An Evaluation Research on Dynamic Hit Stop Using Eye Gaze

Rena Tomizawa[1] and Tomokazu Ishikawa[1,2][a]

[1]*Toyo University, 1-7-11 Akabanedai Kita-ku, Tokyo, Japan*

[2]*Prometech CG Research, 3-34-3 Hongo bunkyo-ku, Tokyo, Japan*

Keywords: Hit Stop, Eye Gaze, Game Design.

Abstract: The purpose of this study was to verify whether the response changes when hit stop, one of the elements of GameFeel, is changed according to gaze information. First, several participants play the action game by changing the hit stop duration and answer a questionnaire. Based on the results of this questionnaire, the boundary between pleasant and unpleasant hit stop duration is determined based on the idea of discriminant analysis method. Next, within a comfortable hit stop duration range, we examined whether the response is different when the hit stop duration is changed according to the gazing duration. As a result, designing hit stop duration that corresponds to staring duration is important to improve GameFeel.

1 INTRODUCTION

In recent years, the topic of indie games and game development has often been discussed at the research level. At the same time, attention is being paid to the mechanics of the game. There has been a lot of talk about the "GameFeel" element as a mechanism in the game. GameFeel is the "sense of feeling" that players receive during gameplay. Games are multisensory experiences, but the narrative content, music, art, and many other aspects of the game influence the feel of the game. GameFeel places more emphasis on the role played by interactivity. This paper will focus on the design of player interaction with the game, with reference to the survey by Pichlmair and Johansen (Pichlmair and Johansen, 2022).

In explaining GameFeel, it is necessary to describe "juice". Juice is the excessive amount of feedback in relation to user input to enhance interactivity. The purpose of juice is to make people feel that the players' actions have meaning and that game players can predict the outcome. A game that is good texture, properly staged and lively is sometimes called a juicy game.

A research on GameFeel concerns how players' minds and bodies experience emotions when playing games. How to design for the emotional aspects of the play experience should be studied not only in the field of games, but also in relation to design theory, psychology, ergonomics, philosophy, and many other fields. It is believed that elucidating the elements of GameFeel will help us to understand what variables are involved in enhancing the immersive experience of a game, and will broaden the scope of expression in game development. Pichlmair and Johansen classified the components of GameFeel into the following five categories; "movement and actions", "event signification", "time manipulation", "persistence" and "scene framing"in Figure 1 (Pichlmair and Johansen, 2022). These elements are further subdivided into 31 items. When designers intentionally elicit emotion, "hit stop" is often used from among these elements.

The purpose of this study was to verify whether the response changes when hit stop, one of the elements of GameFeel, is changed according to gaze information. Hit stop is a type of visual feedback in which the animation displays a pause or slow-motion effect at the moment of impact (attack, being hit, landing depending on the falling altitude). In previous researches related to hit stop, it has been discovered that the pseudo-shock sensation is increased by vibrating the remote control simultaneously with hit stop (Hachisu et al., 2011) or by changing the duration of hit stop according to body velocity (Ban and Ujitoko, 2021).

In this study, an experiment is conducted to test the hypothesis that if the pseudo-shock sensation can be increased by combining hit stop in addition to tactile sensation or body velocity, then the combination between visual information and hit stop may provide

[a] https://orcid.org/0000-0002-9176-1336

Tomizawa, R. and Ishikawa, T.
An Evaluation Research on Dynamic Hit Stop Using Eye Gaze.
DOI: 10.5220/0012461400003660

In *Proceedings of the 19th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2024) - Volume 1: GRAPP, HUCAPP and IVAPP*, pages 151-158
ISBN: 978-989-758-679-8; ISSN: 2184-4321

Design Element	Physicality	Amplification	Support
Movement and Actions			
Basic Movement	●		
Gravity	●		
Terminal Velocity			●
Coyote Time			●
Invincibility Frames			●
Corner Correction			●
Collision Shapes	●		●
Button Cashing			●
Spring-locked Modes	●		
Assisted Aiming			●
Event Signification			
Screen Shake	●	●	●
Knock-back & Recoil	●	●	
One-Shot Particle Effects		●	●
Cooldown Visualisation			●
Ragdoll Physics	●	●	●
Colour Flashing		●	
Impact Markers		●	●
Hit Stop		●	●
Audio Feedback	●	●	●
Haptic Feedback	●	●	●
Time Manipulation			
Freeze Frames		●	●
Slow Motion		●	●
Bullet Time		●	●
Instant Replays		●	●
Persistence			
Trails			●
Decals & Debris			●
Follow-Through	●		
Fluid Interfaces	●		●
Idle Animations			●
Scene Framing			
Highlighting			●
Dynamic Camera		●	●

Figure 1: Components of GameFeel.

a change in GameFeel.

