The Effect of Control-Display Ratio in Handheld Motion Controllers on Player Immersion: A Pilot Study

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ABSTRACT

Motion controls are experiencing a renaissance in current Virtual Reality (VR) gaming applications. While there is significant work on how motion controllers affect player experience in games compared to other controllers, relatively little is known about the experiential effects of concrete, low-level design of motion controls. Therefore, this study explores the relationship between immersion and control-display ratio in motion controllers in a VR setup. A pilot experiment compared a 1:1 'natural' mapping ratio with a decelerated ratio. While quantitative results were inconclusive, interviews showed that novelty might be playing an important role in the results.

CCS CONCEPTS

• **Human-centered computing→Gestural input**; *Virtual reality*; • *Applied computing→Computer games*

KEYWORDS

Motion control; handheld motion control; player experience; control-display ratio; VR; immersion

1 INTRODUCTION

Controllers shape how players experience games [1], affecting a variety of constructs. The use of motion controllers for instance has been found to increase engagement and social interaction [2]; affect enjoyment [3–5], presence [4–6] and interactivity [7]; and increase cognitive aggression, immersion and realism [8–10]. The controllers studied ranged from steering wheels to realistic firearm controllers, musical bongos replicas and more regular *Wii* remotes. With the latest VR gaming platforms gaining popularity – HTC Vive [11], Oculus Rift [12] or PlayStation VR [13] – motion controllers are experiencing a rise in popularity. The main argument for using motion controllers is their 'natural' mapping between what the player does in front of the game and what their character does in the virtual environment. This naturalness is seen to increase immersion in the virtual world [6–8, 14–16], a highly desired experiential quality in VR gaming [17, 18] [19–21].

While current research provides a useful high-level understanding of the relation between different kinds of controllers and player experience, they are not forthcoming about the aspects arguably most relevant to game designers, namely the low-level details of control schemes, how they best invoke the different mechanics of certain game genres [22, 23], and give rise to 'satisfying' controller experiences such as 'game feel' [24].

This study explores one particular important yet understudied low-level design parameter in control design: the control-display ratio [25]. Control-display ratio can be defined as the coefficient that maps the physical world movement to the resulting on-screen displacement of e.g. a cursor or virtual actor [25, 26]. Previous research has shown that modifying the control-display ratio can have an effect on user performance and usability [25–27]. However, we don't know how it affects user experience, particularly with regard to game controllers. Therefore, we wanted to test how a change in control-display ratio in a motion controlled VR game can affect immersion.

2 RESEARCH QUESTION

We formulated the following research question: *How does control-display ratio affect player immersion in a handheld motion-controlled game?*

We here operationalize control-display ratio as the amount of time it takes for the position of the controller representation in the virtual world to update to the controller's position in the real world. A 1:1 ratio means that a 1cm/sec movement of the controller corresponds to a 1cm/sec movement in the virtual world. Prior work on controllers and immersion suggests that a 'more natural' control scheme would translate into more immersion. We assume a linear constant 1:1 control-display ratio to be 'natural', while an accelerated or decelerated should be 'unnatural' and therefore less immersive.

Based on this, we formulated the following hypothesis:

Hypothesis: *A 'natural' 1:1 control-display ratio will produce higher immersion in a motion-controlled game than an 'unnatural' decelerated ratio*.

3 METHOD

16 subjects participated in our pilot study, 9 male, 7 female, with age ranging from 18 to 45 years. The game used was a modified VR default game from Unreal Engine [28] with a total of 6 tasks to perform: push a button to drop objects, pull a lever to move platforms, play freely with boxes that could fly, spawn objects with a button and a slider, use a virtual set of drawers and paint on a whiteboard. All interaction with the game was made on the HTC

Vive VR system [11], which included a stereoscopic headset and a pair of handheld controllers, tracked in real-time with two sensors placed on the ceiling of the room, in opposite corners. We measured immersion with the Immersive Experience Questionnaire (IEQ) [29], as it is well-established and has been used in the past to assess how controls affect immersion [16].

Participants were divided into two conditions. Condition A (control group) played the 'natural' 1:1 control-display ratio game. Based on observation and code analysis, we took the inbuilt default control-display ratio of the HTC Vive tasks to be 1:1. Condition B played a version with a decelerated control-display ratio. The only manipulation was a delay between updating the on-screen virtual hand displacement in response to changes of the position of the handheld motion controllers.

To mathematically describe the decelerated function (DF), the distance of the hand movement between frames (ʋ) was calculated and multiplied by a speed coefficient (*x*).

$$DF = \upsilon * x \quad (1)$$

In the constant linear function, the speed coefficient (*x*) was 1. However, in the decelerated function, the speed coefficient (*x*) was greatly reduced to 0.03, to make deceleration during gameplay palpable. We arrived at this ration through prior informal testing to identify the minimum required DF to achieve readily noticeable effects. Instead of using pixels or centimeters in the function, unreal engine world units were used, having a direct translation between pixels and unreal engine units of a 100 pixels/unit.

