al. 2010]. The importance of timing holds true when controlling a virtual character. Even small delays might be noticed or can alter the game experience. In particular, slow responsiveness is a common topic amongst gamers [Leadbetter 2009]. Although researchers have investigated the effect of network delays, most previous studies focus on the question how much delay can be tolerated. In these studies, users are asked to compare different types of delays and to rate the playability of the game while their performance is measured.

In this paper, we thoroughly investigate the consequences of latencies in a setting where the user is not conscious about their presence and users are not given a side-by-side comparison of different delays or controllers. In addition to measuring the user's performance, we evaluate the effect of delay on the perceived ease of control, player enjoyment, and player frustration, which are key elements of the gaming experience. We also ask the question of whether delays change the players' perception of the game and the character. We consider two game settings with different levels of challenge (see Figure 1 for an example). Finally, we investigate if a user can learn to handle delays.

To answer these questions, we developed two game-like levels with a player-controlled virtual character animated with state-of-the art motion captured animations. We measured the players' performance during play and asked questions after each level and at the end of the game. Our findings suggest that a slow responsiveness affects the player's enjoyment of a game even when they are not aware of the delay, but this becomes most important when presented a challenging task. Furthermore, players can learn to adapt to a delay and adjust the way they control a character.
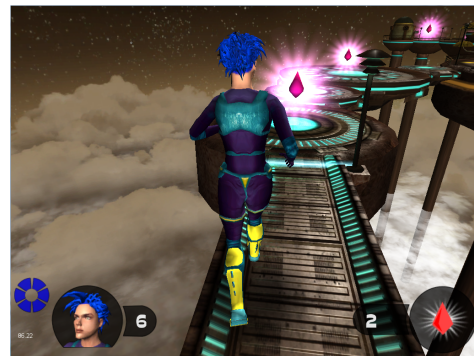
Figure 1: *Screenshot from Level 2 of our game: The player steers a virtual character through a futuristic world, crossing narrow bridges, jumping from platform to platform, collecting gems, and avoiding stationary and moving laser beams.*

2 Related Work

Studies investigating the effect of the responsiveness on the player's experience mostly examine the consequences of network latency. Their results show that the amount of tolerable latency highly varies depending on the type of game [Claypool and Claypool 2006]. For

example, the requirements of a prompt response to user input are less strict for standard board games played online or for realtime strategy games [Sheldon et al. 2003]. A faster response is required for games where the player directly controls an object or avatar and has to react quickly to the situation in the game. First person shooters, sports games, jump-and-runs or racing games are examples where delays might destroy the game experience. In this study, we focus on the perceptual consequences of delay in the control of an avatar.

Several studies assess the effect of network limitations on specific games, such as Everquest 2 [Fritsch et al. 2005], Quake IV [Wattimena et al. 2006], or Little Big Planet [Beznosyk et al. 2011]. Dick et al. [2005] evaluate the amount of tolerable delay in the first person shooters Counter-Strike and Unreal Tournament 2004. They find that players notice delays as small as 150ms. Nevertheless, for Counter-Strike even delays of 500ms were rated as "acceptable" and out of the four delay conditions in the study – 0ms, 50ms, 150ms, and 500ms – the highest score on average was achieved with the largest delay, which suggests that even relatively high delays do not necessarily decrease performance. Clayton and Clayton [2006] advises 100ms as the maximal latency for first-person shooters and racing games while role-playing games using third-person avatars can still be played with latencies up to 500ms. Those delays are based on performance assessments in games such as Unreal Tournament 2003 or Madden NFL 2004. Beznosyk et al. [Beznosyk et al. 2011] focus on the effect of delays in cooperative games. They find that delays over 100ms decrease player performance, and user enjoyment decreases for higher delays.