- To propose and validate a methodology for determining the boundaries of pleasantness and unpleasantness of hit stops
- To confirm that GameFeel is improved by changing the hit stop duration according to the staring duration

Since action games are frequently implemented with the hit-stop direction, which is effective for users, this study implements and verifies the proposed method on an action game.

2 RELATED WORKS

Brown and Cairns interviewed game players to define immersion based on their experiences and discussed the quality of immersion (Brown and Cairns, 2004). Using Grounded Theory, they firmly categorized immersion into three levels: engagement, engrossment, and total immersion. This division suggests new lines of demarcation for investigating immersion and moving into software domains other than games.

Pichlmair and Johansen classified GameFeel with reference to over 200 games (Pichlmair and Johansen, 2022). As a result, three distinct domains of the intended player experience were derived: physicality, amplification, and support. In this paper, it is also noted that another study must be conducted to determine when elements of GameFeel are called ”good game feel” for game players. Therefore, we examine effective hit stop direction methods when new physical information is inputted.

Ban and Ujitoko proposed and evaluated the incorporation of hit stop effects and vibratory tactile sensations into VR (virtual reality), which pause the action at the moment of impact or display slow motion animation on VR tennis, a VR sport (Ban and Ujitoko, 2021). They evaluated the effect of hit stop with and without vibration and the effect of hit stop in duration by using the magnitude estimation method to estimate the number of seconds of hit stop that is comfortable. They also stated in their paper that they need to confirm whether hit stops are effective in other VR experiences.

Lin et al. analyzed the elements of juicy impact feedback in action games and found that hit stops, sound coherence, and camera control have a significant impact on the player’s sense of hitting (Lin et al., 2022). Within this paper, they presented 19 feature frameworks, and tested them in actual games. It was suggested that the player’s impact feeling may be compromised if any one of the three functions, hit stop, sound coherence, and camera control, is not designed specifically for the player.

Hachisu et al. investigated the use of pseudo-haptic feedback effects using vibration and proposed two new methods for enhancing pseudo-haptic feed-

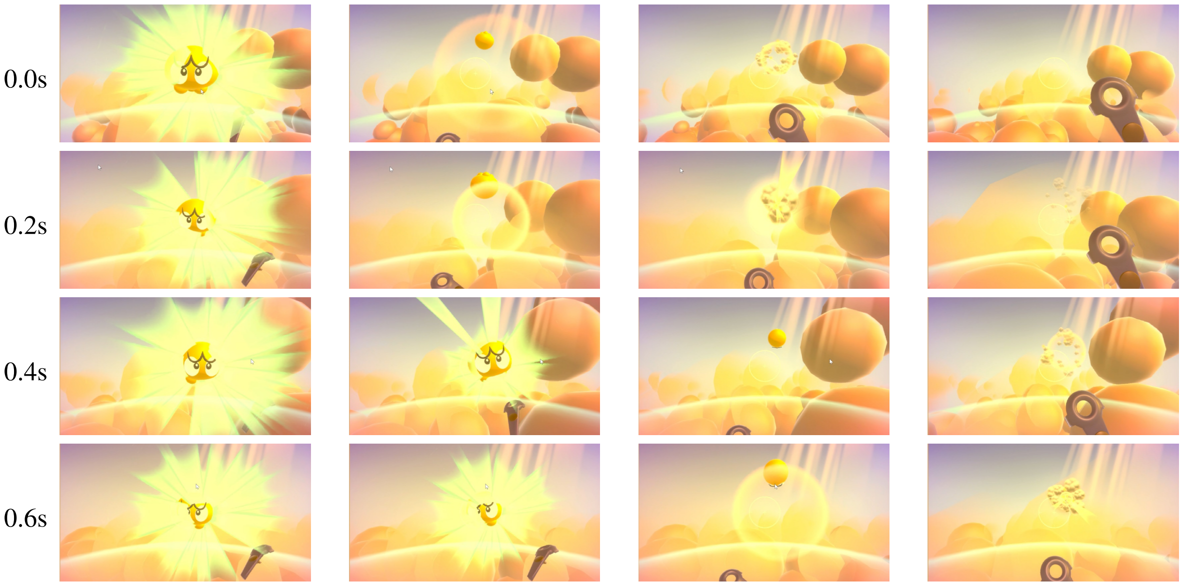


Figure 2: Difference of animation by hit stop duration: 1, 11, 21, and 31st frames at 24 fps.

