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Geospatial Google Street View with Virtual Reality: A Motivational Approach for Spatial Training Education

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Abstract: Motivation is a determining factor in the learning process, and encourages the student to participate in activities that increase their performance. Learning strategies supplemented by computer technology in a scenario-based learning environment can improve students' motivation for spatial knowledge acquisition. In this sense, a workshop carried out with 43-second year engineering students supported by Google Street View mobile geospatial application for location-based tasks is presented, in which participants work in an immersive wayfinding 3D urban environment on virtual reality. Students use their own smartphones with Google Street View application integrated in virtual reality (VR) 3D glasses with a joystick as locomotion interface. The tool to analyse the motivational factor of this pedagogical approach is the multidimensional measurement device Intrinsic Motivation Inventory with six subscales: interest, perceived competence, perceived choice, effort, tension, and value, measured on a seven point Likert scale. Scores in all subscales considered are above 4 on a scale of 7. A usability study conducted at the end of the experiment provides values above 3 on a scale of 5 in efficacy, efficiency and satisfaction. The results of the experiment carried out indicate that geospatial Google Street View application in Virtual Reality is a motivating educational purpose in the field of spatial training.

Keywords: education; geospatial applications; motivation; spatial training; usability; wayfinding

1. Introduction

Spatial knowledge is necessary in all those disciplines that make use of geospatial information, such as geomatics, geography, engineering, architecture, urban planning, geoscience and urbanism, among others. This is not only in professional fields, though, as everybody does wayfinding and uses spatial knowledge all the time. It is what enables us to behave and interact in the environments we live in. It can be acquired, in addition to maps (map learning or survey learning), through navigation and wayfinding activities at the ground level. Wayfinding or route-based learning is the intellectual process used to establish the route to get from one place to another one, and it has been a relevant component in spatial knowledge research [1].

The wayfinding process involves mental representations, route planning and estimation of distances, and the user perceives surrounding space and acquires spatial knowledge and orientation about it. Using cartography, the orientation is determined by a geographic north, but with wayfinding there is not a north, and the spatial oriented knowledge is established through the images of the environment [2].

In an educational context, teachers of subjects related to spatial knowledge have difficulties in planning strategies for it development, since traditional mapping activities can be tedious for students,

which causes a loss of motivation. Motivation is defined (in the educational field) as the student's desire to engage in the learning environment [3]. Motivation is a determining factor in the learning process, and encourages the student to participate in activities that increase their performance [4,5]. A student motivated to learn has more possibilities to persist and invest efforts to complete a task [6,7].

In the field of education related to geo-information and cartography, Van de Schee et al. [8] said that it is necessary to make classes more interesting for students, in order to increase their motivation. In this sense, experiences carried out with Augmented Reality and GIS geospatial technologies showed an improvement in the motivation of the students [9–11].

Related to spatial knowledge learning, it is therefore necessary to raise more motivating navigation strategies for students, and outdoor activities could be an alternative. However, wayfinding training educational activity in open environments (open-air environments or real-world environments) involves logistical problems (to transport the participants, weather conditions, among others) and even risk if there are participants with some degree of disability. In this sense, virtual 3D environments with geospatial applications can represent an alternative for carrying out navigation activities. Three-dimensional applications that provide self-localization and orientation in wayfinding are becoming increasingly popular in recent years due to the advancement of technologies in this field [12]. Many researchers agree that virtual reality training is equivalent to training in an open environment, in terms of spatial perception, and that therefore, there are almost no differences in route-based learning between real and virtual environments [13–18]. There are even researchers who conclude that users feel better in a virtual environment than a real one, as they feel they have better control over the space around them [19].

Virtual technologies can make students feel more motivated. Learning strategies supplemented with computer technology in a scenario-based learning environment can increase students' learning motivation [20–23]. Although student motivation is an important and even determinant factor in some cases for the completion of studies, research on virtual reality has been neglected in educational technology. The impact of virtual reality on teaching–learning processes from a motivational approach has not been studied in depth. It is necessary to analyze the motivational factor of a three-dimensional, immersive and dynamic visualization teaching–learning environment such as virtual reality [24–26]. It is also necessary to know if virtual reality is easy to use for the visualization of urban environments. Usability is understood colloquially as simplicity of use. If the degree of usability of this technology is not high, the student could reject it, and this would diminish his or her motivation.

