21. Education Through Navigation

Exploring Wayfinding in Mission HydroSci

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Abstract: Some popular 3D educational video games incorporate vast amounts of content with limited direct instruction. This exploratory study investigates player navigation to determine how wayfinding aids and level design impact interaction with embedded instructional content. To investigate player behavior, participants completed navigational tasks within a larger usability study of an environmental science video game, *Mission HydroSci*. This study adopts a mixed-method approach, including: (a) demographic questionnaires and geographic skills assessment, (b) virtual participant observation, (c) game logs of user actions, and (d) analysis of eye-tracking data related to in-game navigational aids. We found that participant self-reported average weekly gameplay, affect toward science, and navigation experience correlated to player interaction with some wayfinding aids and the speed in which participants completed tasks. In addition to these demographic correlations, in-game player movement and visual fixation duration present differences that may be valuable for future behavioral clustering. We use these results to discuss design implications for 3D virtual learning environments.

Introduction

As immersive virtual learning environments (IVLEs) are increasingly adopted in both K–12 and higher education, it may be incumbent on instructional designers to understand and potentially create virtual worlds that effectively guide students to reach particular locations with embedded instructional content. Game designers often employ navigational systems to support wayfinding in virtual worlds, and researchers have made an effort to understand how these aids influence player behavior. Explicit visual signaling to complete in-game tasks, for example, may be used to reduce cognitive load in an IVLE (Nelson, Kim, Foshee, & Slack, 2014). Although signaling or feedback may aid players in navigational tasks, others have noted that designers may want to hide apparent paths to promote exploration in video games (Moura & Bartnam, 2014). In virtual worlds without explicit signaling, environmental patterns as well as player variables, such as experience with 3D games, may influence the ease with which some players complete navigational tasks (Biggs, Fischer, & Nitsche, 2008). Some researchers (Si, Pisan, Tan, & Shen, 2017) go further to say that demographics may contribute to dominant and subordinate exploration archetypes when conducting in-game tasks.

This exploratory study investigates an additional element in this balancing between demographics, navigational systems, and exploration: topographic knowledge. While conducting a larger, summative evaluation of *Mission HydroSci* (*MHS*), an environmental science and scientific argumentation video game for middle school students, we asked the following question: *What forms of navigational behavior emerge within this* IVLE?

Findings from this pilot study not only provide summative results for *MHS*, but they contribute to the body of knowledge on player exploration in IVLEs. Our results may inform instructional designers on how to include and scaffold embedded content without hindering exploration.

Research Questions

To answer the main RQ of *What forms of navigational behavior emerge within this* IVLE?, there are the following subquestions: (a) *What is the relationship between player demographics and unguided navigation*? And, conversely, (b) *How does the inclusion of an explicit wayfinding cue change player behavior*?

Methods

This mixed-methods exploratory study occurred within a summative evaluation project. Participation was divided into three sessions, each consisting of playing two learning units of *MHS* in 90-minute segments. Participants were compensated with a $50 Amazon gift card after completing each session. We conducted this pilot study during the first evaluation session. The following section of this paper presents the context and design of the IVLE as well as the data collection and analysis methods used during this first session.

Participants

Participants were nine middle school students (Grades 6–8); 56% percent of the sample was female (44% male). We obtained Institutional Review Board approval as well as parental/guardian consent and the assent of the students before beginning the study. Recruitment was conducted via email through established points of contact with local middle schools. To maintain confidentiality, all transcripts and data were anonymized.

Mission HydroSci

To investigate player behavior within an IVLE, we used *MHS*, a 3D game focusing on water in socioecological systems and scientific argumentation. *MHS* aligns with Next Generation Science Standards (NGSS; National Research Council, 2013) and is an i3- and IES-funded research and design project by Adroit Studies at the University of Missouri (MIZZOU). *MHS* positions players as junior scientists on an interstellar mission to establish a settlement on a newly discovered alien planet. Because *MHS* places players in a 3D world with varied terrain, this game is well positioned as a medium to research player navigation in an unfamiliar virtual environment.