back in virtual object exploration (Hachisu et al., 2011). In this paper, two methods are proposed to adjust the cursor change on the screen: the first method uses stripe patterns to enhance the pseudo-haptic texture, using vibrations to enhance the pseudo-haptic texture, thereby adjusting the amount of cursor movement; the second method uses visual vibrations to adjust the cursor change by simulating the texture of the virtual object.

In recent years, applications that incorporate eye gaze have also been well studied (Skaramagkas et al., 2023). Eye tracking is gaining ground in the research community, but it is not yet a common approach for detecting emotional and cognitive states or for incorporating it as an element in games. Charoenpit and Ohkura designed and implemented a prototype to record learners' eye movements and investigate the relationship between two emotions, interest and boredom, and evaluated the experimental results (Charoenpit and Ohkura, 2015). From this experiment, they found that gaze fixation time and number of gazes were negatively correlated with boredom content. If interest and boredom can be detected by eye gaze, we thought we would evaluate the contribution to the fun of the game by performing a dynamic hit stop as an output of eye gaze and behavior in game.

3 PROPOSED METHOD

We create an original action game in which hit stops are presented in a variable manner depending on the gazing point and gazing time, and evaluate the effects of dynamic hit stops based on eye gaze. This study is conducted in two phases: to determine the borderline between pleasantness and unpleasantness of hit stops, and to confirm the effectiveness of the dynamic hit stops designed based on this borderline. This section describes the methodology for each phase.

3.1 Phase 1 : Borderline Between Pleasantness and Unpleasantness of Hit Stops

Several players are asked to play the game by changing the hit stop duration in the range of 0.0s to 0.7s and to answer a questionnaire. An animation of the game created and with the hit stops changed is shown in Figure 2. In our implementation, hit-stop duration refers to the amount of time that an enemy character's vanishing animation is prolonged when a player attacks an enemy character (Figure 3). From the perspective of the game context, we experimented with a total of three scenes, preparing two patterns of weapons (sword and bow) and a mode in which the player could freely switch between these weapons. Figure 4 shows a scene in which a bow is used. So, participants play up to 24 patterns (with 8 levels of hit stop duration for each of the 3 scenes). As shown in Figure 5, we ask the participants to play a reference task with a hit-stop time of 0 s at the beginning of each scene.

For the post-play questionnaire, five items were selected from the indices of Ban and Ujitoko's

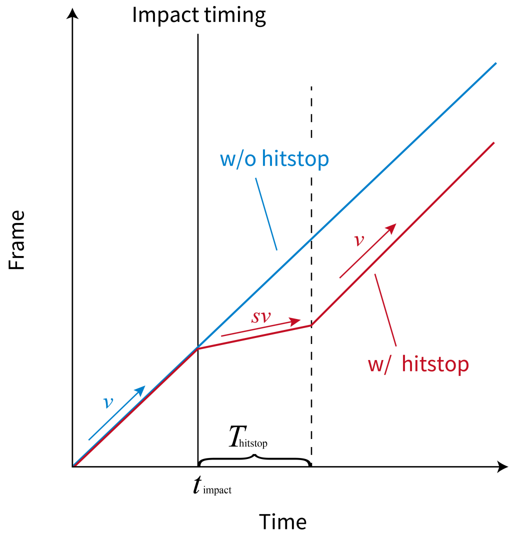


Figure 3: Diagram of hit stop effect. We call $T_{hitstop}$ hit stop duration. The playback speed during $T_{hitstop}$ is s times normal speed, and we set $s = 0.01$.

Figure 4: A scene where a player is attacking an enemy using a bow.