In this paper, we evaluate the consequences of a small delay on the player's game experience and performance. As part of the game experience we investigate player frustration. A small amount of player frustration is part of the experience of play, however, if the task is perceived as too hard compared to the skills available or as unfair ("but I did press jump"), the game experience can quickly be spoiled [Canossa et al. 2011]. In contrast to previous studies, our subjects are not aware that we included a delay in the response of the virtual character and are not presented different options to compare with. Furthermore, we perform a thorough analysis not only of the noticeability of a delay but also of the way it changes the perception of the game, the performance of the player in scenarios of different challenge levels, and the player's experience.

3 Hypotheses and Design

We investigate the effects of responsiveness on the user experience, performance and perception of the game. We introduce a controller delay of 150ms, which, based on previous literature, we expect to be noticeable while keeping the game at a playable level [Dick et al. 2005]. A pilot experiment with delays of 500ms and 150ms confirmed that choice. When the game was played with a controller latency of 500ms, participants reported a delay after a few seconds of gameplay, whereas they did not mention a delay when the latency was only 150ms. We expect the responsiveness of the virtual character to be crucial for the user experience and perception of the game, even for a delay as small as 150 ms.

Our hypotheses are as follows:

- H1: The player finds it more difficult to *control* the character when there is a delay. We hypothesize a learning effect that reduces the differences in control ratings after a few minutes of playing experience.

- H2: The player's *enjoyment* decreases when the character is less responsive to the controls.

- H3: The player's *frustration* increases when the responsiveness of the controls is slow.

- H4: The player's *performance* first decreases when the character is less responsive. Again, we hypothesize a learning effect that reduces the differences in performance after a few minutes of playing experience.

- H5: The responsiveness has an effect on the player's *perception of the virtual character* and the *perception of the game*.

To test these hypotheses, we create two levels of a platform game with a high-quality virtual character, motion captured motions and a futuristic looking environment using the Unity game engine. We collect data in two ways: First, we ask each participant to fill out a questionnaire between and after playing the different levels of the game. Second, we record their actions while they play and analyze the game play metrics.

3.1 Stimuli

Most human-like virtual characters in current games are animated using motion capture [Gleicher 2008]. We therefore use motion capture to animate our character and create two levels of different difficulty using the professional game engine Unity. We captured a set of stand, jog, and jump motions of a female performer. Based on those motions, we created two controllers, which vary in their responsiveness, to steer the motions of a female virtual character.

Our first condition called *Quick* switches to the currently required motion immediately when the user gives the command to do so. Unlike traditional character controllers in games, we do not compute transitions or perform blending between animations, so that the switch in motion is immediately visible. This method ensures the quickest possible responses. In our second condition, *Delay*, we reduce the responsiveness of the character: The motions are generated in the same way as for the Quick-controller but we introduce a delay before each command is carried out. New commands are queued to produce a consistent delay. The delay is implemented as a number of frames of waiting time before a command is carried out. Thus, the delay time (in milliseconds) will vary with the frame rate. This delay behavior best simulates what happens in real game situations with a slow network connection or a poorly implemented game: the delay slightly varies over time, which makes it harder for the user to adapt. We aimed for an average delay of 150ms. As our average frame rate was slightly below 70 fps, we chose a 10 frame delay.

We create two game-like levels to test our hypotheses. In the first level, which is designed to be simple, we ask the player to steer the character along a path as quickly and as accurately as possible while collecting gems and avoiding lasers (see Figure 2). At the start of the level the character emerges in a tutorial area where the player can practice with the controls, collect two gems and gather experience with two laser beams without losing health. The actual game starts as soon as the player leaves the tutorial area, which the participant is asked to do when feeling comfortable with the controls. In the second level, which is designed to be challenging, we ask the player to steer their character across a series of elevated platforms from which the character can fall and die if the player does not time the jumps accurately. When losing a life, the character respawns at a position close to its death and the user can try again until six lives are lost. In level 2, players also collect gems while avoiding lasers, similarly to level 1 (see Figure 3).