Exploration tasks within MHS. This study presents initial findings on player behavior during Unit 2 of *MHS*. We focused on two particular tasks:

1. *Task A—Navigation Without an Explicit Wayfinding Cue*: The player is separated from his or her team of nonplayer characters (NPCs) on an alien planet. To reconvene with the team, the player must use embedded content such as a topographic map as well as an in-game menu that stores "Backing Information," such as previous dialogue and task prompts. The surroundings themselves are also educational content; they provide identifying landmarks that correspond with the topographic map. In addition to this content, the game provides players with an in-game visualization of how to use a topographic map before beginning the challenge.
2. *Task B—Navigation With an Explicit Wayfinding Cue*: Having reconvened with his or her team, the player must gather evidence from the two nearby rivers to determine which will better support hydroelectric power. The game

aids players with a single wayfinding cue that sequentially pinpoints where to gather this evidence. As players move through the environment, they have the opportunity to interact with supplemental instructional content, such as objects and an NPC who provides information regarding watershed size.

Figure 1. (Left) In Task A, participants may use only a topographic map and embedded content to navigate the environment. (Center) In Task B, participants may also rely on a prominent navigational waypoint. (Right) The environment that houses Task B also includes supplemental educational content in the form of in-game objects and an NPC.

Instruments

We employed three instruments to determine player navigational patterns and interaction with in-game content.

Demographic interview. Because curiosity and value influence learner performance (Keller, 2008), we employed the Measure of Affect in Science and Technology questionnaire (MAST; Romine, Sadler, & Wulff, 2017). As this research is ongoing and postintervention MAST questionnaires have not yet been conducted, we instead relied on brief demographic interviews, asking participants to report enjoyment of science and video games (measured with separate 10-point scales) as well as average weekly gameplay hours as this may influence in-game navigation (Biggs et al., 2008; Si et al., 2017).

Topographic knowledge assessment. Because spatial cognitive processes and visual fixations may differ between students with varying degrees of geographic skills (Dong, Zheng, Liu, & Meng, 2018) and might influence in-game behavior, we asked participants to complete a topographic knowledge assessment before playing *MHS*. This assessment, created by a subject matter expert, consisted of four multiple-choice questions related to elevation, predicting water flow, and placement of watersheds based within 2D topographic maps.

Navigation experience questionnaire. We adopted three Likert-scale questions to evaluate participant self-reported navigation experience in everyday life (Si et al., 2017). They are: (a) Every time I leave home, I have a clear understanding of the distance I have traveled and directions to get home, (b) I am easily disoriented in an unfamiliar environment, and (c) I have a good spatial memory of places I have visited. For example, I can recall the placement of objects throughout a room I recently visited. According to Si et al. (2017), these questions embody key aspects of navigational abilities of distance estimation, spatial orientation, and spatial memory.

Play Measures

For this initial study, we used three play measures to investigate relationships with the instrument data.

Eye tracking. Because eye tracking may provide an understanding of attentional processes (Duchowski, 2017), participants wore Tobii Pro Glasses 2, a wearable eye-tracking system, to capture viewing behavior while conducting the gameplay tasks. We used the associated Tobii API to help conduct live-stream observation and to scrutinize postrecording analytics. For this pilot study, we examined players' total fixation durations while viewing the topographic map in Task A as well as heat maps showing fixations.

Game logs. In addition to observation, we relied on data derived from game logs. These data included: (a) navigational paths, which depict the movement across the in-game environment, (b) number of instances when accessing navigation aids such as topographic maps and in-game resources, (c) timestamps of completion of both the guided and unguided tasks, and (d) interaction with supplemental in-game objects and NPCs.

Observations. We observed each task, making note of emerging patterns of in-game movement (Boellstorff, Nardi, Pearce, & Taylor, 2012). These observational notes guided additional questions for post-gameplay, semistructured interviews.

Results

Data Analysis

We conducted a multivariate relationship exploration between demographics, in-game logs, and pretest topographic assessment scores. All correlations were calculated based on Spearman correlation formula, which is a nonparametric method based on original data's ranks. Our correlational map highlighted that participant self-reported average weekly gameplay, affect toward science, and spatial orientation as well as distance estimation experience correlated to player interaction with some wayfinding aids and the speed in which participants completed tasks with and without explicit navigational cues.

