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PhyMEL-WS: Physically Experiencing the Virtual World. Insights into Mixed Reality and Flow State on Board a Wheelchair Simulator

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Abstract: Psychology has widely probed the relationship between body, mind and emotions, these findings have been traditionally applied to physical learning but its penetration into the academic environment was still slower than expected. Virtual worlds, augmented reality and gamification applied to learning experiences, have once again highlighted the correlation between the emotional state of the student and his learning outcomes. There have been many studies around the concept of *flow* proposed by Csíkszentmihályi in 1988, what factors influence their extent and how to promote it. Although the proposed model is widely accepted by the scientific community there are some studies showing discrepancies between theoretical models and experimental results. The scientific community demands more studies on how to measure flow and how to analyse the factors behind these discrepancies. This paper presents a study with 20 students between 21 and 36 years using a wheelchair simulator to reach awareness about the difficulties that people with disabilities face daily. Experience confirms the discrepancies between emotions calculated from the model and expressed directly by students. Two of the main findings of this study are: (1) the influence of gender on emotions and (2) some of the factors that moderate the theoretical measures to fit empirical values are related to the four defining traits of a game proposed by McGonigal (challenging goals, clear rules, real time feedback and voluntary participation).

Keywords: Accessibility, Simulation, Wheelchair, Virtual Worlds, disability, social awareness, learning, 3DOF, Unity3D, flow state
Categories: L.3.0, L.3.1, L.3.6, L.5, J.3

1 Introduction

Researches in neurobiology and psychology have shown that sensory and motor information plays an important role in cognitive process [Adams, 10]. Along the same line, relationship between emotions and cognition has also extensively tested in particular mental process such as attention, memory and reasoning that are specially related to learning [Dolan, 02]. These findings have had a big impact on the way in which different stakeholders approach the learning process. We are sensory beings, and the more senses are involved in a learning experience; the easier it will be to recover this information when needed [O'Connor, 13]. Our senses are involved not only in external perception but also in our internal mental processes. Our brain barely distinguishes between external experiences and those that originate internally when we remember an experience or just imagine it. That is why both, emotions and physical perceptions are so important in the learning process.

1.1 Body, Mind and Emotions in the literature

The relationships among body, mind and emotions have been traditionally applied to physical domains such as sports [Loehr, 95], dance [Bläsing, 13] or medicine (especially in Easter philosophies) [Chan, 02] under the concept of thoughtness [Jones, 02], but the practical application of this findings in academic environments is still very slow.

General psychological theories such as Multiple Intelligences [Gardner, 06] or Neuro-linguistic Programming [Dilts, 95], [O'Connor, 13] have shown that these findings are applicable to generic learning experiences not necessary oriented to the physical domain, but this approach has not been fully exploited. All these studies have contributed to demonstrate that the alignment of all our systems (sensory, motor, emotional and mental) allows reaching an optimal state of consciousness that Csíkszentmihályi called *flow state*. According to [Csíkszentmihályi, 88], the *flow* is an optimal state of intrinsic motivation, where the person is fully immersed in what he is doing and it is characterized by nine factors: clear goals, immediate feedback, perceived balance between skills and challenge, merger of action and awareness, concentration on the tasks, control, a loss of self-consciousness, an altered sense of time, and autotelic experience (engage in the experience without apparent external reward). Flow state and its influence on learning have been widely accepted by scientific community, but have open two important questions: (1) how to promote and (2) how to measure this flow state.

1.2 Promoting and measuring Flow State in 3DVW

In the last decade, measure flow state and analysing its impact in student's performance has become a very active research area. [Dickey, 05], [Dalgarno, 10], [Choi, 11] and [Ibáñez, 14] have analysed some of the factors that contributes to reach flow state such as realism, immersion, interactivity or gamification. Emergent technologies such as 3D Virtual Worlds (3DVW) or Augmented Reality (AR) have proven to be a great tool for research in this area for two main reasons: On the one hand, they have some of the ingredients that increase motivation and contribute to the flow state. On the other, these technologies provide a controlled environment in which it is possible to operationally measure some of these factors that can contribute to the flow state. According to [Bell, 08] virtual worlds that uses 3D interfaces (3DVW) offers realistic and immersive spaces where user, by means of their avatars, can explore, interact and modify the world. When 3DVW includes haptic devices the sense of immersion is enhanced but new affordances appears on how to effectively support the linking, mutual influence and transitions among activities happening simultaneously in physical and digital spaces to reach student satisfaction and effective learning [Delgado, 12].