In our setup, we use a third person camera, typical of adventure and platform games, which automatically follows behind the character. The player does not have direct control of the camera except to reset
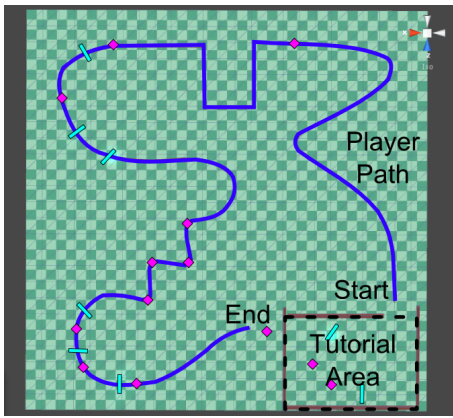
Figure 2: *Map of level 1. Gems are represented with pink lozenges and laser beams with blue rectangles. The tutorial area can be seen on the bottom right. The path that the player has to follow is marked in blue.*

its position behind the character. Without a reset, the camera gradually readjusts to behind the character whenever she turns. This type of camera was chosen to accommodate players without previous experience with gamepads. Furthermore, it allows the user to briefly observe the character from the side or even front, so they can form an impression of it. The controls were made as intuitive as possible. When no control was activated the character would perform an idle standing motion. With the analog thumb stick of the gamepad the user can steer the jogging of the character. With the X button of the gamepad, the user can make the character jump.

Figure 3: *Map of level 2: Gems are represented with pink lozenges and laser beams with blue rectangles. Narrow bridges and floating platforms increase the challenge of this level.*

3.2 Participants and procedure

Eighteen people participated in the experiment (6f, 12m), 9 were subject to the Quick condition (3f, 6m) and 9 to the Delay condition. We used a between-group design so that users could not compare different conditions. Thus, each participant played all levels using the same controller and experienced only one type of responsiveness. The participants were students and faculty from a variety of disciplines, ranging between 18 and 40 years of age, and were naïve as to the purpose of the experiment. They were rewarded with $5 for their participation.

The study lasted about 20 minutes. Participants were first asked to sign a consent form and answer basic demographic questions as well as their experience with digital games on a 7-point scale.

They were then given the instructions describing the goals of the game and the controls. They were asked to play through level 1, level 2, and then again level 1 (which we call level 3, but is in fact the exact same level). The goals of playing level 1 a second time are on the one hand to evaluate learning effects and on the other hand to measure the player's reactions in a more boring task. During the whole game, we recorded the position of the character every half second as well as any gems collected and health or life lost. After each level, players were asked to answer four questions on 7-point scales: how much they enjoyed the level (1=not at all, 7=a lot), how satisfied they felt about their performance (1=very unsatisfied, 7=very satisfied), how difficult/easy it was to control the character (1=very difficult, 7=very easy), and how they would rate the quality of the motions (1=very low quality, 7=very high quality). At the end of the experiment, they were asked to evaluate how much specific attributes applied to the game (e.g., entertaining, challenging, repetitive) and to the character (e.g., agile, human-like, sympathetic) and were given time to write down any comments they might have.

4 Results

To evaluate the four questions that were asked after each level (enjoyment, satisfaction with performance, difficulty of controls, and motion quality), we use two-way repeated measure ANOVAs with the factors Responsiveness (between-subjects variable with the values Quick and Delay) and Level (within-subjects variable with 3 values). In the next sections, we detail the answers that belong to each of our hypotheses.

4.1 Control

For the ratings on the difficulty of controlling the character, there is a main effect of Responsiveness ($F_{(1,16)}=4.7$, $p<0.05$) and a main effect of Level ($F_{(2,32)}=24.6$ $p\approx0$). As expected the character in the Delay condition was rated significantly more difficult to control. Furthermore, controlling the character was rated easiest in level 3, followed by level 1, and most difficult in level 2, with all differences being significant. The detailed results are shown in Figure 4 (a).

