S3D Depth-Axis Interaction for Video Games: Performance and Engagement

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ABSTRACT

Game developers have yet to embrace and explore the interactive stereoscopic 3D medium. They typically view stereoscopy as a separate *mode* that can be disabled throughout the design process and rarely develop game mechanics that take advantage of the stereoscopic 3D medium. What if we designed games to be S3D-specific and viewed traditional 2D viewing as a separate mode that can be disabled? The design choices made throughout such a process may yield interesting and compelling results. Furthermore, we believe that interaction within a stereoscopic 3D environment is more important than the visual experience itself and therefore, further exploration is needed to take into account the interactive affordances presented by stereoscopic 3D displays. Stereoscopic 3D displays allow players to perceive objects at different depths, thus we hypothesize that designing a core mechanic to take advantage of this viewing paradigm will create compelling content. In this paper, we describe *Z-Fighter* a game that we have developed that requires the player to interact directly along the stereoscopic 3D depth axis. We also outline an experiment conducted to investigate the performance, perception, and enjoyment of this game in stereoscopic 3D vs. traditional 2D viewing.

Keywords: Stereoscopic 3D, video games, interaction, depth-axis, mechanics, perception

1. INTRODUCTION

Video games are potentially the most interesting, and challenging, artistic medium to develop intriguing narrative experiences. While there has been a considerable amount of experimentation regarding stereoscopic 3D with respect to 3D storytelling in film, the work describing 3D storytelling with respect to video games is sparse given that video game designers and developers have yet to embrace stereoscopy with as much enthusiasm as filmmakers. That being said, the challenges of designing engaging stereoscopic 3D content are compounded by the interactive nature of video games. While there are many game developers who have included stereoscopic 3D modes in their games, the nature of the gameplay does not take into account the stereoscopic nature of the display. Since there are relatively few stereoscopic TV's in the home, game developers usually view the inclusion of stereoscopic 3D as a "mode" rather than the primary viewing paradigm, implying that the game must be playable ***with*** and ***without*** S3D enabled. In our opinion, this is what is hindering the development of compelling interactive S3D content. To develop compelling content, one must embrace the medium completely and tailor the content to take advantage of what the medium has to offer. We believe that in the interactive video game medium, it is the ***interaction*** with the content that fulfills the user, not only the visuals. Although stereoscopic 3D game development is in its infancy, it is poised to have significant impact on the consumer entertainment market (e.g., Jeffrey Katzenberg, CEO of Dreamworks Animation, has twice gone on record at the *3D Entertainment Summit* that video games will drive S3D to the home)[1]. Therefore, we must examine ways to make use of the stereoscopic nature of the display and couple this paradigm with the core game mechanics (interaction mechanisms) used in the gameplay. This paper describes *Z-Fighter*, a video game developed specifically with this in mind and a study to determine how players react to such gameplay in both 2D and S3D. Our goal is to try and understand how interaction paradigms affect S3D and player engagement. Expanding our knowledge in this area will enable game designers to develop compelling S3D content.

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Stereoscopic Displays and Applications XXIV, edited by Andrew J. Woods, Nicolas S. Holliman, Gregg E. Favalora,
Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 8648, 86481B · © 2013 SPIE-IS&T
CCC code: 0277-786X/13/$18 · doi: 10.1117/12.2004537

1.1 Game Mechanics for S3D Games

Game mechanics are the *"action(s) invoked by an agent to interact with the game world"*[2]. This definition captures the essence of how players interact with the game system (as well as how other systems interact with sub-systems) thus causing gameplay to emerge from the repeated succession of these actions. Running, jumping, flying, shooting, climbing, and placing tiles, are all examples of game mechanics employed in video games. The mechanics that the player can use can be described as being either a binary state (which can be mapped to a joystick button) or an analog axis (which can be mapped to the variable position of the analog joystick normalized to be within the range [-1,1]). Typically, video games contain a movement mechanic that enables the player to move a character or object within the game world, allowing the player to explore the world and solve puzzles/problems that are presented to them. In traditional two-dimensional (2D) sprite-based games, this movement is limited to the *x-y* axis. For example, in the platform game *Super Mario Bros*, this mechanic manifests itself as the player controlling Mario with left-right movement (*x*-axis) or up-down movement (*y*-axis, through jumping/falling). In top-down shooter type games such as *Xevious* or *1942*, this mechanic manifests itself as a forward-backward movement (*y*-axis) and left-right movement (*x*-axis) to control the flying vehicle. These particular 2D games simulate depth through the use of parallax sprite backgrounds; creating layered sprites that move at different rates enable the designers to simulate things that are further away by changing their speed to be slower than foreground objects and players are rarely able to move the interactive character between these layers.

