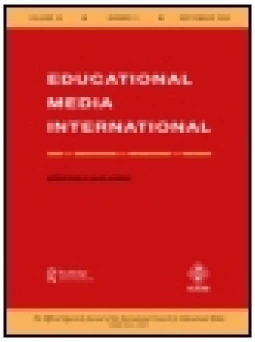

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Relationships between motivational support and game features in a game-based virtual reality learning environment for teaching introductory archaeology

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ABSTRACT

Virtual reality (VR) and game-based learning strategies have rarely been investigated together with a keen focus on motivational processing. This lack of understanding on motivational support of VR game-based learning has hindered the design of such environments to effectively and efficiently support intended learning processes. The study revealed relationships between learners' motivational processing and perceived game features in a VR learning environment for delivering introductory archaeology content to college students. The first part of the study adopted the complementary concurrent mixed-method design, which applied qualitative results to clarify quantitative findings to delineate motivational support perceived by 40 participants. The second part employed quantitative survey data only from the same sample to reveal perceived game features and relationships between motivational support and game features. Findings suggest that learners' motivational processing was supported by the Confidence and Satisfaction components of the ARCS motivational design model. Additionally, not all motivational components were supported by perceived game features according to multiple regression analyses. The discussion of the findings is focused on in what areas and to what extent multimedia-rich VR elements might compete with game-based learning in the same learning environment for learners' limited cognitive and behavioral learning capacities.

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Virtual reality; game-based learning; motivational support; ARCS motivational design model

Introduction

Like many natural sciences, a critical component of archaeology is field work. Excavation experience is critical, and in many cases, college and university anthropology departments require field experience as part of their undergraduate

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curriculum. For financial and logistical reasons, field experience is not an option for most students. At the same time, today's students are largely visual or visual kinesthetic learners, preferring to be engaged in course content through exploration and interaction (Jukes, McCain, & Crockett, 2010). Similarly, research has repeatedly shown that these experiences significantly increase students' interest, learning, and problem-solving abilities (Boyle et al., 2007; Da Silva, 2014; Fleischner et al., 2017).

The challenges of teaching archaeology in the classroom are well met by the unique capabilities of virtual reality (VR), a computer-generated simulation of a three-dimensional world that allows a user to interact with their environment in a natural way, thereby transforming data analysis into a sensory and cognitive experience. We present the design and delivery of an immersive, interactive virtual archaeology course for university undergraduate students that teaches archaeological theory and the physical methods of archaeological field excavation using game-based design. At the same time, we will assess the efficacy of this technology and its integration into a larger archaeology curriculum. In particular, we evaluate learning outcomes through multiple modalities to evaluate the effectiveness of game-based VR learning within this specific test case.

Virtual reality has its home and largest application in the gaming industry. Generations of learners have grown up immersed in technology, and digital gaming has become ubiquitous (Jukes et al., 2010). As such, the presentation of educational content using a VR environment lends itself to a game-based approach. Many have agreed that game-based learning, with its multifaceted features and interoperability between different genres, is capable of engaging learners with fantasy-enabling environments, competitive activities, and opportunities to control the causal relationships between their actions and outcomes (Gunter, Kenny, & Vick, 2008; Hamari et al., 2016; Moreno-Ger, Burgos, Sierra, & Fernández-Manjón, 2008; Raybourn, 2006; Rieber & Noah, 2008; Westera, Nadolski, Hummel, & Wopereis, 2008). Its practical educational values, however, need further investigations grounded in learning theories and instructional design evaluation and research (Garris, Ahlers, & Driskell, 2002; Squire, 2005).

Unique affordances of virtual reality for teaching archaeology

Archaeological field work involves exploration and discovery, a significant physical component, and the manipulation of 3D objects, making it challenging to present in a traditional classroom. Theoretical and methodological issues become more real, comprehensible and intriguing if there is an opportunity to handle evidence and personally wrestle with fundamental problems of identification and quantification. The physical action allowed by VR and that is proposed with this project is designed to engage students in activity that is similar to the activity they would engage in in the real world as they learn foundational principles of archaeological field work. This whole-body immersion is also an effort to increase a student's physical engagement with digital content to reacquaint themselves with their body's sense of proprioception and physical cues that are absent in traditional digital displays like computer or phone screens. VR offers additional capabilities for learning and practicing archaeology that are absent from more traditional learning modalities, including:

- Physical interaction and manipulation of artifacts through intuitive interactions
- Opportunities outside a student's normal experiences, like excavating human remains or prehistoric artifacts and constructing a building from archaeological ruins. Since many archaeological artifacts are unique, valuable, and incredibly fragile, students are limited in what archaeological materials they can handle. Virtual artifacts are easily recovered, allowing students access to otherwise unavailable materials.
- Exploration and discovery that are part of archaeological field work but an impossibility in the real world; a student can intuit where and how to look for hidden objects in virtual space based on accumulated data and an ability to recognize patterns through repetitive experience
- Realistic recording and measuring of data (documenting location and description of artifacts in situ)
- Reconstruction and visualization of a bigger picture

The innovation and instructional integration

This study test-designs a virtual reality scenario in which students are immersed in the methods and tools typically used by archaeologists to understand spatial and temporal concepts using the scientific method. As they proceed through a "dig," students will put these concepts into practice by critically thinking, generating ideas, and evaluating hypotheses within the context of a VR video game.

The subject matter delivered by this prototype is the equivalent of approximately four to six weeks of the curriculum in an introductory archaeology class (based on the syllabus of the Introduction to Archaeology course at a Midwestern US Research One land-grant university). The activity is designed for a single user with interaction and direction provided by the professor, as needed. The single-user game would later be combined into a larger, group-focused effort.

The virtual environment has been created based on the concept of a stratigraphic excavation, that is, a site formed by successive layers of soil deposited over a long period of time. The virtual excavation is a fictional site that was created with the ability to focus student attention and activities on specific aspects of the environment to address different topical foci and different learning objectives. This is a cave site that is both visually engaging to capture students' interest and stratigraphically complex to promote advanced level excavation scenarios. It has the added benefit of being a novel and exotic location, lending itself to the "fantasy world" that is a feature of many digital and virtual games. A student is to be totally immersed in this environment with the ability to interact with its relevant features.

Technology

The project is developing a room scale virtual excavation experience based upon the HTC Vive VR platform, which is a high-quality, mass-produced, low-cost, consumer VR system that became available in 2016. It includes a PC with a VR-capable graphics card, the HTC VivePro wireless VR headset, two trackable hand controllers and two base stations for emitting a tracking signal. Two base stations are installed at opposite sides of a room and project infrared laser stripes across the room, which are detected by photodiodes on the headset. Users hold controllers that can be tracked so that interaction with objects in the virtual world can be simulated. These affordances of the HTC Vive system allow us to most closely match the size and interactions of an actual excavation experience.

The project is under development using Unreal Engine 4 because of its high-quality graphics, particularly with respect to terrain, particle properties, and dynamic lighting effects (for example, Cascade Visual Effects), since one of the most important aspects of this project is how visually engaging the virtual environment can be for the user. With a huge developer and user community, this education application of the gaming engine can be open source to the public and other developers for testing, use and development. Unreal Engine 4 is already well integrated into the latest VR headsets, and it has been thoroughly developed and refined. This enables us to automatically handle movements of characters and objects, collision detection, lighting conditions, rendering and other forms of physics in the virtual world. We also have been using Blender or Maya to build 3D models of tools and artifacts appropriate for the digging site. These tools allow us to design interaction mechanisms so that physical processes, such as digging and sifting, can be virtualized in a manner that helps communicate the important aspects of the real scenario to the students.

The virtual environment in which a student operates the VR system, a square region of 16 cubic meters, closely mimics the size and shape of a real excavation and should look as realistic as possible. The ground of the virtual world has been realistically rendered by texture-mapping techniques that use data from these photographs. The ceiling and four walls are rendered using panoramic video. The side and top viewing directions are mapped onto the four walls and ceiling in the virtual world. This enables students to feel like they are participating along with a larger team and obtain an immersive

Figure 1. Screenshots of the VR cave.

experience that is close to reality. See the screenshots below from the VR cave. See Figure 1 for the screenshots of the VR cave.