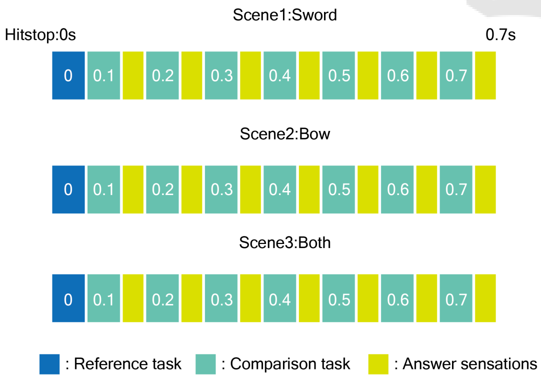


Figure 5: Phase 1 task procedure.

study (Ban and Ujitoko, 2021) and the GEQ (Game Engagement Questionnaire) items (Brockmyer et al., 2009): "sense of impact", "sense of presence", "enjoyment", "initiative", and "stressfulness". For each item, the magnitude estimation method is employed by setting the condition without hit stops as 100 and asking the respondents to respond with a numerical value ranging from 0 to 200. From the questionnaire items, assuming that "stressfulness" is an element of unpleasantness, items that conflict with unpleasantness are extracted by calculating correlation coefficients. Based on the rating values of the pleasant/unpleasant items in the questionnaire, the distribution of which hit stop duration the participants felt were the best/worst is determined. To obtain the distribution of unpleasantness, each participant votes for the hit stop duration at which the participants answered the highest "stressfulness".

For game design of the next phase, it is necessary to determine the borderline between pleasant and unpleasant. We considered obtaining this borderline as a discriminant analysis method for the two classes of pleasantness and unpleasantness. Assuming that each distribution follows a normal distribution, we set the boundary between pleasant and unpleasant as the hit-stop time at which the Mahalanobis distance (Mahalanobis, 2018) from each distribution is equal. If the Mahalanobis distance from the pleasant/unpleasant distribution at the boundary x_{th} is D_p, D_u, respectively, we find x_{th} such that $D_p = D_u$ and $x_p < x_{th} < x_u$.

$$D_p = \frac{|x_{th} - \overline{x_p}|}{s_p}, \quad (1)$$

$$D_u = \frac{|x_{th} - \overline{x_u}|}{s_u}, \quad (2)$$

where $\overline{x_p}$ and $\overline{x_u}$ are the mean, s_p and s_u are the standard deviation.

For the next phase, we also obtain the gazing duration for the enemy character for each player during this experiment. Based on this measurement data, the average and maximum gazing duration ($\overline{y}$ and y_{max}) of the player toward the enemy character are obtained.

3.2 Phase 2 : Design of Dynamic Hit Stop Based on Gazing Duration

One of the novel game effects in this research is to change the hit stop duration according to the gazing duration. Since it is likely to be judged as unpleasant if hit stop duration crosses the borderline obtained by the method in Section 3.1, the hit stop duration should be varied up to this boundary line. First, we prepare Function (1) as the reference task. Function (1) is a constant function characterized by a fixed hit-stop time of 0.39 seconds, representing the average duration of a comfortable hit stop. Since there are several possible functions that map the gazing duration y to the hit stop duration x, we prepare four functions for experiment (see APPENDIX for more information on trial and error during design). To these patterns of

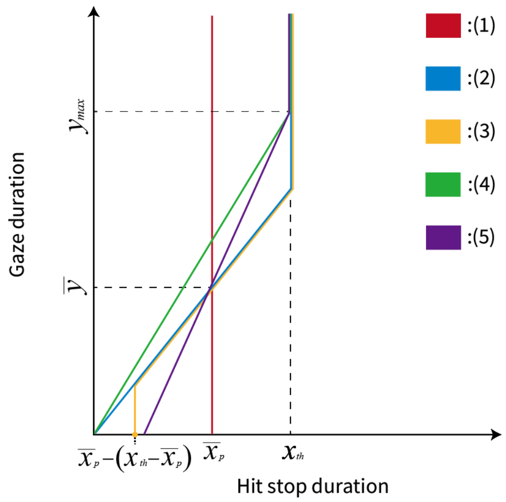


Figure 6: Functions of gazing duration and hit stop duration used in Phase 2. Function (1) is a constant function with the average value of the pleasant hit stop duration. Function (2) is a linear function that passes through the origin and the point $(\overline{x_p}, \overline{y})$. Function (3) is clipped from function (2) in the range of $\overline{x_p} - \left|x_{th} - \overline{x_p}\right| \leq x \leq x_{th}$ (outside this range is a constant value function). Function (4) is a linear function that passes through the origin and the point (x_{th}, y_{max}). Function (5) is a linear function that passes through two points (x_p, $\overline{y}$) and (x_{th}, y_{max}). Function (6) cannot be represented graphically because the hit stop duration is randomly determined relative to the gazing duration.