Stereoscopic viewing can be used effectively for 2D sprite-based games since each layer may be assigned to different stereoscopic disparity levels. This can create a very compelling experience and examples of such games that work well in this regard (anecdotally) are *Trine* and *Limbo.* However, neither of these games takes full advantage of S3D in terms of interaction as they were designed specifically for 2D displays. They are still 2D platformer type games where the game character is controlled via movement along the *x*-axis (left-right movement) and jumping/crouching/falling along the *y*-axis. In contrast, a stereoscopic 3D display allows for the creation of visual experiences along the *depth*-axis as well; why not create experiences that allow players to *interact* along this *depth* axis?

Much of the work in stereoscopic 3D for video games has focused on enhancing the visual experience rather than focusing on player interaction. S3D displays uniquely enable the player to perceive objects at different depths relative to the screen plane. We hypothesize that adhering to stereoscopic 3D game design guidelines as in Schild et al, (2011)[3] and designing a core game mechanic specifically to utilize this capability, similar to *YouDash3D's* mechanic described in Schild et al, (2011)[4] will create a compelling and engaging experience. In this paper we present *Z-Fighter*, a game that developed specifically that requires the player to interact directly along the stereoscopic 3D *depth* axis. We also describe the results of a study that was conducted to test our hypothesis using Z-Fighter. Our objective for this study was to investigate the differences in performance, perception, and enjoyment of S3D video game content where the core game mechanic requires the player to interact directly along the stereoscopic depth axis.

2. A GAME FOR DEPTH-AXIS INTERACTION

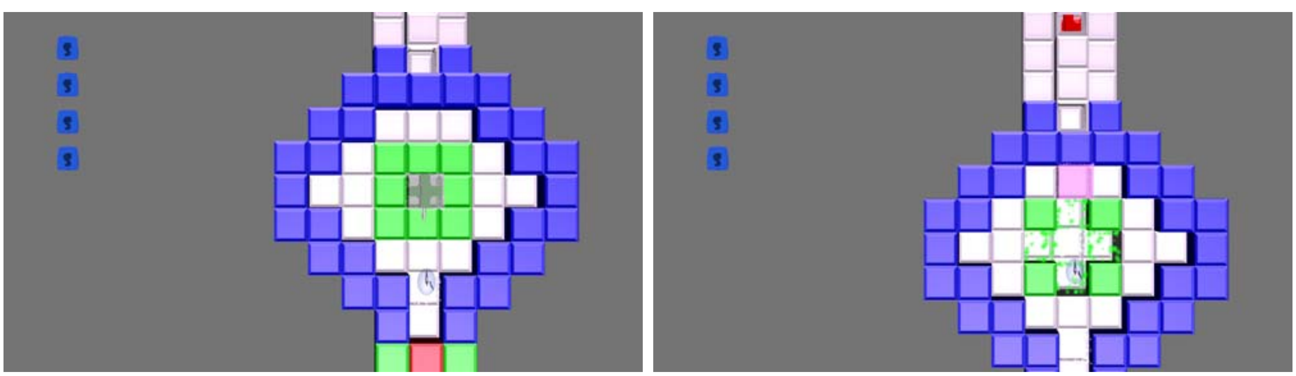

Figure 1. View of the game during basic targeting level. Players focus on targeting the crosses seen here on the left in the middle of the green blocks. Successful destruction of this block causes a chain reaction to the other green blocks and enables the player to move under the blue obstacle blocks.

We have developed *Z-Fighter*, a simple top-down space shooter video game (see Figure 1), similar to many arcade game classics. Players fly a ship along the x-*y* screen plane, avoiding and attacking enemies as they advance throughout the level. We decided to adopt this genre and investigate how to best design the game specifically for S3D displays taking into account that we have the ability to display at different depths. Thus, we also allow player movement along the *z* (*depth*) axis allowing the player to fly at different elevations above the blocky-terrain. This creates interesting possibilities for novel gameplay and problem solving as the player can now dodge enemies by moving in and out of the screen plane. The player now has the ability to fly beneath blocks and avoid destruction by moving above or below enemy missiles. The game consists of a player controllable spacecraft that is always moving forward. Rather than designing a 2D game and then enabling S3D viewing, we designed this game specifically for S3D viewing and then enabled 2D viewing.