[Choi, 11] has identified interactivity and representational fidelity as two of the main technological factors that influence student engagement and can be used to predict their flow state in this environment. But there are other factors such as immediacy of communication, consistency and persistency that are also related to flow state but cannot be used as predictors because has no causal relationship with it. [Bulu, 12] identify also the realism of the experience to increase presence and therefore the student satisfaction. [Dalgarno, 10], [Faiola, 13] and [Ibanez, 14], have used some of this finding about technological factors to promote students' flow state and produce an impact on learning effects (cognitive process, performance and learning outcomes), but as noted by [Engersen, 08], there are some technical and methodological problems related to the discrepancies between theoretical and empirical models and more empirical studies are needed to measure the flow state, its operational components (balance between skills and challenge) and moderating factors that affect this measure in order to validate theoretical models.

In line with the findings of Engersen, this paper proposes an exploratory study using mixed methods (qualitative and quantitative) to measure students' flow state, in an experience in a 3DVW using haptic devices. The proposed approach consists of: (1) design a meaningful experience in a 3DVW that involves students physically, mentally and emotionally, (2) quantitatively measure the flow state with two different methods: first from its operational components (skills and challenge) and then by directly asking the students about the emotions experienced at different phases of the activity. (3) Compare qualitatively both measures to examine the main factors involved in the differences found.

2 How to create meaningful experiences

One of the main challenges of education is not only to achieve better learning outcomes, but also to make educational designs that result in meaningful, transformative and easily recalled experiences. The first question to answer is what ingredients should have an experience to be meaningful?. Traditionally meaningful experiences have been collected in drama, storytelling, mythology, or even religious traditions. Joseph Campbell [Campbell, 08] studied all these stories and identified a common narrative pattern that appears in all of them and called "The Hero's Journey". This pattern describes the adventure that lives the archetype known as "The hero", who goes out and achieves great deeds on behalf of his group. The journey has 12 stages represented in (Figure 1a). These stages may also be interpreted as an inner journey, inherent to any transformative process and particularly in a learning process [Fernández-Panadero, 2013a].

2.1 The design: PhyMEL Framework

PhyMEL (Physical, Mental and Emotional Learning) [Fernández-Panadero, 13a] is a conceptual framework designed with two main objectives: (1) the deployment of meaningful experiences according to the Hero's journey represented in Figure 1a, and (2) the creation of multimedia reports using tangibles and multimedia reports according to the template provided in Figure 1b. To achieve these objectives, PhyMEL explains how to map any learning process (physical, virtual or blended), to the 12 stages of the Hero's journey using the 4 Burch Stages for learning: (1) unconscious incompetence, (2) conscious incompetence, (3) conscious competence and (4) unconscious competence. These 4 steps describe mental states experienced by the learner during his heroic journey. The framework indicates what kind of activities are recommended in each stage according to [Bloom, 56], what intelligence are involved according to [Gardner, 06], what interactions among peers or supervisors are recommended according to [Dillenbourg, 99] and what is the relationship between challenge, skills and flow state [Csíkszentmihályi, 88]. When learning experiences are gamified, PhyMEL provides also some indications about which kind of gamification elements (missions, levels, competition, badges hints, rewards, characters, locations etc.) are recommended in each stage and how to introduce them. This recommendations have been selected in order to maximize student satisfaction and sense of flow according to previous findings by [Avouris, 00], [Beck, 06] and [McGonigal, 11]. PhyMEL Framework can be applied to different granularity levels in a learning experience like a fractal structure.

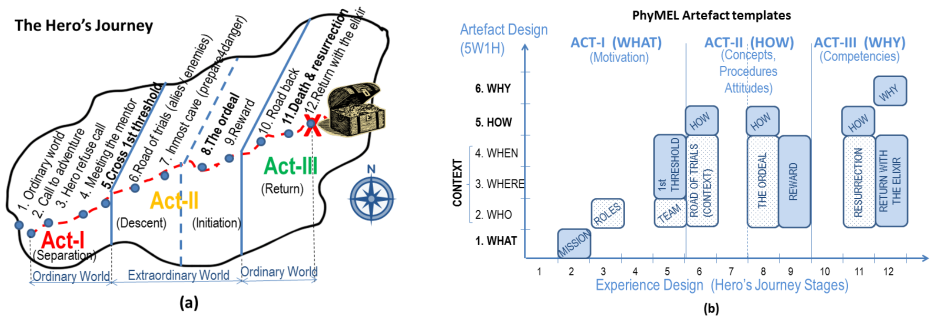


Figure 1: PhyMEL Framework. (a) Storytelling represented by The Hero's Journey. (b) Artefact Design template. Solid modules represent the fixed part of the multidimensional report and dotted modules, the info that can be personalized for each student.