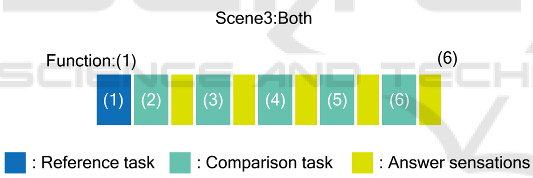


Figure 7: Phase 2 task procedure.

Figure 8: Implementation of a game user interface that presents the gazing point and gazing duration.

functional change, we add one with a constant hit stop duration and one with a randomly changing hit stop duration as shown in Figure 6.

A total of six patterns are played by the experimental collaborators, who are asked to complete the same questionnaire as in the Section 3.1. As shown in Figure 7, we ask the participants to play a reference task at the start of the experiment that uses Function (1).

We implement an user interface that allows the experimenter to know the gazing point and gazing duration while playing the game. The implemented gameplay screen is shown in Figure 8. Gauges near each enemy character increase with the amount of time spent gazing at them.

4 EXPERIMENTS AND RESULTS

VIVE Pro Eye is used to measure the player's line of sight and reflect it in the game in real time. We develop a game for experiment on Unity. FEEL (MoreMountains, 2015) is used as an asset, and hit stops are introduced to the action game. We use a PC with CPU: 11th Gen Intel® Core™ i9-11900 CPU @ 2.50GHz, RAM: 16GB and GPU : NVIDIA GeForce RTX 3060 Ti 8GB for our experiments.

As shown in Figure 9, participants are equipped with VR headsets and enter a room reproduced in the VR space to play the game. Inside this VR room, a television is placed, and participants play the game through this television. This setup allows participants to feel a gaming experience in VR that closely resembled playing a game in the real world. The experimental picture is shown in Figure 10.

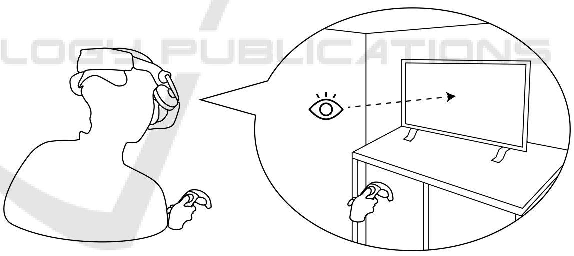


Figure 9: Schematic diagram of the VR space that participants will experience during experiment.

Figure 10: A photograph during the experiment. Participants in the experiment wear VIVE Pro Eye and play games to answer the questions. A questionnaire response form was also created within the VR space.

4.1 Results of Phase 1

In the Phase 1 experiment, men and women in their teens and twenties participated, and data were collected from 16 participants for Scenes 1 and 2 and 15 participants for Scene 3. First, we calculated correlation coefficients for the five items of the questionnaire that were answered, varying the hit stop duration for each scene. The results are shown in Figure 11. In all scenes, “enjoyment” and “stressfulness” were found to have a strong negative correlation. Therefore, we employed “enjoyment” as pleasant and “stressfulness” as unpleasant, and calculated their distributions.

Based on the questionnaires, two distributions were created by voting one vote for each hit stop duration for which the experimental participant gave the highest score for “enjoyment” or “stressfulness”. If there were n tied scores, $1/n$ voted for each hit stop duration. The histogram created according to this procedure is shown in Figure 12. Overall, the longer the hit stop duration, the more uncomfortable it tended to be.

Since no normality was observed in the histogram of unpleasantness in Scene 2, the Mahalanobis distance was used to obtain the boundary line between pleasant and unpleasant for Scene 1 and Scene 3. The averages of pleasant and unpleasant for Scene 1 $\overline{x_p}$, $\overline{x_u}$ were 0.37 and 0.56 seconds, respectively, and the variances s_p, s_u were 0.03704 and 0.05163. The means $\overline{x_p}$ and $\overline{x_u}$ were 0.39 and 0.57 seconds, respectively, and the variances s_p, s_u were 0.03782 and 0.04214 of Scene 3. From these results, the borderlines between pleasant and unpleasant hit stop duration x_{th} obtained were 0.537 and 0.55 seconds, respectively.