Figure 2. Gameplay controls. The left analog stick controls the ships' *x-y* movement, the left shoulder buttons control elevation (*depth* axis), the right shoulder buttons control the elevation (*depth* axis) of the homing missile target, the right analog stick controls the *x-y* movement for the homing missile target and pushing inward on the right analog stick will enable you to fire your bomb/homing missile.

2.1 Gameplay

The player interacts with the system using an Xbox 360 controller. They use the analog stick to control the *x-y* axis and the shoulder buttons to control the elevation (*depth* axis) of the ship and targeting system (see Figure 2). If the ship moves forward to the edge of the screen, the world scrolls faster. The world is a series of colored blocks in the visual aesthetic style of *Tetris* (see Figure 3). Hitting a block with the ship causes the ship to be destroyed and the blocks are re-positioned at different depths protruding in/out of the screen. The player must navigate successfully to the end of the level to proceed to the next level. In order to add challenge and stereoscopic 3D interaction, the user is able to move along the stereoscopic depth axis using the shoulder buttons on the controller. This enables the player to fly higher (out of the screen) or lower (into the screen) to avoid obstacles. A second mechanic includes the ability to target objects and shoot with a homing missile. The target may also be moved along the *x-y* and *depth* axes and the bomb/homing missile will move to that specified location.

We developed a specific skill progression in *Z-Fighter* to both train the player with respect to the main game mechanics, and then use the practiced skills to solve navigation puzzles and engage in combat. To accomplish this progression, we created the following five levels:

- **Level 1**: Basic Navigation. Players must navigate through the level and reach the end using only the *x-y* axis to navigate their craft. This allows players to learn the basic flying controls.
- **Level 2**: Vertical Navigation. Players must navigate through the level successfully using *x-y* movement plus depth axis movement. This allows players to learn/practice the *depth* axis control.
- **Level 3**: Basic Targeting. Players must shoot specific objects to move through the level successfully. These objects must be targeted at different depths and increase in difficulty. Targeting is the only interaction mechanism in this level. There is no navigation (minimal movement along the *x-y-depth* axes) required given that movement is along a straight path with obstacles (the player must both target and shoot).

- **Level 4:** Combination Navigation + Targeting. Players must navigate in both *x-y-depth* and target in the *x,y-depth* axes to complete the level successfully.
- **Level 5**: Boss Combat. Players must defeat a "boss" who is moving along *x-y-depth* axes. To defeat the boss, they must avoid the boss' missiles (movement) and target the boss at the appropriate location.

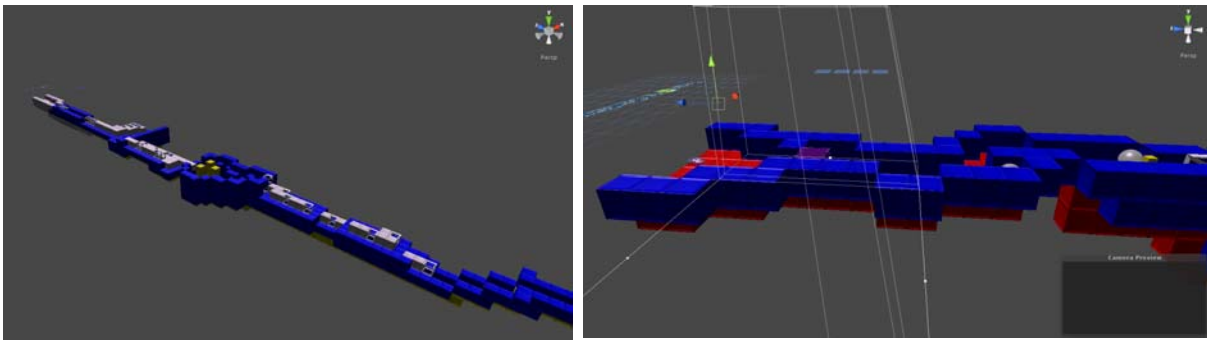

Figure 3: The game world. The left image shows one entire level *Z-Fighter*. The image on the right provides a close-up view of the starting point of the same level.

