Challenges in Experimental Serious Game Design

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INTRODUCTION

Keep the Ball Rolling is a collaborative research project between researchers at Ryerson University, University of Toronto, and Georgia Tech. It stands in a Serious Games tradition that approaches games as instruments for experimental psychology. Benefits of such an approach have been documented (Calvillo-Gámez, Gow, & Cairns, 2011), but Järvela et al. note a lack of guidelines, which "presents challenges especially when comparing findings between studies and in generalizing the results" (Järvelä, Ekman, Kivikangas, & Ravaja, 2014). This abstract suggests such overarching design criteria through the discussion of the design of *Keep the Ball Rolling* as a sample project.

We situate the project in this field; discuss the iterative design aimed to support spatial cognition through a combination of Virtual Reality (VR) and Tangible Interaction design; and close by tracing three challenges we identified in our research.

CHALLENGE

Spatial skills are strongly related to learning capabilities and students success in STEM disciplines has been traced to them (Lubinski & Benbow, 2006). These skills are foundational in many practices, including surgery, design, or emergency response. But teaching them in these contexts is difficult and costly (Baby et al., 2019). The efficiency of VR training in this regard has been documented in principle (e.g. for surgery (Cobb, Taekman, Zomorodi, Gonzalez, & Turner, 2016) for first response (Feng, Gonzáleza, Amorb, Lovreglioc, & Cabrera-Guerrerod, 2018)) but how underlying design decisions support this efficiency remains unclear.

Our project focused on how a combination of tangible and VR interfaces support these cognitive spatial abilities. To that end, we designed and implemented a game targeting penetrative thinking, which is the ability to visualize the internal structure of an object based on examinations of its external form. This spatial skill is essential in fields like geoscience, medicine, and mechanical engineering (Cohen & Hagerty, 2012).

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DESIGN

Keep the Ball Rolling combines tangible interfaces with VR visualization to increase immersion and emphasize embodiment. Players experience the game world through an HMD (Oculus 2nd gen) as they control a virtual slicing tool via a custom-built physical plane. For a design overview see also Chang et al. (2019). Unlike its fast-paced counterpart, *Beat Saber* (Ilavský, Hrinčár, & Hrinčár, 2018), cuts are made carefully and consciously as players have to match a specific target cross section by operating the slicing plane. Imagining the cut and controlling angle and height of the plane are both essential to succeed.

Harteveld argues for a triadic game design that balances "Reality" (referring to real world and historic matters), "Meaning" (referring to cognitive effects), and "Play" (referring to gameplay) (Harteveld, 2011). *Keep the Ball Rolling* attempts such a balance by using gameplay (play) to stimulate spatial cognition (meaning) and improve a player's overall cognitive abilities (reality). It does so in the sub domain of games as experiments. Järvelä et al. identified four additional key elements for the design of such games: "(1) matching and regulating task type, (2) determining data segmentation and event coding, (3) ensuring compatibility between participants and (4) planning and conducting data collection" (Järvelä et al., 2014). The project was custom-built, and compatibility and data collection were not the most challenging problems. Instead, we focused on the first two points, which reside largely in Harteveld's "meaning" and "play" domains.

The main spatial puzzle-based interaction design for *Keep the Ball Rolling* was developed in an iterative design cycle over multiple scenarios and variations. Initially, we tested it as a lock-puzzle, wherein players use the slice to free a trapped bird from its cage by matching a cross section in cutting through a lock. Playtests indicated a lack of context and direction in the task definition. The interface itself worked, but the scenario and motivation in the "play world" were not clear. Instead, the background of trees moving in a simulated breeze appeared distracting. The second iteration, thus, created a linear path that presented clear progression and clearer obstacles, as well as reduced other distractions. It loosely refers to game classics *Marble Madness* (Atari, 1984), itself lauded for spatial cognitive activation (Subrahmanyam & M.Greenfield, 1994), and *Super Monkey Ball* (Nagoshi, 2001), also used to test for spatial presence (Ravaja et al., 2004). However, our focus is not on navigation. Players do not control the ball, but have to overcome obstacles along a blocked path by cutting through these objects with the help of the tangible cutting plane. Quoting another game design trope, background details were reduced to a selection of islands in an endless sea. The aim was to enhance focus on the obstacles themselves in the task design while motivating engagement and contextualizing progression in play. Further iterations fixed the camera in transitions, optimized visualizations of the cutting plane, and adjusted the complexity of obstacles.

The changes ensured that the system remained game-based in nature as well as in appearance, but centered on the experiment's question. Its iterations exemplify a gradual adjustment towards "matching and regulating task type" through optimization of the play world.

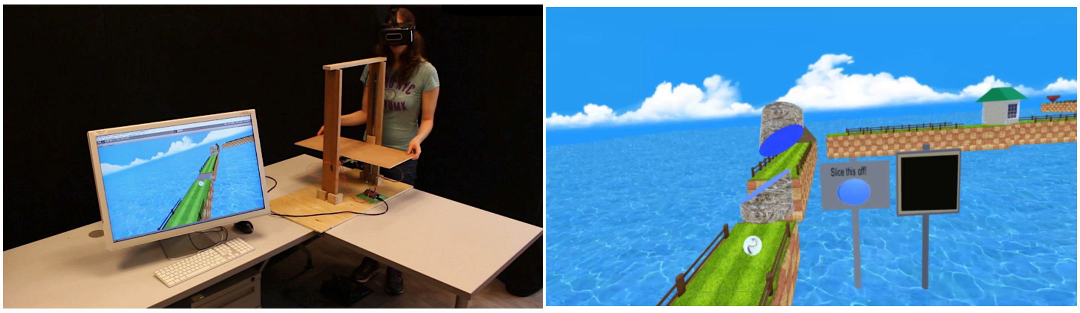

Figure 1: *Keep the Ball Rolling* control and in-game view.

Our game system (featuring motivation, engagement, immersion, playfulness) stands within the whole experimental set up, which is based in cognitive science research (including video data, questionnaires, standardized tests, comparative control conditions). To address "data segmentation and event coding", the system tracks in-game performance in high fidelity. It records the details of individual cuts - time stamps, angle, height, and resulting distance from the target cut. These data are combined with data collected outside the game play experience (via questionnaires, interviews, field notes, behavioral data) in Harteveld's "reality."

CONCLUSION

Three main game design challenges emerged in our Serious Games design process for VR:

- Complexity: reduce visual and other representational details unless they support the key interaction; this assists in controlling the actual variables instead of game world presence effects e.g. reducing level of detail in background visuals

- Engagement and agency: interact only with that which is essential to the experimental question; the agency of the player needs to be clear and follow efficient human computer interaction principles, e.g. providing clear progression and delivering real-time feedback from the tangible interface

- Balance: provide motivation without distraction; optimize visual detail, camera work, lighting, or sound effects as well as interaction design to fit the test, but without losing the positive game qualities e.g. support the win condition through animations of the slicing effect

The adjustments of our design via an iterative process that used gameplay and game tropes while focusing on the experimental hypothesis is one design-based contribution. The emphasis on the whole experimental set up is another. Experimental game design inherently remains within the context of a larger experiment, which include many other components. These need to be accounted for.

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