4.2 Results of Phase 2 and Discussion

We examined whether the response differs when the hit stopping duration is changed according to the gazing duration within the range of comfortable hit stop duration determined in Phase 1. Scene 3, which has a longer range of comfortable hit stop duration, was selected as the experimental scene for Phase 2. The results of Phase 2 questionnaire are shown in Figure 13. Since the scores of the reference when the hit stop duration is constant are 100, it was found that the research purpose, whether the sense of impact improves according to the gazing duration, can be achieved by methods other than function (4). In addition, as for enjoyment, games with dynamically changing hit stop duration was rated higher than those with fixed hit stop duration. Since function (5) had the narrowest value range among the functions (2) to (6) designed in this study, it can be seen from the enjoyment and initiative items that the hit stop duration was comparable to the constant condition.

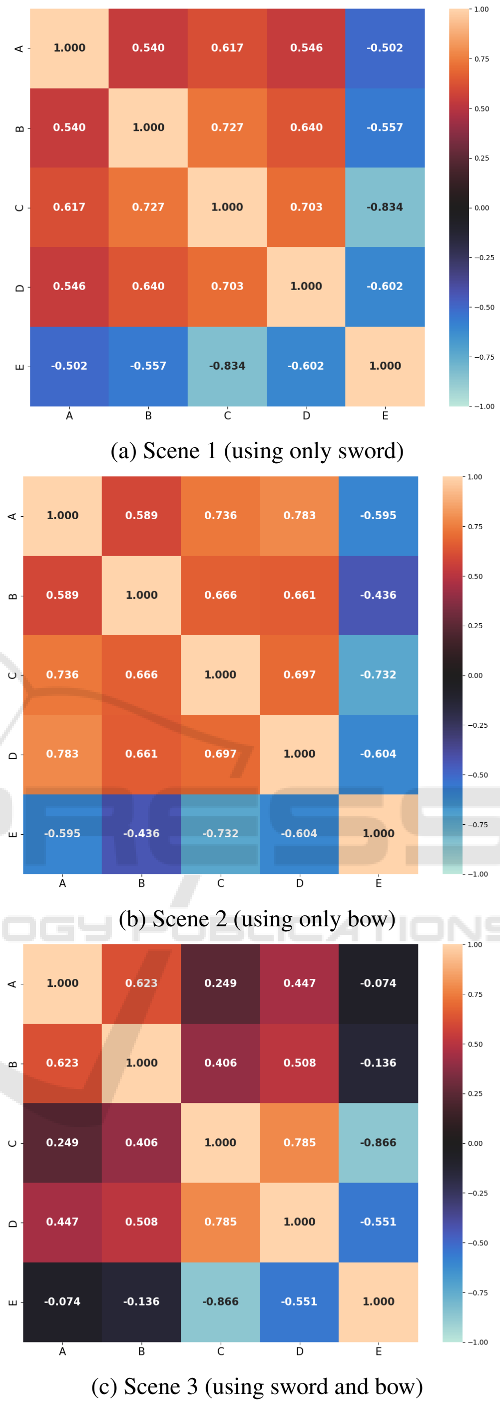


Figure 11: Correlation matrix of the rating values of the survey items in each scene. The axis labels, A to E, correspond to “sense of impact”, “sense of presence”, “enjoyment”, “initiative”, and “stressfulness” in order.