3. OUR STUDY

3.1 Study design

To develop a clearer understanding of the effectiveness of this game mechanic, we designed a user study to determine whether S3D, and more specifically, the addition of the third (*depth*) axis, and the interaction it affords (as described in Section 2), out-performs traditional 2D viewing, by evaluating quantitative performance characteristics and qualitative measures to determine comfort, enjoyment, and engagement. Each participant was required to play the game with and without stereoscopic 3D viewing (counter-balanced conditions). While the participant was playing, their performance was recorded by monitoring the following statistics: i) the time taken to complete the game, ii) number of deaths, and iii) targeting accuracy. A comparison of these statistics provides an indication of how well the participant performed in each play session. The game was designed such that a person playing in 2D mode was capable of completing the game. Along with capturing the performance data, participants completed the Game Engagement Questionnaire[5] (GEQ) after their play session to gauge their perceptions of the game.

Based on preliminary observations, we hypothesized that players using stereoscopic 3D will out-perform players using traditional 2D viewing, and more specifically, stereoscopic 3D will allow players to complete the game faster, with fewer deaths, and higher targeting accuracy. In contrast to the results of LaViola et al, (2011) [6] who found that S3D did not provide any significant performance benefits to the user in commercial video games, we expect to see performance benefits when the mechanic is specifically designed around utilizing the stereoscopic 3D display. We predict that players will have a higher GEQ score in the S3D condition than in comparison to the 2D condition and we also predict that the freeform comments will indicate a higher degree of enjoyment in (and preference of) the S3D condition.

3.2 Participants

Our participants were selected from the Game Development and Entrepreneurship undergraduate program (16 participants) and the Masters of Computer Science program (5 participants) at the University of Ontario Institute of Technology (UOIT). Prior to participating in the study, each participant filled out a demographic questionnaire to gain an understanding of their prior gaming, S3D gaming experience and preferences. 72.7% of the participants were between the ages of 18 –23. The majority of the participants were well practiced with video games, with 63.6% playing more than 5 hours a week, and 42.8% of those playing more than 10 hours. Fifteen (15) of the 21 participants had previously played a game in stereoscopic 3D, and all participants had previously viewed stereoscopic 3D movies. Furthermore, 40.9% of participants indicated that their prior experience led them to believe that stereoscopic games are more enjoyable in 3D, compared to 18.1% who found them less enjoyable. 40.9% of the participants found S3D movies more enjoyable, while 36.4% finding S3D movies less enjoyable. Seven (7) of the participants wore prescription eye glasses. When asked about what components of ***traditional 2D*** games were important, participants rated interactivity to be the most important aspect of the game experience while surround sound, multi-player and realistic graphics were rated as the least important components of their game experience. When asked about the most important components of ***stereoscopic 3D*** games, participants indicated that seeing *deeply* into the screen and having objects come *out-of-the-screen* were the most important aspects. The experiments abided by the University of Ontario Institute of Technology Research Ethics Review process. All participants were initially screened using the standard Randot Stereo Test to determine normal stereoscopic depth perception.

3.3 Setup

The study was visually presented on a Zalman ZM-M240 24" stereoscopic 3D monitor (with 1920 × 1080 pixel resolution and 5 ms response time). Stereoscopic images were presented using horizontal interlaced rows in the rendered images and required the participant to be 30-60 cm away from the monitor. To achieve the best stereoscopic 3D viewing with these monitors, the line from the user to the monitor was 90 degrees on the horizontal and 12 degrees on the vertical. Viewers wore the passive (polarized) stereoscopic glasses that were included with the Zalman monitor. Participants were seated comfortably with the monitor adjusted to maintain the above viewing requirements. They sat in a darkened room to minimize reflections on the glossy screens and interacted with the game using an Xbox 360 game controller. The controls were set as naturally as possible keeping the same interaction metaphors as with existing games in the genre (the control mapping can be seen in Figure 2). The PCs used were standard Dell XPS 720 computers with ATI Radeon 6870 video cards. The game used was developed using Unity 3D Pro v3.0 and we used the *Stereoskopix 3D* plugin (now called FOV2GO) to provide stereoscopic rendering support. We employed fixed stereoscopic settings: field of view of 24 degrees, interaxial of 100 units, zero parallax plane at 1275 units with our furthest object being 1500 units away from the camera.