The experience designed for this study corresponds to the stage 6 (road of trials) of the Hero's Journey, act IIa (the descendant) (see Figure 1a). In this phase the student is at the stage of conscious incompetence, recognizes the need to learn but he has not the skills. This stage is characterized by the mistake as part of the learning process, and it is associated with a mental state of anxiety due to the unbalanced relationship among difficulty and skills. This variability in difficulty and skills makes stage-6 an interesting phase to take measurements about the students' state of flow.

2.2 The scenario: Living the city in a wheelchair

In order to select a meaningful scenario for the experience, authors have revised the main priority challenges of the European Commission related with Health, Wellbeing and Inclusive Cities [Horizon 2020, 13] and they have selected the problem of accesibility barriers. This problem has been widely discussed in the literature [Abellard, 10]. The increase of the number of people with mobility problems due to the demographical change has made this problem more acute. Accessibility barriers for people driving a wheelchair are a societal challenge that has to be faced globally, but the way to deal with this problem is different for different stakeholders (generic citizens, wheelchair users, medical staff or architects).

Multiple successful wheelchair simulators [Pivik, 02], [Alqasemi, 07] have been deployed during the past three decades with different technological support (motion platforms, haptic devices, displays, etc.). These simulators have been proved to be an effective learning tool to address physical problems and to deal with role play situations that requires mental toughness (conflict resolution) or emotional control. However there are several main problems that remain unsolved in the literature: (1) most of the wheelchair simulators are partially focused (one specific audience, one set of skills, one disease, one scenario, one assessment method, etc.) , (2) lack of mechanisms to perform quantitative analysis on acquired skills after the simulation and (3) measure the student satisfaction and flow state.

This social background and the possibility to involve learners physically, mentally and emotionally makes medical simulation, and in particular, wheelchair simulators, excellent test scenario to investigate the affordances described in the previous section.

2.3 The tools: PhyMEL-WS Wheelchair Simulator

PhyMEL-WS [Fernández-Panadero, 13b] is a wheelchair simulator designed under the PhyMEL framework [Fernández-Panadero, 13a] that presents a global solution for different stakeholders (medical staff, people with disabilities, architects and general people). In this work we complete our previous research conducting a new experience with 20 users among 21 and 36 years to analyse their feeling using the simulator to reach awareness on living the city in a wheelchair.

The tool consists of an immersive environment comprising a motion platform of 3 degrees of freedom, virtual reality glasses, and a joystick connected to a computer with Unity3D to simulate the experience of driving a wheelchair. PhyMEL-WS has been designed to be modular, safe and easy to use. This section describes the hardware and software components of the simulator and its graphical user interface. The simulator *hardware* consists of a computer to control de simulation and a set of peripherals illustrated in Figure 2. The platform is a real car seat situated on a 3DOF motion platform. The platform contains a three-point seatbelt, to grant safety onboard PhyMEL-WS and is compliant with the voluntary standard called ANSI/RESNA WC19 [WC19-wheelchair, 14] to grant the security of wheelchairs as motor vehicles. The simulator only works when seatbelt is fastened. The simulator *software* consist of (1) a set of javascript and C# modules for Unity-3D and (2) a set of dlls that control peripherals (joystick, VR glasses), communication between 3DOF platform and the computer and synchronization between the real and virtual wheelchairs. Software has been developed using Unity3D.

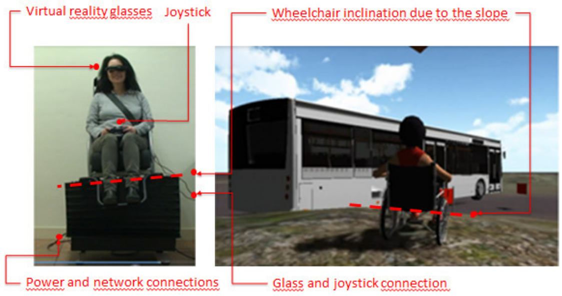


Figure 2: PhyMEL-WS simulator

3 Experimental design

This section describes the main issues related with setting up, deployment of the experience and data analysis. The purpose of this study is to recreate a situation that engage participants physically, mentally and emotionally and analyse their flow state using different measurement techniques. The study focuses on the following research questions: [RQ-1]: What are the main student perceptions about the tool and its intended use; [RQ-2]: What is the relationship between the perceived balance between challenge and skill and the flow state? Match this prediction with the emotion expressed by the student?; [RQ-3]: Are emotions depending on some other factor related to the student as gender, mobility problems, guidance mode or phase that addresses the problem (before-during-after)?. The situation chosen it is the experience of living the city in a wheelchair. The scenario reproduces part of the campus of Universidad Carlos III de Madrid. The virtual world has been intentionally made simple because the goal was not to be innovative but realistic. Some barriers such as a lift or a bus have been artificially added to the scenario. These obstacles have been taken from the nearby environment in order to be easily recognizable by students.