In the present research, therefore, a workshop is presented, in which 43 engineering students experiment in an immersive wayfinding 3D environment, through the Google street view geospatial application on virtual reality visualization display. The impact on the motivation of the students is analyzed in six motivation dimensions. In turn, data are provided on the usability of virtual reality to visualize urban environments in terms of efficiency, effectiveness and user satisfaction.

2. Virtual Immersive Environments with Google Street View Geospatial Application

A virtual 3D environment represents the view that the user would have if he were present in that environment in reality. It is a three-dimensional environment generated by a computer that the user accesses and becomes an active subject within that environment through virtual reality in real time [27,28]. Virtual reality allows a sense of immersion, navigation and interaction [29]. Numerous researchers agree that virtual reality environments are increasingly being used in education given the ability to provide a real-time visualization with which the user interacts in real time, as if in a real world [30–33]. In addition to the educational field, virtual environments are also used in architecture, engineering, medicine and entertainment, among others [34].

Stock et al. [35] established three categories of virtual environments: text-based, desktop and immersive virtual reality (VR). The interaction with the environment is via text in text-based environments. The 3D images are incorporated in a desktop VR, but in a non-immersive mode. Finally, immersive virtual environment, or *immersive on-line real-time 3D environments*, allows a first person practice, in which the

user feels immersed while interacting with the environment through VR 3D glasses and motion sensors. These immersive virtual environments, also called virtual worlds [33], are of great interest to the educational community, and researchers such Nussli [36] claim to integrate the 3D Immersive Virtual Worlds in teaching: "The potential for this technology in a classroom setting seems limitless."

The environment in which the participants navigate in this research is an urban environment represented in 3D through the application Google Street View (installed in the smartphones of the students) on virtual reality mode. Street View application provides an immersive experience, and has been used in wayfinding spatial orientation research for educational purposes [12,37]. This kind of three-dimensional immersive representation is close to the real environment, and allows wayfinders to look around for visual cues to orient themselves. Objects typical of urban environments allow the construction or decomposition of any locality: significant milestones or signals, routes or paths that connect the landmarks and nodes (interchanges or junctions between routes) [38]. Researches in the field of spatial knowledge consider landmarks critical in the interpretation of wayfinding instructions, and consider that adding landmarks in route instructions significantly enhance the wayfinding task, especially for pedestrians [39]. There are even researchers that state that references to street names in route instructions cause significant delays during navigation compared to landmark-based instructions [40,41]. In the experiment carried out in the present research, two of the three landmark categories proposed by Sorrows and Hirtle [42] have been used: visual landmarks (reference points that stand out, are identifiable and are remembered by comparing them with other objects around) and cognitive landmarks (references that are important because of their cultural or social relevance for the user, such as a bar, for example).

Exploratory navigation requires real time interaction [43]. Students move around the environment using a joystick as motion sensor (also known as locomotion interface), which allows them to advance, turn left, right and go back (motion direction). This configuration provides a sense of presence and the user has an immediate return of his/her movements and position, which simulates the physical presence. This sensation is described in the definition that Björk and Holopainen [44] wrote about virtual reality. Interfaces such as virtual reality 3D glasses and a remote control for movement generate, in turn, a feeling of immersion [45]. Waller [46] affirms that navigation through virtual environments (VEs) may depend on the user's ability to manipulate the locomotion interface. In this sense, the joystick allows a very intuitive and low price hands-on training setup for educational purposes (Figure 1).

Spatial knowledge can be acquired through virtual environments that represent real architectural environments [47]. Thus, in this research, we use an urban environment represented through the Google Street View application. Research has been carried out in which it is stated that the estimation of distances in immersed processes using virtual reality is similar to that obtained in open environments [46], and that the acquisition of spatial knowledge is as effective as that acquired in an open environment [48–50].

Figure 1. (**Left**): Woxter Neo virtual reality (VR) 3D glasses. Bluetooth remote control with joystick. (**Right**): Virtual urban environment generated.