3.4 Experimental Procedure

Participants were seated comfortably in the Game User Research Lab at the University of Ontario Institute of Technology. Participants were assigned one of the two random counterbalanced conditions (either in S3D or 2D). Players wore S3D glasses under both conditions. First they completed a demographic questionnaire to determine their gaming ability and preferences. They were then instructed on how to play the game and then played the game until they completed the mission or gave up entirely. After each condition, they completed the GEQ survey online and then played the game again in the next visual condition. After the second condition, participants were encouraged to fill out free-form comments to describe their preferences.

3.5 Results

As previously described, the game recorded the player's performance, measuring and recording attributes such as time of completion, number of deaths, and accuracy. Prior to running the study, we set out to determine a good performance metric that includes all three of our measured quantities. However, we discovered that due to the number of people who had difficulty completing the 2D condition, *time of completion* was more indicative of performance. Thus, here we focus primarily on the amount of time it took the average participant to complete each checkpoint, level and game, since the amount of time was dependent on the number of deaths, and how accurate the player was in shooting targets. Completion time provided us with a simple and easy to understand "score". We were also interested in analyzing the completion percentage (how much of the game the user was able to complete in the different conditions), to provide us with a general understanding of how well participants performed under stereoscopic 3D viewing conditions in comparison to traditional 2D viewing.

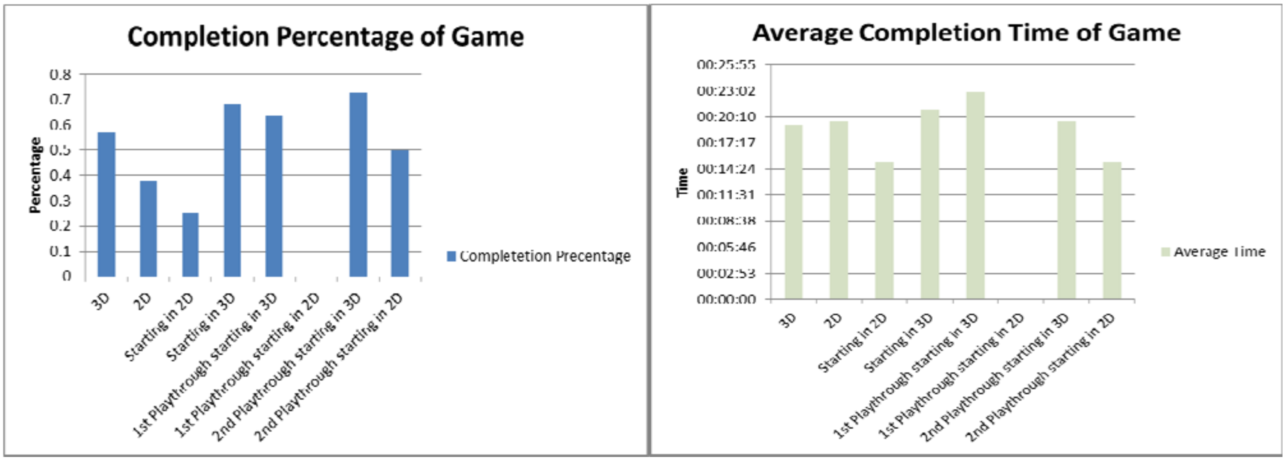

Figure 4. Completion percentage of the game in different conditions (left) and the average time of completion of the game in these conditions.

In Figure 4, a general overview of how well participants performed in the stereocopic 3D and 2D conditions is provided. The 3D and 2D labels above stand for stereoscopic 3D and traditional 2D viewing methods, respectively. The *"Starting in.."* label refers to which condition the participant began their gameplay, and finally, the *"… Playthrough"* refers to the specfic attempt by the participant. Participants started under one condition (either S3D or 2D), and switched to the other condition on their next playthrough. For example the"2nd Playthrough starting in 3D" specification indicates that the the partipant was playing under the traditional 2D display condition. The ordering of the conditions were counterbalanced.