Theoretical and design frameworks

Opportunities afforded by game-based learning

A game is a playful context where individual and teamed players compete in attaining game goals and objectives. The playing process should be a "voluntary effort to overcome obstacles" (Suits, 1978). Nevertheless, playing in games also can be a serious activity in the context of enriching learning experiences, which could require learner-players to make decisions to acquire game objectives (Abt, 1970). Prior literature has effectively proposed certain instructional benefits of digital game-based learning:

- Creating meaningful and hands-on problem-solving experiences for learners. Learners learn from their mistakes, and the mistakes of their peers, to improve skills and discover winning strategies. Vicarious learning, to a large extent, plays a role in affording the intended learning processes (Abdul Jabbar & Felicia, 2015; Boyle et al., 2016; Law, Mattheiss, Kickmeier-Rust, & Albert, 2010).
- Enriching learning experiences by fostering motivation for learners to interact with other players and the game system (Mayer, 2019). This is particularly true in massive multiplayer online role-playing game (MMORPG)(Suh, Kim, & Kim, 2010).
- Affording a wide range of learning complexity across subject matter areas, which allows learners to develop versatile problem-solving skills for science learning (Abdul Jabbar & Felicia, 2015; Boyle et al., 2016; Qian & Clark, 2016).

Design approach: aligning game features to motivational support

In this study we aim to align game features with intended motivational and cognitive learning outcomes. This study adopts the findings of a preliminary

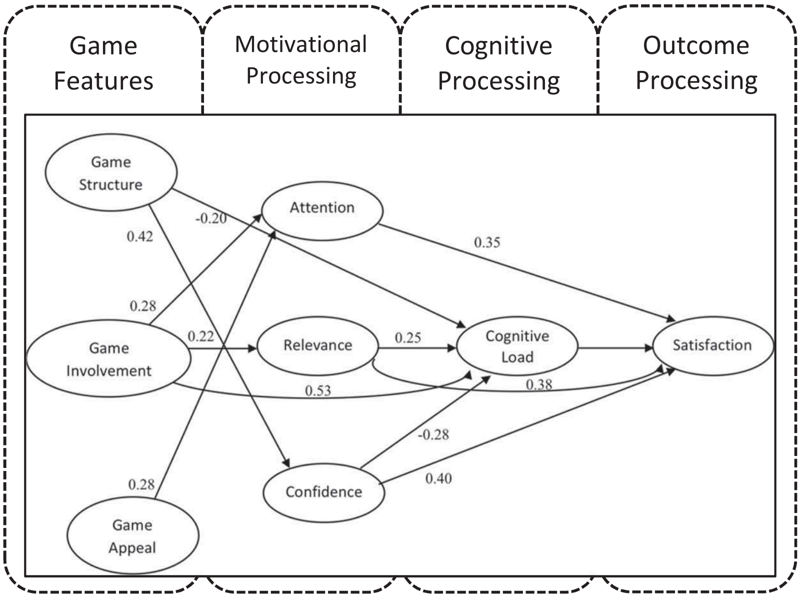

Figure 2. Empirical connections between game features, motivational support, and cognitive learning support (Huang, Johnson, & Han, 2013).

motivational-cognitive processing model in game-based learning environment (Author, 2013) as the guiding design model. The model also provides tangible design factors for measuring perceived game features and motivational support in the game-based VR environment. See Figure 2.

Game-based learning features

Game structure

Rules. Rules embody and guide preferred problem-solving processes for learners to follow. By complying with the rules in the game, learners can gain first-hand experience practicing a methodology to resolve given problems. Additionally, the game rules, to a large extent, ensure fair play among participating players (Bennett & Mary, 2007; Björk & Holopainen, 2003; Boyle et al., 2016; Hays, 2005; Moreno-Ger et al., 2008; Westera et al., 2008).

Tasks. The role of tasks in games is twofold. First, tasks are building blocks or performance benchmarks for players to achieve the winning goals or objectives. Game tasks also embody the outcome assessment criteria. Second, game tasks help players assess their performance formatively and summatively. In many cases, incomplete tasks would require players to visit them repeatedly until their performance meets the task requirement (Bennett & Mary, 2007; Björk & Holopainen, 2003; Boyle et al., 2016; Csikszentmihalyi, 1990; de Felix & Johnson, 1993; Gredler, 1996; Hays, 2005; Ke, 2016).

Learner autonomy. Players have a great extent of control over what paths to take to complete game tasks. This feature helps develop players' self-identities while sustaining their intrinsic motivation. Furthermore, the autonomy helps players develop a sense of ownership of decisions they make during the game play (Abdul Jabbar & Felicia, 2015; Belanich, Sibley, & Orvis, 2004; Malone, 1981; Malone & Lepper, 1987).