For the guided Task A, we found a correlation with (a) the amount of time to complete the task and self-reported average gameplay hours (correlation coefficient = -0.6963, p-value = 0.0372) and (b) distance navigated to complete the task and distance estimation experience (correlation coefficient = -0.8141, p-value = 0.007757). These correlations existed for Task B, but they were less pronounced. Additionally, we found that students with higher affect toward science used the topographic map more than their peers (correlation coefficient = 0.7463, p-value = 0.0209). For Task B specific correlations, we found an additional relationship between completion time and spatial orientation (correlation coefficient = -0.780, p-value = 0.0132).

In our investigation of students' prior knowledge level of topology and its relationship with other variables, we did not find a significant relationship with completion time in either the guided tasks or, to our surprise, the unguided task. Instead, the only significant correlation with the topographic assessment was, oddly, with checking the in-game map during Task B (the guided part). We will need more data to verify this unexpected relationship, such as posttest gains, as well as an evaluation of the topographic assessment instrument.

Unguided Navigation Observations

Throughout the virtual observations, players exhibited three different styles of behavior during the unguided navigational task, which we are categorizing under the labels *Tracker*, *Roamer*, and *Mountaineer*.

Trackers. *Trackers* accessed their topographic map an average of 8.8 times during Task A, totaling an average of 5.886 seconds with it open. Observation of in-game movement revealed that these players relied more heavily on the contours of a prominent geographic feature (a climbable mountain). Participants who exhibited this behavior finished Task A in 97.008 seconds. Five participants exhibited this navigation style. These players reported average scores of enjoyment of science as 7.4 and video games as 7.4 on a 10-point scale as well as 13.6 average hours of video gameplay per week. *Trackers*, on average, answered 55% of questions correctly on the topographic knowledge assessment. Concerning real-life navigational experience, players who exhibited *Tracker* behavior reported an average distance estimation score as 4.4, spatial orientation as 2.6, and spatial memory as 3.6 on 5-point scales.

Roamers. *Roamers* accessed their topographic map an average of 11 times during Task A, totaling an average of 5.99 seconds with it open. Observation of in-game behavior revealed that these players used the topographic map to first position themselves and then jettison forward in shorter increments. Participants who exhibited this behavior finished Task A in 117.66 seconds. Three participants exhibited this navigation style. These players reported an average of enjoyment of science as 7.33 and video games as 9 on a 10-point scale. They reported 10.5 average hours of video gameplay per week. *Roamers*, on average, answered 44.6% of questions correctly on the topographic knowledge assessment. Players who exhibited *Roamer* behavior reported average scores of distance estimation as 4.33, spatial orientation as 3.33, and spatial memory as 3.67 on 5-point scales.

Mountaineers. One player exhibited behavior that did not fit into the *Tracker/Roamer* dichotomy. This player accessed the map seven times during Task A, totaling an average of 3.33 seconds with it open. Rather than following the base of the mountain like a *Tracker*, the player decided to climb the mountain range and survey the land to reach the destination. By using this navigational strategy, this player finished Task A in 249 seconds. This player reported enjoyment of science as a 5 and video games as a 7 on 10-point scales as well as an average of six hours of video gameplay per week. This *Mountaineer* scored 0% on the topographic knowledge assessment. This player reported a distance estimation score of 3, spatial orientation as 3, and spatial memory as 4 on 5-point scales.

Figure 2. Examples (left to right) of Tracker, Roamer, and Mountaineer paths.

Analysis of eye-tracking data. Using the eye-tracking analysis software, the researchers assigned an Area of Interest (AOI) to the mountain pass in the topographic map (see Figure 1). Because of technical issues, recordings for two participants (both *Trackers*) were lost, leaving only seven participants to analyze. *Trackers* fixated on the AOI the least with an average of 5.37 seconds; *Roamers* fixated on the AOI an average of 8.49 seconds; the lone *Mountaineer* had the longest total fixation duration with 17.12 seconds. Heat mapping of fixations on the topographic map did not present any notable patterns within nor between the different categories of navigational style.