We observe that stereoscopic 3D results in a higher completion percentage (60%), in contrast to traditional 2D displays (38%). In fact, none of the particapants that beginning the experiment on a traditional 2D display were able to complete the game on their first playthrough, while those beginning the experiment on a stereoscopic display completed it 60% of the time. We also conclude that there is a learning effect, since particpants improved on their second playthrough. This may be attributed to the nature of the gameplay, and more specifically, there are several navigational and targeting puzzles throughout the levels which may become easier if solved previously. Another interesting result is that participants who started the experiment in S3D *out-performed* those who played in S3D on their second playthrough, possibly due to the fact that those participants playing under stereoscopic conditions in their second playthrough developed "bad habits" or became frustrated with their first playthrough in 2D. The average completion times are fairly consistent across both conditions; there is a decrease in time during the second playthrough which could be attributed to the learning effect described above.

The level breakdown of the completion percentage (Figure 5) shows that participants playing on a traditional 2D display had problems as soon as the vertical navigation component or interaction along the *depth-axis* was added to the game. This is also supported by the completion time results (see Figure 4). All partipants had similar completion times on the first level, however completion times on the next three levels (Vertical Navigation, Basic Targeting and the Combination Level) were much higher for the participants whose first playthrough was in 2D.

3.6 GEQ and Free form comments

Participants completed the Game Engagement Questionnaire to provide us with a measure of their engagement after each condition. They were also encouraged to describe their preferences, and provide other general comments in the free form section at the end of the study. In general, 16 of the 21 participants indicated in their free-form comments that the S3D experience was more enjoyable and that they preferred the S3D, while only two (2) participants preferred the 2D. Both of these participants played the S3D condition first and indicated in their comments that this helped them learn the game mechanics allowing them to complete the 2D version faster and more effectively. Their comments to this effect were:

> *"The second session [S3D] was more fun, since I had picked up the nuances of the game in the first session. During the first session I had to become familiar with the up-and-down movement of the ship, and how the environment changes to match my elevation (i.e. blocks becoming transparent if I am under them)."*

"The second time [S3D] around it seem to happen fast. I was able to do it quicker than the first session. Interesting game and would probably play it again if there were more levels."

Three (3) participants remained neutral and did not indicate a preference. A paired samples t-test indicated that there were no significant differences between the GEQ scores $t\,(21) = -0.132$, $p = 0.896$ in general for the two conditions.

3.7 Discussion and Future Work

Here we presented *Z-Fighter*, a a game that we developed that requires the player to interact directly along the stereoscopic 3D depth axis. We also presented the results of a user study that was conducted to investigate the performance, perception, and enjoyment of this game in stereoscopic 3D vs. traditional 2D viewing. Results indicate that for this particular game, as expected, participants using stereoscopic 3D displays have a significant advantage over participants using more traditional 2D displays when interactions are along the depth axis.

Our results demonstrate that game designers can design enjoyable games specifically tailored for stereoscopic content, and that unfortunately stereoscopic content won't be easily ported to traditional 2D displays. We originally hypothesized that rather than thinking of 3D as a "mode" of the 2D game, designers should design mechanics for the S3D game first and tailor the gameplay towards the 2D viewing "mode". Our results however suggest that depth-axis mechanics are very difficult to adapt to 2D displays. Given that almost no one could finish the 2D version with the depth axis mechanics, it is clear that such adaptations are not feasible. Therefore designers should consider the interaction mechanics for 2D and S3D separately to address the affordances of the display type.

The results of this study indicate a performance increase on interactions along the depth axes that designers should be able to take advantage of when building games specifically designed for stereoscopic content. It also demonstrates that when building a game specifically for stereoscopic viewing, players with traditional 2D displays may find it much more difficult than the intended design.

This study does show significant promise in stereoscopic 3D, paving the way for new interactions and mechanics within an interactive stereoscopic 3D gaming environment. However, it does not provide any indication of whether the appeal of these new mechanics outweighs the negative aspects of stereoscopic 3D (such as player discomfort and increased development time). Furthermore, it does not examine whether there are other depth cues such as shadows and HUD which can allow for similar performance when dealing with interactions along the depth axis in 2D. The second problem provides us with an interesting follow up study to specifically investigate stereoscopic 3D against other forms of depth cues. A follow up study to minimize the learning effects is currently being developed to investigate this aspect further.