Game involvement

Challenges and competition. The level of challenge in games should encourage learners' to cultivate their performance to exceed their potential competency capacity, in order to overcome the obstacles presented by the tasks. If the level of challenge is excessively greater than learners' existing abilities, learners may experience frustration in the early stages of play. Similar frustration also could be experienced if the level of challenge is below learners' current abilities (Abdul Jabbar & Felicia, 2015; Baranauskas, Neto, & Borges, 2001; Bennett & Mary, 2007; Boyle et al., 2016; Csikszentmihalyi, 1990; Garris et al., 2002; Malone, 1981; Malone & Lepper, 1987; Rieber, 2001). Competition in games further differentiates game playing from other human activities. Learner-players could compete with themselves, the game system, peer or rival players, or other teams (Amory, 2007; Crawford, 1982; Csikszentmihalyi, 1990; Moreno-Ger et al., 2008; Rieber & Noah, 2008).

Fantasy worlds in games. Games enable fantastic explorations and experiences that are otherwise impossible to acquire (Kirriemuir & McFarlane, 2004). Players may be placed in a different social, spatial or temporal context to experience different form of lives or identities (Abdul Jabbar & Felicia, 2015; Amory, 2007; Crawford, 1982; Csikszentmihalyi, 1990; Rieber & Noah, 2008). Fantasies in games may immerse players cognitively, affectively, physically, and socially. Players in turn consider themselves as part of the game environment or the narrative. Competition, fantasy, fun, and mystery are often implemented into games to enhance the immersive effect (Asgari, 2005; Bennett & Mary, 2007; Csikszentmihalyi, 1990; Dickey, 2007; Malone & Lepper, 1987; Moreno-Ger et al., 2008).

Role-playing. Role-playing complements the challenge, fantasy, storyline, and other engaging features of games. Players "pretend" to be someone or something else in all aspects of their interactions with other players and the game system. This feature also enhances players' intrinsic motivation to perform continuously in a challenging game-based environment (Björk & Holopainen, 2003; Gredler, 1996).

Game appeal

Multimedia representations. Today's digital games take full advantage of multimedia representations to embody the aforementioned characteristics. Not only do multimedia representations help reduce cognitive demand on players' limited capacities, but they also develop players' visual and spatial analysis skills (Abdul Jabbar & Felicia, 2015; Ang, Zaphiris, & Mahmood, 2007; Bennett & Mary, 2007; Björk & Holopainen, 2003; Ke, 2016).

Motivational support in game-based virtual reality learning environments

The Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivational design (Keller, 1987a, 1987b) has been adopted for learning technology design and evaluation studies for decades. The four components articulate motivational support in instructional and learning settings (Keller, 2009; Klein & Freitag, 1991). Attention represents how learners might feel cognitively aroused or interesting in completing intended learning tasks. Learners' perceived Relevance is grounded in learners prior, current, and future learning processes and outcomes. The Confidence perception is supported by learners' hands-on learning experiences and opportunities for developing self-efficacy in completing intended tasks. The Satisfaction perception, to a large extent, could be supported by learners' overall assessment of the learning processes and outcomes according to the invested efforts (Chang & Lehman, 2002; House, 2003; Means, Jonassen, & Dwyer, 1997; Huang, Huang, Diefes-Dux, & Imbrie, 2006; Song & Keller, 2001). In the context of game-based learning, Dempsey and Johnson (1998) proposed a scale to measure games' motivational support (ie., the ARCS Gaming Scale). Positive effects were identified when applying instructional games to retain information (Klein & Freitag, 1991). Along with the advancement of learning technologies, the application of the ARCS model for design and evaluative purposes has also been evolving from computer-assisted instruction to fully online courses and to digital game-based learning environments (Author, 2013; ChanLin, 2009; Keller, 1999; Keller & Suzuki, 1988; Shellnut, Knowlton, & Savage, 1999). However, game-based virtual reality learning environments' motivational support has yet to be examined through the lens of the ARCS model based on the literature of this present study. As the instructional efficacy of virtual reality (VR) remains inconclusive (Parong & Mayer, 2018), the motivational support from VR-delivered game features need to be empirically examined. The present study, therefore, is guided by this research question: *What are the relationships between motivational support grounded in the ARCS model and game features in the VR environment to deliver introductory archaeology content?*

Method

The study consists of two parts. The first part adopted the complementary concurrent mixed-method design (Cameron, 2009; Greene & Caracelli, 1997). This part of the study applied qualitative results to clarify quantitative findings to delineate motivational support perceived by participants. The second part employed quantitative survey data only to reveal perceived game features and relationships between motivational support and game features. The study was conducted on a Midwestern US public university campus during a regular 16-week semester. The study recruited 40 undergraduate and graduate student participants through an on-campus anthropology course and campus-wide recruiting emails during the period of three weeks. See Table 1 for the participant demographics.