The difference between the Responsiveness conditions is especially salient for level 2, where the character is rated considerably more difficult to control than in the other levels. We conclude that a quick responsiveness is particularly important for the user when the task is challenging. The character was rated as significantly easier to control in level 3 than in level 1, even though those levels were identical for each individual participant. This result indicates the presence of a learning effect. This interpretation is endorsed by comments in the debriefing phase, for example, one participant asked if the controls were changed in level 3 as it felt as if the character was following the path nearly automatically. We can not determine, based on our data, if the learning effect reduces the differences between the Delay and Quick conditions as the differences are not significant for level 1 nor for level 3. H1 is therefore only partly supported.

In the debriefing or in the comments part of the questionnaire many participants in the Delay condition complained about the bad controls. However, none of them mentioned being aware of the delay as the cause of the bad controls. In pilot tests, larger delays were noticed quickly. Thus, 150ms is an adequate delay for the purpose of our experiment.
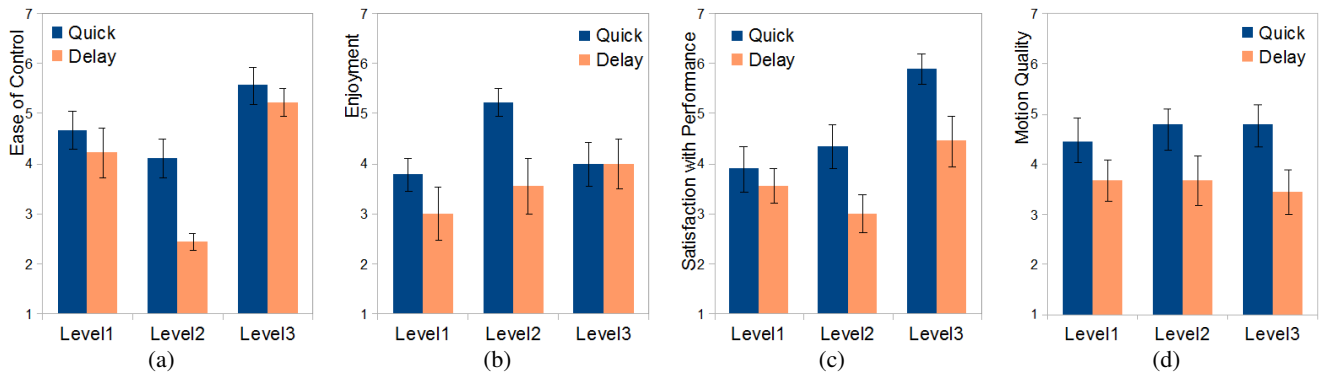
Figure 4: *Results of the four questions asked after each level. Error bars represent one standard error of the mean in all graphs. (a) Ratings of how easy or difficult players judged the control of the character in each condition and level (1=very difficult, 7=very easy). There are main effects of Responsiveness with D<Q and of Level with L2<L1<L3. (b) Ratings of how much the players enjoyed the game. The challenging second level was enjoyed significantly more than the other levels. (c) Ratings of how satisfied players felt about their performance. We found main effects of Responsiveness with D<Q and of Level with L1,L2<L3. (d) Ratings for the quality of the character's motions. There were no significant effects.*

4.2   Enjoyment

When analyzing the responses to the question of how much the players enjoyed the level, we find a main effect of Level (F(2,32)=4.7, p<0.05). A Newman-Keuls post hoc test shows that this is mainly due to level 2 being rated significantly more enjoyable than level 1 and 3. Level 3 is enjoyed more than level 1 on average but with p≈0.07 the difference is not significant at the 5% level that we are using in this study. The interaction effect between Level and Condition is also just not significant with p≈0.054. The results are represented in Figure 4 (b).