Each participant was receiving a briefing session to explain the controls and then played for 5 minutes. After that, they were asked to fill in the IEQ. Finally, participants were interviewed regarding their experience. The qualitative data gathered was used to better understand the outcome of the quantitative analysis. In the interviews, questions about the general experience, interaction and difficulty were asked:

- How would you describe your experience with the game?
- How would you describe your interaction with the environment?
- Did you experience any issues you might want to highlight?
- How difficult was for you to perform the different tasks presented?
- If you would be able to change anything, what would it be?
- Any other comments?

4 RESULTS

A two-sample t-test was performed over the average IEQ score of both condition groups. The average IEQ score of the 'natural' display ratio (condition A) was 4.5, lower than the decelerated ration (condition B), which scored 5.2. However, results were non-significant with $p = 0.083$. The effect size (Cohen's *d*) was large, with $d = 0.9$. Overall, this means we have to reject our hypothesis.

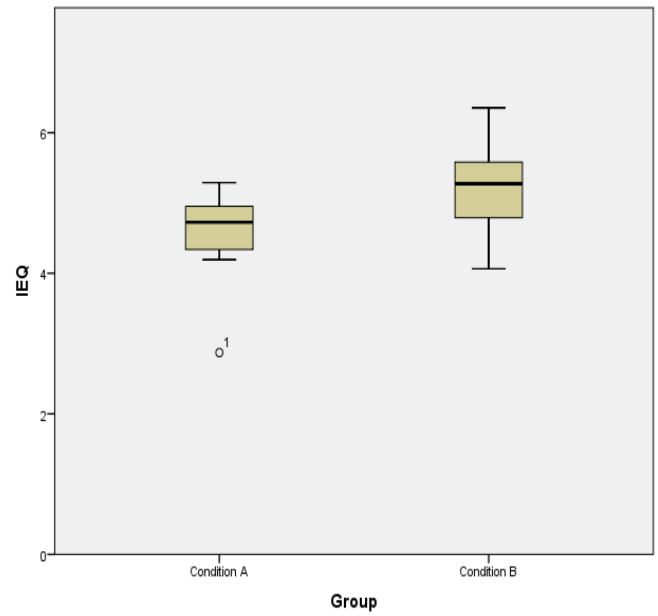

Fig. 1 Box plot of IEQ Score means

The quantitative results were mirrored in interview responses: no but a small minority of participants in decelerated Condition B mentioned anything indicating that they noticed the decelerated control-display ratio. Most answers were related to the control scheme and the buttons to press, as well as the novelty of the experience. Even participants in Condition B that noticed the deceleration, they didn't describe the experience as more difficult, frustrating, or less immersive because of it. Participants generally used the words 'natural', 'real' and 'good' to describe how the experience felt, and several of them pointed out how aesthetically 'simple' the environment seemed.

In any of the conditions, participants that never used the HTC Vive presented a higher enthusiasm during the interview, as well as a generally higher immersion score. As commented above, is interesting the fact that even though the 'unnaturalness' of the movement was palpable in Condition B, the average immersion score was higher.

5 DISCUSSION

Based on the results in this pilot study, it is not possible to say that control-display ratio in handheld motion controllers is influencing immersion in VR games. Possible alternative reasons for our results are the small sample size, an insufficiently strong manipulation, or a problematic operationalization, as we effectively manipulated latency not spatial input-output ratios.

Due to the large effect size encountered when analysing the data, is worth looking at why the immersion score was higher in Condition B. One possible explanation might be because of the cognitive overload of interacting with a decelerated interface, needing a higher effort and concentration to manipulate the environment, potentially leading to a higher immersion score[17, 30]. Another possible explanation might be the brain sync effect [31], where the fact that the virtual hands where decelerated and the players where only seeing their virtual limb representation, created a stronger sense of immersion and embodiment [32, 33]. Interviews opened the further possibility that immersion might have been influenced chiefly by the novelty of the used VR games (see **[**34**]** for similar observations), overshadowing any effects of the control scheme manipulation.

6 CONCLUSION AND FUTURE WORK

Seeing this result, it could be theorised that the necessity for a perfect 1:1 mapping wouldn't be needed in most handheld VR experiences. However, due to the sample size and the qualitative answers, is important to acknowledge the fact that further research should be done on this matter to better understand the relationship of player engagement in VR, embodiment and novelty. Some participants noticed the latency while others didn't notice at all. Some of the participants slowed down their movements while others didn't. It might have been that the prototype chosen wasn't the best option available, and the experiment would benefit from a fully finished videogame where there is a clear goal and more complex task to perform.

Because of all the reasons mentioned above, a future study to follow this pilot one is proposed, better controlling the different conditions that might be affecting the results. The study would consist of 40 participants divided into four different groups: with and without VR setup, and for each group, with and without deceleration. With the proposed experiment, we hope to gain more knowledge in how the modification of control-display ratio affects immersion, and how VR might be having an influence over the results.

Nonetheless, as the game industry further pushes VR game development, the knowledge in how players immerse with the game environment becomes relevant and needed. This study is a small step in better understanding the relationship between immersion and motion controllers in VR games, and marks beginning of an interesting and exciting path to explore.

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