Instrumentation

Motivational support

The Instructional Materials Motivational Scale (36 items) was applied to measure participants' perceived motivational support (Author, 2006; 2013). In addition, two open-ended interview questions were developed for the complementary mixed-method design:

(1) In what areas and to what extent do you find the learning experience with the game-based VR enjoyable and why?
(2) In what areas and to what extent do you find the learning experience with the game-based VR challenging and why?

Game features

The study adopted the game feature survey (Author, 2013) to measure participants' perceived game features. See Table 2 for the 14-item survey.

Table 1. Demographics of the participants (N = 40).

	# of Participants
Sex	
Male	12
Female	28
Academic year	
Freshman	7
Sophomore	3
Junior	11
Senior	8
Graduate	11
Is this your first VR experience?	
Yes	27
No	13
Is this your first VR experience for educational purposes?	
Yes	36
No	4

Table 2. Game feature factor items from Author (2013) (Cronbach's alpha = .89).

Factors	Items
Game Structure	The game's rules are easy to follow.
	The game's goals are clearly presented.
	The game tasks are clearly presented.
	The game provides all information necessary for me before the playing process.
	The game provides all information necessary for me during the playing process.
	The game provides enough support to help me accomplish the game tasks.
Game Involvement	The game engages me deeply in the playing process.
	The game situates me in a fantasy world.
	The game allows me to role-play.
	The game keeps me interested throughout the playing process.
	The game is fun to play.
Game Appeal	The game's graphics are attractive.
	The game's animations are attractive.
	The game's audio elements (e.g., background music, narrations) are attractive.

In addition to the IMMS and game feature scale, four demographic items were added to the survey. The final survey with 54 items was hosted online with a 9-point Likert scale for participants to respond.

Study procedure

Each participant, upon providing written consent to participate in the evaluation, followed the process below to complete their participation. On average, each participation session took 45 min to complete. All participations were completed in a quiet office space with minimal interruption.

(1) Review a 7-min long instructional video on how to interact with the VR game-based learning module.
(2) Read through task instruction.
(3) Put on the VR headset and get familiar with the handheld trackers, with the assistance of the research team.
(4) Complete the task in the VR environment, which entails retrieving digging apparatus, teleporting to designated digging area, excavating the digging area with tools to locate artifacts, retrieving the measuring tape, measuring the artifacts, and return the digging tools and measuring tape to a designated area.
(5) Remove the VR headset and return the handheld trackers
(6) Complete online survey on perceived motivational support and game features based on the VR experience.
(7) Complete a face-to-face interview to provided open-ended responses on the VR experience.

Findings

Reliability of the instruments

In terms of the online surveys, both instruments reported good scale reliabilities based on the 9-point Likert scale. The IMMS reported a Cronbach Alpha = .88. The game feature scale reported a Cronbach Alpha = .77.

Motivational support

In term of the quantitative data, the IMMS collected participants' perceived motivational support based on the ARCS model. The Relevance component of the ARCS model received the lowest rating (M = 6.54, SD = 1.03) while the Confidence component received the highest rating (M = 7.86, SD = .61). See Table 3 for the rating means and standard deviations from the IMMS.

The qualitative data analysis followed the direct content analysis procedure (Hsieh & Shannon, 2005) to align participants' interview input with predetermined coding categories based on the ARCS model. See Table 4 for the general code descriptions. After transcribing all 40 participants' interviews, each statement was analyzed by two researchers. When appropriate, multiple codes were assigned to one statement to capture all meanings from the participant. The coding process yielded 181 coded statements across all four ARCS codes. The Satisfaction code was assigned most frequently (30) from participants' statements describing how enjoyable the VR learning experience might be. When asked the challenges encountered during the VR learning experience, the Confidence code was the most frequently assigned (39). See Table 5 for the code distribution based on 40 transcribed interviews.