In summary, our data is not conclusive to confirm H2, that the players' enjoyment decreases when the character is less responsive to the controls. However, the tendencies point in the predicted directions in each case and it would be interesting to test this hypothesis with a larger pool of participants.

4.3   Frustration

To assess the player's frustration, we first evaluate the ratings on how satisfied the players felt about their performance after each level (see Figure 4 (c)). We found a main effect of Responsiveness (F(1,16)=6.5, p<0.05) with participants feeling significantly less satisfied about their performance when they played the Delay condition. There was also a main effect of Level (F(2,32)=11.4, p≈0) with players feeling most satisfied after playing level 3.

A further indication of player frustration is the number of gems collected. In level 2 the goal was to reach the big gem at the end of the level. It was left open to the participant to collect all gems. Most gems were directly on the character's path but a few of them required small detours. Out of the 15 participants who managed to reach the end of level 2, five participants did not collect every possible gem, which might indicate player frustration. Four of those five participants played the Delay condition. One played the Quick condition.

The comments collected during game observation and debriefing add further insights into players' frustration. Two of the eighteen participants got so annoyed about the jumps that they went around some of the laser beams in level 1 and level 3 instead of jumping above them even if this was contrary to the task of those levels. Two other participants complained repeatedly about the controls. All

four participants were in the Delay condition. In summary, multiple metrics indicate that players' frustration increased when the responsiveness of the controls is slow, which supports H3.

4.4   Performance

We measured several metrics during game play: the amount of health lost, the number of lives lost, the percentage of the time spent standing, jumping, or jogging, the amount of time spent in the tutorial area, and lastly, the amount of time needed to finish the level. Furthermore, in levels 1 and 3 we asked participants to follow a path as quickly and accurately as they could. We measured their position every half second and computed their average distance from the path.

In each metric participants playing the Delay condition showed a lower performance on average. To evaluate the differences in the time spent in the tutorial area in level 1, we used a t-test. We found a significant effect of Responsiveness with p<0.05 (we also confirmed this result with a Mann-Whitney U test). On average, the players in the Delay condition spent 106 seconds in the tutorial area, whereas players in the Quick condition were ready after only 68 seconds.

We analyzed the loss of health with a two-way ANOVA. Health is lost every time the character touches a laser beam, e.g., when a jump is triggered too early or too late. We found a main effect of Responsiveness (F(1,16)=5.8, p<0.05) with players in the Delay condition losing 2.3 more health points on average (see Figure 5). We also found a main effect of Level (F(2,32)=12.1, p<0.001) due to the fact that players lost significantly less health points in the last level.

The analysis of the accuracy when following a path showed a main effect of Level (F(1,16)=5.3, p<0.05), with players following the path more accurately in level 3 than in level 1. This confirms that there is a learning effect, however we can not determine if there is a difference of learning between the Delay condition and the Quick condition based on our data.

Even though not all metrics lead to significant results, we find a clear diminution of the players' performance in our experiment for participants in the Delay condition. Nevertheless, as we can not confirm that the differences between the performances in the two conditions decrease, we can not fully support H4.
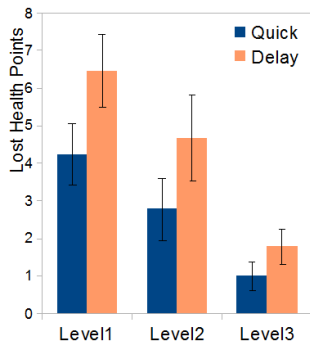
Figure 5: *Lost health points in each condition and level. We found a main effect of Responsiveness with Q<D and a main effect of Level with L3<L1,L2.*

4.5 Perception of the virtual character and the game

We asked participants to judge ten attributes of the character (e.g., agile, sympathetic, confused) and five attributes of the game (e.g., challenging, repetitive) on 7-point scales at the end of the experiment. For most attributes, a t-test results in no significant effect of Responsiveness. We fail to reach significancies for how realistic the game is and for how human-like and how sympathetic the character is with p<0.1. The attributes are rated to apply less in the Delay version in all three cases.