ACKNOWLEDGMENTS

We gratefully acknowledge the funding provided for this project by the *Ontario Media Development Corporation* (OMDC), and the *Ontario Centres of Excellence* (OCE) through the iGO3D consortium. We also thank the Social Sciences and Humanities Research Council of Canada (SSHRC) for partial funding of this project through the IMMERSE initiative

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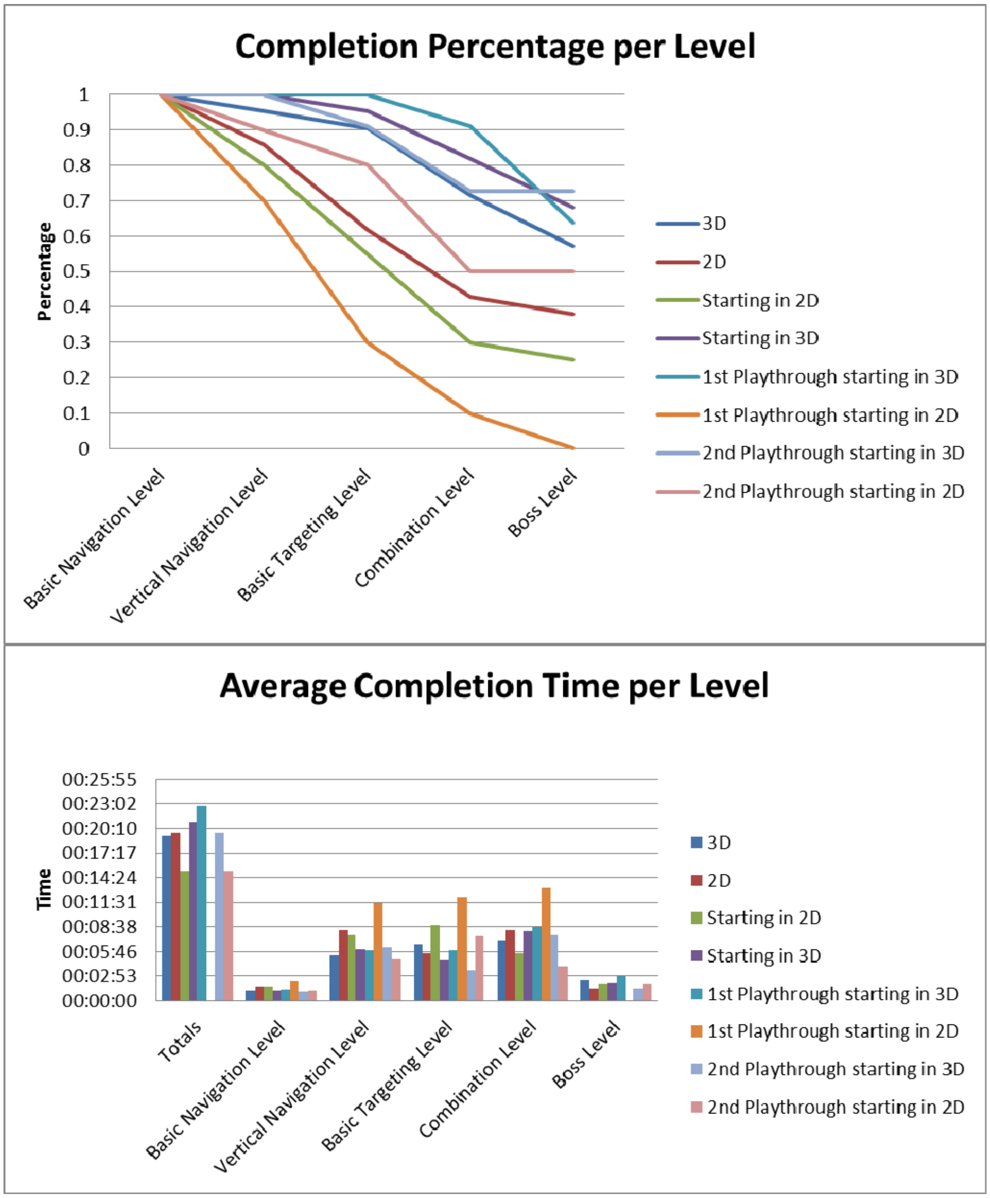

Figure 5. Completion percentage per level (top) and player completion times (bottom). This shows how the various conditions affect the percentage of completion of the game broken out by level/stage of the game. For completion time, lower is better while for completion percentage higher indicates better performance.