Table 3. Means of perceived motivational support ratings on a 9-point Likert scale (N = 40).

	Mean	Standard Deviation
Motivational support: Attention	7.42	.99
Motivational support: Relevance	6.54	1.03
Motivational support: Confidence	7.86	.61
Motivational support: Satisfaction	7.67	.88

Table 4. Code description based on the ARCS model.

ARCS Code	General Description
Attention	The statement pertains to participants' interest, curiosity, and mentions multimedia elements within the VR environment.
Relevance	The statement pertains to participants' prior experience, connection to the subject matter area, and associations with participants' future learning and VR-related activities.
Confidence	The statement pertains to participants' hands-on experience with the task, the difficulty of the task, the structure of the task, and self-efficacy related to learning from the provided VR environment.
Satisfaction	The statement pertains to participants assessment and evaluation regarding the learning experience from the VR environment.

Table 5. Distribution of ARCS codes among 40 interviews.

	Attention	Relevance	Confidence	Satisfaction	Total
Number of coded statements asked how enjoyable the VR learning experience was.	24	28	21	30	103
Number of coded statements asked how challenging the VR learning experience was.	16	17	39	6	78

Table 6. Means of perceived game features ratings on a 9-point Likert scale (N = 40).

	Mean	Standard Deviation
Game feature scale: Game structure	8.53	.73
Game feature scale: Game involvement	7.87	.87
Game feature scale: Game appeal	6.72	1.14

Game features

Descriptive analysis

In terms of perceived game features, participants rated "game structure" the highest (M = 8.53, SD = .72) and "game appeal" the lowest (M = 6.72, SD = 1.14). See Table 6.

Relationships between game features and motivational support

Upon verifying whether both the skewness and kurtosis statistics are within acceptable ranges (West, Finch, & Curran, 1995) for the collected data, the Satisfaction component from the ARCS model was removed from further data analysis due to its non-normality distribution. Multiple regression analyses were conducted to reveal relationships between game features and perceived motivational support. The generic model with omitted constants is listed below based on a prior study (Author, 2013):

ARC (A, R, C) = Game Structure (GS) + Game Involvement (GI) + Game Appeal (GA)

The regression analyses yielded two significant models:

(1) Attention = GS+ GI*+ GA* (R^2 = .55, $F(3,40) = 14.55$, $p < .01$) where GI significantly predicted Attention (β = .40, $p < .05$) and GA significantly predicted Attention (β = .42, $p < .05$).

(2) Relevance = GS+GI+GA* (R^2 = .29, $F(3,40) = 4.95$, $p < .01$) where only GA significantly predicted Relevance (β = .41, $p < .01$).

Discussion

In term of perceived motivational support based on the ARCS model, the online survey data revealed the lack of perceived Relevance regarding motivational support for participants. Considering the study was conducted in the first semester of the 2-year project, this finding was anticipated by the project team since the scope and depth of the learning tasks within the VR cave were not fully developed. Nevertheless, the low Relevance rating provides a strong design rationale for the project team to better articulate the association between the learning objectives and the deployed tasks in the VR environment. On the other hand, the Confidence component received the highest rating among the ARCS components, which suggests the VR activities has provided participants with many opportunities to acquire first-hand experiences in the covered archaeological tasks and skills. In addition, the Confidence rating exceeds the Attention rating based on the survey data, which implies not only can the VR environment support participants' self-efficacy in learning, but the characteristics of VR environments were shifting participants' perceptions from focusing on high-fidelity multimedia elements of the environment to immersing themselves in carrying out hands-on activities in VR. This finding, grounded in the ARCS model, could suggest the design of VR learning environments to focus equally on the cognitive and behavioral aspects of the intended learning processes. It might be insufficient to only emphasize on "what" learners interact with in VR without considering "how" such interactions should occur.

The qualitive aspect of the motivational support, through analyzing the interview data, presented two patterns. First, participants were focused on their Satisfaction perception (see Table 5) when asked to articulate how enjoyable the VR learning experience was. Participants were able to reflect on other aspects of the VR learning experience regarding the graphics, prior experience in archaeology, and prior experience in VR, to support their satisfactory experiences. See the selected quotes below.