Lastly, we analyzed the perceived quality of the motions. The motions of the character were identical in both conditions and all levels: they were delayed but not altered. On average the motions in the Quick condition are rated as more realistic than in the Delay condition, but the difference fails to be significant at the 5% level with p≈0.07 (see Figure 4 (d)).

In summary, our data does not support H5, that the responsiveness has an effect on the player's perception of the virtual character or the game.

5 Discussion

Our study shows that even a relatively small delay of approximately 150ms on average affects the user experience in several ways. We confirmed that the player finds it more difficult to control the virtual character with the delay. Generally, the Delay condition caused players to be less satisfied with their performance both subjectively and objectively: players with the Delay condition took longer in the tutorial section, collected fewer gems, lost more health, and lost more lives. However, players were most frustrated with their performance in level 2, where the delay hindered their ability to play.

The motions in our experiment switched without any transition as we wanted the players to directly see the response to their controls. In general, in games with realistic motions, transitions are computed between consecutive motion fragments. The computation of these transitions can in fact be one of the reasons for delays, especially when using more sophisticated controllers, such as motion graphs [McCann and Pollard 2007; Kovar et al. 2002; Lee et al. 2002]. It would be interesting to determine if control latencies have a similar effect when different types of smooth transitions are used.

Based on our data, we were not able to provide evidence that learning effects might reduce the differences of performance and control ratings between the Delay and the Quick condition over time. To assess this assumption, we would need to ask players to repeat level 2 at the end of the experiment or add further challenging lev-els. However, we do see increased enjoyment and satisfaction after level 3 even with Delay, which suggests that a learning effect may be present.

Our participant pool was very diverse regarding their backgrounds and experience with digital games. We see potential effects in the perception of the character, which have significance values of less than 0.1. These results suggest that there might be effects of responsiveness on the player's perception of the character. However, participants' responses had a higher variance than we predicted and therefore our estimated participant pool was too small to prove this hypothesis.

6 Conclusion and Future Work

In this paper, we thoroughly evaluate not only whether a specific delay in responsiveness is noticeable or disturbing to the player, but how the delay affects the player's enjoyment of the game, the player's frustration, objective performance, and the perception of the player-controlled character. In our study, participants are not aware that we are investigating responsiveness in games and that we introduced a delay in the controller. Nevertheless, participants in the Delay condition are more frustrated than participants getting immediate feedback, even if they are unaware why.

In summary, we do show that a quick responsiveness is very important for the player but becomes crucial for more challenging tasks that require precise control. We verify that delays increase the perceived difficulty for controlling the character, increase player frustration, and reduce the performance for some tasks. We also investigate whether a learning effect during the Delay condition might cause a player to adapt to the controls and hence ultimately view the experience more positively. Our data suggests insights into our hypothesis, but more experiments are needed to determine whether the effects are significant. Though these effects may not seem surprising, understanding the effect of delay on a player's perception of his performance and his player-controlled character may help us implement better games, be it to create a more stimulating entertainment experience or to leverage the learning outcome of an educational game. For example, when playtesters complain of either bad controls or an unrealistic and unsympathetic character, the true cause may actually be poor responsiveness in the controls, rather than a problem with the character or game concept.

The next step to understand the consequences of controller latencies is to vary the added delay to find important thresholds, for example, when player frustration starts to increase or when a control lag is consciously recognized as such. Furthermore, future research will investigate how our results scale to different types of tasks and games, such as first-person shooters or sports games. Besides of the difficulty of the task, further parameters, such as the level of immersion, the influence of other modalities (e.g., sound), or the realism of the character might play a role. Lastly, we would like to study the effect of controller features that increase the quality and realism of the character animation, such as higher quality transitions, possibly at the expense of responsiveness.

Acknowledgments

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