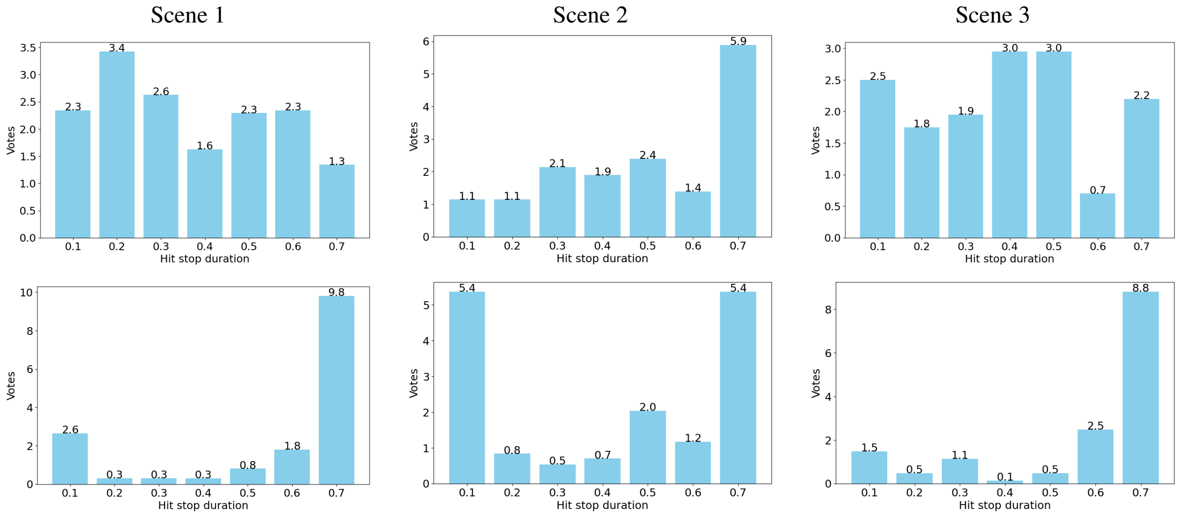


Figure 12: Histograms of pleasantness (top) and unpleasantness (bottom) in each scene.

The following is a discussion of the impact sensation, which was the objective of this study. Functions (2) and (4) are considered to have less impact sensation than the other functions because the hit stop duration becomes 0s when the gazing duration is 0s. We consider that function (3) differs from function (2) in that it includes a bottom value, which results in a stronger sense of impact. Since the respondents felt a stronger sense of impact with function (3) than with random (6), we conclude that the hit stop effect, which varies with the gazing duration, is highly effective in increasing the sense of impact.

5 CONCLUSIONS AND FUTURE WORK

In this study, the boundary between pleasant and unpleasant hit stop duration was determined by discriminant analysis method based on the questionnaire of the experimental participants. As result of this experiment, we found that the context in the game (in this case, the type of weapon) caused differences in the time perceived as unpleasant. Next, we conducted an experiment in which we varied the hit stop duration according to the gazing duration up to the hit stop duration that felt comfortable. It was concluded that changing the hit stop duration according to the gazing duration can enhance the impact sensation.

As a future work, the distribution and bounds of pleasant and unpleasant hit stop duration for different types of weapons in action games need to be studied in more detail. Our study suggests that humans might react nervously to animations of consequences, especially when the action is aimed well, as in the case of bows. In this experiment, we counted up the gazing duration only when the gazing point was inside the enemy character, but we plan to study how the results change when this calculation is applied to the area around the gazing point.

ACKNOWLEDGEMENTS

This work was supported by Toyo University Top Priority Research Program.

REFERENCES

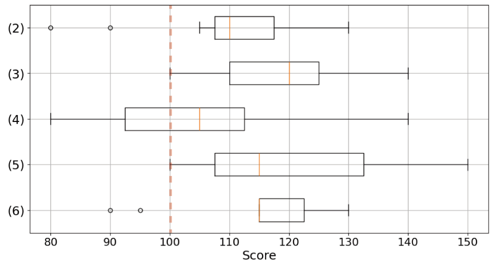
Ban, Y. and Ujitoko, Y. (2021). Hit-stop in VR: Combination of pseudo-haptics and vibration enhances impact sensation. In *2021 IEEE World Haptics Conference (WHC)*, pages 991–996.

Brockmyer, J. H., Fox, C. M., Curtiss, K. A., McBroom, E., Burkhart, K. M., and Pidruzny, J. N. (2009). The development of the game engagement questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology*, 45(4):624–634.

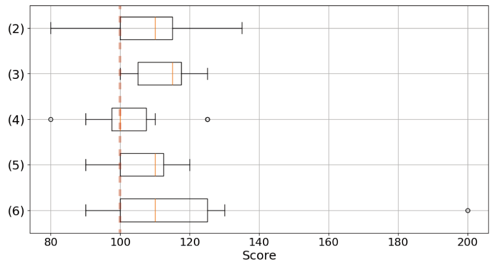
Brown, E. and Cairns, P. (2004). A grounded investigation of game immersion. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '04, page 1297–1300, New York, NY, USA. Association for Computing Machinery.