3. Materials and Methods

3.1. Participants

The experiment was carried out with 43-second year engineering students from La Laguna University (23 males, 20 females) with a mean age of 22.1 and a standard deviation of 1.85, from the 2016–2017 academic course. None of them had prior training in wayfinding in virtual urban environments and none of them had visited the proposed route before. All participants provided their informed consent to participate in the experiment. All of them had normal vision, or had corrected vision.

To encourage effort in the experiment, this activity belongs to the program of practical scheduled activities in the program of the subject of Cartography and Topography, and an extra mark is assigned to the total of the final score of the subject.

3.2. Experiment Design

The design of the experiment was based on previous experiments carried out by Lynch [2], MacEachren [51] and Liao and Dong [12] in the field of spatial orientation in wayfinding. Participants learned a route from point A to point B on a 2D map in an urban environment, and then performed this wayfinding task (to go from A to B) in a 3D immersive environment. The distance between points A and B was one kilometer.

To represent the proposed 2D urban route, the Google Maps free application was used. The 3D urban immersive environment was displayed using the Google Street View free application installed in the smartphones of the participants. The smartphone was integrated in virtual reality 3D glasses (15 Woxter Neo VR 3D glasses equipped with 15 joysticks), and the student moved around the environment (exploratory navigation) via the joystick with Bluetooth connection for remote control. Participants performed the activity with their own smartphones.

The tool to assess the impact of VR on the motivation of the students was the Intrinsic Motivation Inventory (IMI), a multidimensional measurement device developed for the Rochester Motivation Research Group [52]. The tool assesses the subjective experience of the participants in relation to a given activity, contemplating different subscales or dimensions. In the research carried out in the present experiment, six subscales were analyzed, in accordance with the test instructions: interest/enjoyment; perceived competence, perceived choice, effort/importance, felt pressure/tension, and usefulness, measured on a seven point Likert scale (1: Not at all true, 4: Somewhat true; 7: Very true).

The usability of virtual reality to visualize urban environments was also measured. Usability is defined as the measurement of the capability of product users for working efficiently in an enjoyable way [53]. It was measured using the DGM (Data Gathering Method), described in the Review, Report and Refine Usability Methods R3UEMs [54]. The DGM is a questionnaire, a measuring tool to quantify the usability's components. The first component is Effectiveness (accuracy and integrity). A product is effective according to the degree of accuracy for performed tasks and the accomplishments of the aims it has been designed to fulfill. The second component is Efficiency (resources assigned). A product is efficient according to the speed of the tasks performed. The third component is Satisfaction (fulfilling expectations) and is described as the user's freedom for showing his or her agreement or disagreement with the product's use as well as his or her attitude towards it.

3.3. Method

First phase (1/2 hour): Prior to the activity, participants were told to install the 3D Street View Application on their smartphones. Students were provided with 30 min to connect the smartphone to the virtual reality 3D glasses, and connect the joystick through Bluetooth. The instructor checked if all phones were attached correctly. Once all the connections work, students familiarize themselves for a while with the interface and the Google Street View application in Virtual Reality in a sample scene.

Second phase (1/2 hour): A predefined route was given to the participants in Google Maps in 2D. Students were instructed to remember the route and the related information (streets, landmarks,

turns . . .). They were told that once the process of learning the route on the map in 2D was completed, they could not consult or display this information again.

Third phase (3/4 hour activity and 1/4 hour IMI test): The students then put on virtual reality 3D glasses, in which smartphones were inserted with the Street View application for virtual reality. The students started from the point of origin, and were progressing according to the information acquired in the previous phase. Each time they reached a crossroad they had to turn to go to the next direction. With the joystick they could go backwards, as well as turn left or right. They were asked for successive control points, details that appeared on the route (landmarks), such as, the color of the sign of a store, the number of a portal or the name of one street. When the participants finished performing the activity (45 min), they had 15 min to perform the IMI test.

During the experiment, the instructor was recording the verbal reports of the participants on the landmarks, to verify if the route taken was correct. If the landmark was not correct, the instructor would communicate it to the student in order to repeat the navigation until finding the correct landmark and thus continue with the correct navigation task. All students reached point B, but some took a longer time than others. No student exceeded the 45 min of phase 3 assigned to do it.