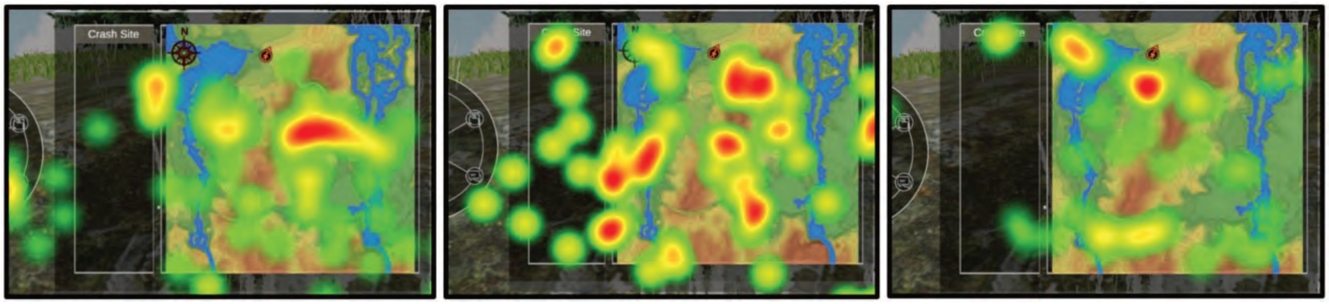

Figure 3. Despite similarities between navigational patterns of some participants, eye-tracking heat maps show a larger amount of variety. Heat maps of Roamers pictured above.

Guided Navigation Observations

Despite the variety of behavior noted in the unguided navigation task, there was little differentiation in player navigational paths in the two guided tasks, which included an explicit wayfinding cue. Although players displayed different patterns of adherence to landscape reliefs near a water feature, navigation patterns noted in Task A did not noticeably transfer to completing the first objective in Task B. Unsurprisingly, there was even less variation in completing the second objective of Task B, which included terrain with another mountain pass; while players could choose to climb these mountains, the landscape was designed to essentially funnel them to their next learning task.

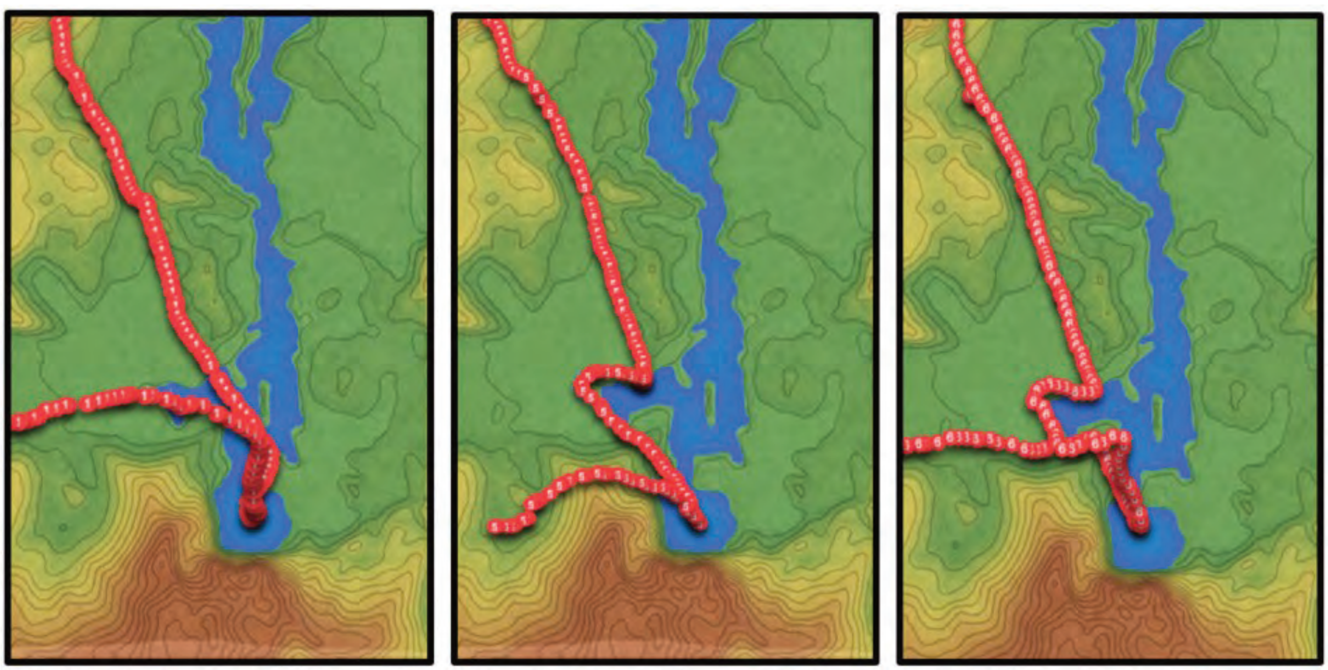

Figure 4. Although there was some variation in approaching the water feature in the map, player navigational paths were relatively similar.