> *"I found it very enjoyable personally because I am an anthropology major and archaeology as my concentration, so it was really helpful to kind of immerse myself in an excavation which is something I haven't done before."*

> *"The graphics are really good right off the bat when I put on the headset on. It was like wow, this is awesome and so that was really enjoyable. The actual excavation too was kind of nice because you knew you were looking for something so it's nice that there is a task involved instead of just like you know lecture information."*

> *"I like the exploring the environment that you are not just task to do the things they have to complete the game, you can actually go and would be nice if you could go up to the stairs and I could do that and try. Yeah, I like that, and I also have never done an excavation, I've seen it, so it was nice that to have that kind of feeling like I am doing this."*

> *"I feel like the actual movements of it is really enjoyable because you may not be able to go to an excavation site, so this will allow people to get that experience. I felt like that was really and you get to like kind of be in the moment."*

The second pattern from the interview data is that participants were focused on the Confidence aspect of the ARCS model when responding to the question on encountered challenges during the VR learning experience. Interface issues seemed to dominate the statements related to Confidence. In particular, participants tried to get used to the “teleporting” function in the VR environment and the movement of the “virtual hands” in relation to the actual physical movements of the handsets. See the selected quotes below.

> *“The most challenging part was just getting used to the equipment since I never done virtual reality before, so I wasn’t sure, I keep teleporting to the wrong area but once you get the hang of it, it was it was actually really easy. So, at first, it’s kind of like hard to navigate on the handset, then it gets easier, so it wasn’t too hard really .”*

> *“I think just getting familiarized with the controller. I was dropping a lot of the items and trying to figure out between the teleport and holding and use of items.”*

> *“It’s just liked a video game, so picking up on how things work I think is the most challenging. Just like picking up how everything works. Yeah, just learning it.”*

Upon triangulating between the quantitative and qualitative findings, both modes of findings complement each other. In particular, both datasets showed that participants’ perceptions on the Confidence and Satisfaction components are more prominent than the rest of the ARCS model components. In comparing participants’ perceived satisfaction between a VR- and VR-less science learning environment, Makransky, Terkildsen, and Mayer (2019) suggest that learners in VR might be focusing more on enjoying the novelty of the environment (i.e., hedonic motivation) than on the learning tasks and materials. If hedonic motivation plays a role in facilitating behaviors in VR, our finding on Confidence and Satisfaction perceptions, to some extent, is supported by the relationship between hedonic motivation and learners’ continuous intention to interact with the computer system (Venkatesh, Thong, & Xu, 2012), which supports learners’ confidence development and enjoyment (i.e., perceived satisfaction) within the VR environment.

The multiple regression analysis results add insights to the influence of impressiveness from VR when it comes to motivational support and game features. First, the absence of Confidence, based on the empirical model from Author (2013), implies that lack of perceived game structure in the VR environment. Although task instruction was given to participants, it is speculated that the immersive and exploratory aspects of the VR might overshadow the perceived learning structure in the game-based VR environment. The absence of Satisfaction component is also consistent with the prior finding that game features could not directly influence the perceived Satisfaction (Author, 2013). When considering both participants’ ARCS rating results (i.e., higher ratings in Confidence and Satisfaction) and insignificant regression relationships between Confidence/ Satisfaction and game features, it suggests the possibility that participants’ motivational processing was not only supported by game features in the VR learning environments.

Regarding the significant regression models, the relationships between Attention and its predictors (Game Involvement and Game Appeal) are supported by a prior study; not only the model is significant, but both predictors were found to have similar level of influence on the Attention components (Author, 2013). The model for the Relevance, however, deviates from the previous finding. Instead of Game Involvement leading to increasing perceived Relevance, Game Appeal was the only predictor in the identified model. It is speculated that participants' lack of educational VR experience might contribute to the finding. Only 10% of the participants have had prior educational VR experience that they could relate to. It is also possible that participants were paying excessive attention to the VR environment's multimedia elements, which might occupy most of their cognitive capacity. A potential outcome would be ineffective connections between newly developed mental models with existing schema in their long-term memory (Author, 2013).

Conclusion

This study adds evidence to the motivational aspect of the VR learning environment when game-based features are embedded. In particular, the study provides preliminary findings to inform the design of VR learning environments that can adequately support learners' motivational processing, which ultimately should lead to efficient cognitive learning. Nevertheless, the study was limited by its small sample size and the formative nature of the VR environment that is lacking comprehensive and long-term learning tasks to engage with participants.

Disclosure statement

No potential conflict of interest was reported by the authors.

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