Charoenpit, S. and Ohkura, M. (2015). Exploring emotion in an e-learning system using eye tracking. *International Journal of Affective Engineering*, 14(4):309–316.

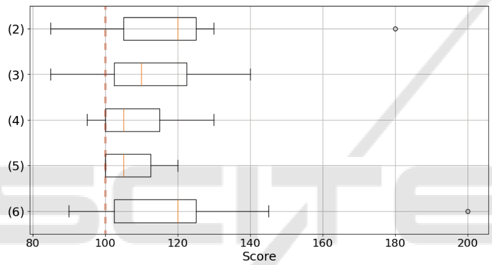
Hachisu, T., Cirio, G., Marchal, M., Lécuyer, A., and Kajimoto, H. (2011). Pseudo-haptic feedback augmented



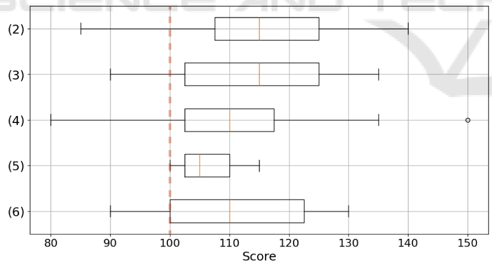
(a) “sense of impact”



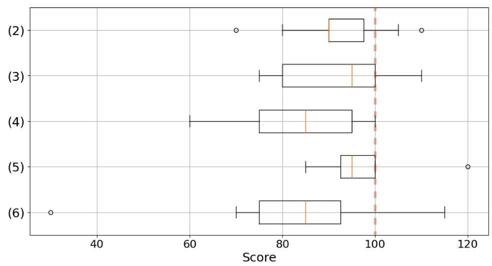
(b) “sense of presence”



(c) “enjoyment”



(d) “initiative”



(e) “stressfulness”

Figure 13: Score distribution of Phase 2 questionnaire results. 100 is the reference score when the hit stop duration is fixed.

with visual and tactile vibrations. In *2011 IEEE International Symposium on VR Innovation*, pages 327–328.

Lin, Z., Duan, H., Wen, Z. A., and Cai, W. (2022). What features influence impact feel? A study of impact feedback in action games.

Mahalanobis, P. C. (2018). On the generalized distance in statistics. *Sankhyā: The Indian Journal of Statistics, Series A (2008-)*, 80:S1–S7.

MoreMountains (2015). FEEL. https://feel.moremountains.com/ (2023.11.17. accessed).

Pichlmair, M. and Johansen, M. (2022). Designing game feel: A survey. *IEEE Transactions on Games*, 14(2):138–152.

Skaramagkas, V., Giannakakis, G., Ktistakis, E., Manousos, D., Karatzanis, I., Tachos, N. S., Tripoliti, E., Marias, K., Fotiadis, D. I., and Tsiknakis, M. (2023). Review of eye tracking metrics involved in emotional and cognitive processes. *IEEE Reviews in Biomedical Engineering*, 16:260–277.

APPENDIX

In designing the functions of gazing duration and hit stop duration, we considered using cumulative distribution function (CDF) with a pleasant normal distribution. We expected to draw an S-shaped curve that could correspond to a pleasant hit stop duration around the mean gazing duration. However, when we plotted the CDF of the normal distribution of pleasantness obtained from the questionnaire, we found that a linear approximation was not problematic (Figure 14). Therefore, in Phase 2, all functions were designed as linear functions. Function (3) was designed to linearly approximate the graph of this CDF.

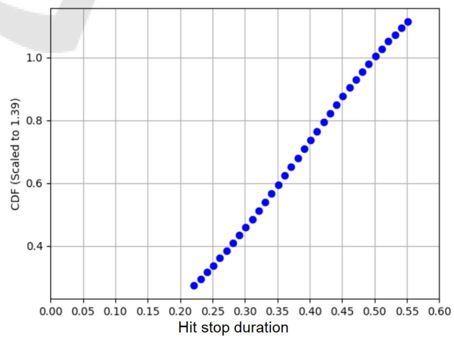


Figure 14: CDF in the range of $\overline{x_p} - \left|x_{th} - \overline{x_p}\right| \leq x \leq x_{th}$ with pleasure as the normal distribution function.