The eye-tracking API we used provides analytics only on static images (such as the topographic map). Because players only nominally used the in-game map after the appearance of an explicit waypoint, we did not conduct eye-tracking analysis for Task B. Instead, we relied on our observations, which showed that players often fixated on the waypoint rather than investigating environmental stimuli.

Supplemental content in the wayfinding task. Rather than exploring the terrain of the IVLE and encountering the supplemental objects and NPC, players appeared to focus almost solely on completing the explicit objective (see Figure 1). This may be due to the design of the environment. For example, although participants had similar navigational paths during Task B, only three participants triggered the cut scene, which hints at the location of the supplemental NPC and content. As such, the sensitivity or placement of the collision event that triggers the cut scene may need adjustment. Nevertheless, despite three participants' viewing this cut scene, only one player actually changed direction to investigate the supplemental content. This may also be due to the researchers ending the play session after completion of the main objective of the unit, rather than allowing participants to revisit the location independently.

Discussion

Overall, we found that participant self-reported average weekly gameplay, affect toward science, and spatial orientation as well distance estimation experience correlated to player interaction with some wayfinding aids and the speed in which participants completed tasks with and without explicit navigational cues. *Trackers*, having the highest scores in these demographics, completed the unguided task the fastest. Their route typically followed prominent contours in the terrain to their destination. *Trackers* also infrequently made use of the in-game menu containing previous dialogue pertaining to the task. Conversely, players who scored lower on the aforementioned demographics (*Roamers* and the *Mountaineer*) used their map more frequently and followed less prominent contours in the environment.

Although there was not a statistically significant correlation between topographic assessment score and task completion time, this preliminary analysis of navigational patterns and topographic skill may be useful for future behavioral clustering or become more significant as we increase our sample size. Additionally, *Trackers* did have the lowest fixation duration on the AOI compared to the other two navigational patterns, which may indicate a better understanding of topographic maps. This would be consistent with findings by Dong et al. (2018) that students more skilled in geography had shorter fixation duration when viewing 2D maps. Further analysis is needed to substantiate this possibility for the current study.

In the tasks that included waypoints, navigational styles exhibited in Task A did not persist. Although the relationship between demographics, average weekly gameplay, and spatial memory remained with regard to completion time, this correlation was less pronounced. Despite embedding supplemental content within this part of the IVLE, only a single participant veered off the direct path to the waypoint to find this supplemental content. Although the inclusion of this wayfinding point may reduce cognitive load (Nelson et al., 2014) and lead to faster completion times, players did not explore their surroundings and access potentially valuable supplemental content.

Conclusion and Implications for Future Research

This pilot study highlighted some of the challenges as well as opportunities for embedding supplemental content into navigational tasks in an IVLE. We found that self-reported average weekly gameplay, affect toward science, and spatial orientation as well as distance estimation experience correlated to player interaction with some wayfinding aids and the speed in which participants completed tasks with and without explicit navigational cues. We were unable to establish, however, whether there were statistically significant relationships between topographic skill and in-game behavior. Nonetheless, based on observation and analysis of visual fixation duration on the topographic aid, player actions certainly did vary in the navigational task without an explicit wayfinding cue. As such, we plan to extend this analysis through our summative evaluation to determine if navigation patterns persist; upcoming units in the game require even greater navigational aptitude as participants survey watersheds for pollution levels without the aid of waypoints. Additionally, as we increase our sample size, future research will benefit from retrospective think-alouds after task completion. This may yield insightful qualitative data regarding navigational behavior. Future publications regarding these research developments will be beneficial to stakeholders in game-based learning, environmental science education, and navigation systems design.

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