At the end of the activity, students performed a usability questionnaire in order to know their opinion regarding the urban virtual reality environments in terms of efficiency, effectiveness and user satisfaction.

4. Results

4.1. Data Analysis

The Cronbach alpha coefficient [55] is calculated in order to estimate the reliability of the questionnaires. The value obtained in the IMI questionnaire (0.87) is enough to ensure its reliability (alpha values above 0.7 are sufficient to ensure reliability). Table 1 shows the intrinsic motivation inventory results.

Scores in each subscale are above 4.0 on a scale of 7.0, except in pressure/tension subscale (2.33). According with the Intrinsic Motivation Inventory instructions, the score of this item is the reverse of the participant's score, thus, a low score indicates that the user has not felt pressure participating in the workshop. In this case, this means that the technology employed has not caused tension or anxiety in the participant during the development of the activity. Therefore, to compare the results of pressure/tension with the rest of the subscales, according with the Intrinsic Motivation Inventory instructions, this score must be reversed, subtracting the item response from 8. In this manner, the reverse score is 5.67.

Comparing each subscale, the highest score is in pressure/tension (5.67), and the lower is perceived competence (4.57). Both results are satisfactory, because both are above 4 on a scale of 7.

Interest/enjoyment: the result obtained (5.57) is high: Students perceive the activity as interesting. The participants perceive virtual reality as an enjoyable technology. This subscale is considered the self-report measure of intrinsic motivation, although the overall questionnaire is called the Intrinsic Motivation Inventory. It is the only subscale that assesses intrinsic motivation, per se.

Perceived competence and perceived choice: These two subscales are considered as predictors of both self-report and behavioural measures of intrinsic motivation. The score is high: 4.57 and 5.35 respectively. Participants believe that the workshop with virtual reality has helped them to increase their interest in tasks related to wayfinding.

Effort/importance: It is a subscale that measures the degree of involvement and effort that students give to their participation in the activity, since they are asked about how much they have tried to do it and how important they consider it to be. That is to say, this measure assesses how hard the activity is for the participant. The results were high in both cases (5.05 and 5.56 respectively).

Table 1. Intrinsic Motivation Inventory. (s.d. Standard deviation)

Intrinsic Motivation Inventory			
Subscale	Average (s.d.)	Item	Score (1–7)
Interest/ Enjoyment	5.57 (0.35)	1. I enjoyed doing this workshop with VR very much. It is an enjoyable activity.	5.33
		2. I would describe this activity as very interesting, because it is a different and attractive educational proposal to practise spatial training.	5.81
Perceived competence	4.57 (0.49)	3. I think I am pretty good and pretty skilled at this activity.	5.05
		4. I think I did pretty well at this activity, compared to other students.	4.58
		5. After working on this activity, I felt quite competent in tasks related to wayfinding.	4.07
Perceived choice	5.35 (0.05)	6. I did this activity because I wanted to.	5.56
		7. I believe I had some choice about doing this activity: the experiment with VR and geospatial application awakened my interest in spatial training.	5.14
Effort/ Importance	5.30 (0.36)	8. I put a lot of effort into visualizing the urban environment in RV.	5.05
		9. It was important to me to do well at each task.	5.56
Pressure/ Tension	2.33 (0.33)	10. I felt very tense while doing this activity.	2.56
		11. I was anxious while working on this task.	2.09
Value/ Usefulness	5.16 (0.16)	12. I believe VR to be of some value to me.	5.12
		13. I think that doing this activity is useful for improving spatial reasoning.	5.14
		14. I think that navigation in immersive urban environments with VR can be useful as a digital educational tool for spatial knowledge training.	5.35
		15. I think this is an important activity to improve my motivation in the field of navigation and wayfinding training.	4.91

Pressure/Tension: It measures the level of anxiety experienced by the student during the activity, so a high value in this variable indicates that the activity could be non-motivating. The value obtained for this variable is low (2.33), that is, the activity has not caused anxiety or tension in the student while performing it.

Value/Usefulness: This subscale measures how people internalize and become self-regulating in regards to the activities that they experience as useful or valuable for themselves. Students consider virtual reality to be a useful educational technology for navigation in urban environments (5.35), which helps them to improve their spatial reasoning (5.14).

Results of the usability questionnaire in a 1–5 Likert scale are in Table 2.

Table 2. Usability Questionnaire. (s.d. Standard deviation)

Usability Questionnaire			
Component	Average (s.d.)	Item	Score (1–5)
Effectiveness	3.65 (0.58)	1. VR is a powerful tool for the three-dimensional visualization of the urban environments.	4.10
		2. The management of VR for the visualization of urban environments is easy and intuitive.	3.85
		3. I better interpret the urban environment with VR than with a street map of Google maps or similar.	3.00
Efficiency	3.73 (0.45)	4. I have been easy and fast spatial navigation with VR.	3.76
		5. I can make turns (changes of direction), and to advance or to return of easy and fast way.	3.71
Satisfaction	3.88 (0.17)	6. I think VR is useful in professions related to the interpretation and representation of the environment.	3.76
		7. I think VR is a good complement to a map and / or plan.	4.00

The Cronbach alpha coefficient obtained in the usability questionnaire (0.71) is enough to ensure its reliability.

The result for Effectiveness (3.65) is high. Students found that VR is a powerful tool for 3D urban environments visualization in an easy and intuitive way. The lowest value in effectiveness is in the 3rd question, but even so, a value of 3 is a high value considering that an emerging technology is compared with the traditional mode of spatial representation.

In relation to efficiency, virtual reality also demonstrates a high value (3.73). Students navigated quickly with virtual reality and they were able to make turns and changes of direction easily.

The questions about user satisfaction also give good results (3.88), and students perceive virtual reality as a tool for the future development of their profession, wherein the conventional resources of cartographic representation will be mixed with new 3D technologies.

4.2. The Observer's Point of View

In the verbal reports of the participants on the landmarks given to the instructor, the students did not use the cardinal points as reference, they did not ask for the north, but they used forward, back, left or right as references to establish the route. This coincides with the assertion of Lynch [2], who stated that the spatial oriented knowledge while wayfinding is established through the images of the environment, not with the north.

Students also reported to the instructor about feelings of dizziness while performing the activity. A total of 50% had not become dizzy, but 15% got a little dizzy, 12.5% got dizzy, 10% got relatively dizzy and 12.5% got very dizzy.

5. Conclusions

The results of the Intrinsic Motivation Inventory in the six dimensions evaluated indicate that the activity performed with geospatial Google Street View application in Virtual Reality serves a motivating educational purpose in the field of spatial training. Students perceive the activity as enjoyable and interesting, and consider it an attractive and different educational proposal for location-based education. This 3D geospatial urban environment with VR is a useful educational tool for spatial knowledge and improves the motivation of students in activities related with navigation and wayfinding.

A 3D environment through virtual reality technology combined with geospatial applications represents a powerful location-based tool for education in the field of spatial knowledge. The motivation research in spatial training carried out in this experiment shows that the present strategy can be implemented in formal teaching to facilitate and motivate the students' interest in spatial knowledge acquisition.

Virtual reality for the visualization of urban environments is also highly valued by users in terms of usability. It is a resource that can be used quickly, easily and intuitively. In their future professional practice, students consider that virtual reality will complement the traditional 2D technologies of representation of the environment. These usability results are similar to those obtained with other three-dimensional visualization technologies such as augmented reality [56]. Regarding the research of the usability of 3D virtual environments, theoretical, technological and methodological aspects still remain to be explored [57].

There are also spatial skills related to navigation, wayfinding and spatial knowledge (such as spatial orientation and spatial visualization), which are a competence to be acquired in numerous STEM (Science, Technology, Engineer and Math) university degrees related to geospatial information. The present paper is focused in the motivational factor, but there is other research conducted in spatial orientation skill development with VR technology in a wayfinding experiment [58].

As future work, and considering that virtual reality is an emerging field that arouses the interest of children, it would be interesting to carry out research to analyse if virtual reality can be used to strengthen geospatial literacy in primary and secondary schools.

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