3.1 Participants

The experience was deployed with 20 voluntaries among people who participated Master Universitario en Robótica y Automatización during November of 2013. They were asked about demographic information (age and gender), if they had had mobility problems before the experience and about the guidance mode assigned during the experience. Information about participants is summarized in Table 1

The sample was selected from a university course about robotics for three main reasons: (1) We wanted them to experience architectonical barriers that they face in their daily life, but using a wheelchair. The campus and surroundings provided a common set of obstacles known by all of them. (2) We wanted to evaluate the realism of the experience and thus it was necessary that students had spent a long period of time at the university and they were familiar with the campus that we were going to reproduce in the virtual world. (3) Finally we wanted to evaluate the emotional impact of using the device, not the impact of the device itself. Students in the area of robotics, are already familiar with the use of advanced electromechanical devices and therefore the use of a motion platform does not involve an additional emotional arousal for them.

Characteristics		Frequency (n=20)	Percentage (%)
Age (years)			
	21-36	20	100%
Gender			
	Male	16	80
	Female	4	20
Previous mobility problems (*)			
	None	12	60
	Wheelchair-user	1	5
	Wheelchair-helper	4	20
	Crutches	4	20
	Baby Stroller	1	5
	Other	1	5
Guidance mode			
	Guided	11	55
	Unguided	9	45

Table 1: Users' characteristics. (*) A person may have experienced more than one type of mobility problems and therefore the sum of the percentages in "previous mobility problems" option is greater than 100%

3.1.1 Procedure and data gathering techniques

The experiment was designed as a trial consisted of a tour in a virtual world containing main barriers that a person driving a wheelchair has to face daily (curbs, narrow corridors, stairs, wheelchair lifts, slopes, ground irregularities, bad parked cars and take on a bus), some of them illustrated in Figure 7. The experience was divided in three phases: (1) preparation before the experience, (2) trial during the experience, and (3) feedback after the experience. Data gathering techniques was summarized in Table 2.

During the preparation phase (15min), the students (n=20) received general information about the study and their phases, they were divided randomly in two groups that would use different guidance mode: guided (11), unguided (9), and finally, they signed the authorizations to participate in the study and to be recorded (audio, video) during the process.

During the trial, all participants sat on PhyMEL-WS simulator, fasten his seatbelt, put on the VR glasses and started the simulation performing a route in the virtual world using guided or unguided mode. The guided tour takes 2-3 minutes per user and unguided tour takes different duration depending on user skills. The virtual world partially reproduced an outside view of Universidad Carlos III de Madrid (e.g.: buildings, corridors, ramps and curbs), adding some difficulties belonging to the immediate environment such as wheelchair lift and bus, and emphasizing some obstacles such as the narrowness of corridors or the height of the curbs and ground irregularities in some areas. On the guided tour the wheelchair was moved automatically by the system during a two minutes tour. User experiments kinaesthetic sensations through the three degrees of freedom motion platform and visual sensations through virtual reality glasses. In the unguided tour a joystick was provided to the user so that he could drive the wheelchair and face the obstacles freely and the system only provided visual navigation support using an arrow to indicate the user the location of the next challenge. This phase with monitored in different ways: During the experience, at least two observer took field notes [FieldNotes] to document the situation that were completed with multimedia recordings [MMRecordings] and a stream of data with technical parameters from the platform such as time per obstacle, position, velocity or acceleration [Physics3dof].

During the last phase (5-10 min), when the tour was finished all participants completed a survey [UserSurveys] and informal short interviews [UserInterviews] to provide feedback about demographic data (age, gender, previous mobility problems, etc.) and their impressions using the simulator with open and closed questions.

Data Source	Type of Data	Label
User survey	Questionnaire with open and closed questions and demographic data	[UserSurveys]
User interviews	Unstructured interviews after the experience (non mandatory)	[UserInterviews]
Field observations	Transcription of notes taken by 3 observers	[FieldNotes]
Multimedia recording	Picture and videos recorded during the experience	[MMRecordings]
3DOF plataform	Technical parameters from the platform (t,x,v,a)	[physics3DOF]

Table 2: Data gathering techniques

3.2 Instruments for data analysis

The study has followed an explanatory sequential design analysis strategy in 3 phases: (1) data gathering, (2) quantitative analysis, (3) qualitative analysis. The data gathering phase collect quantitative and qualitative information as shown in previous section and summarized in Table 2.

The quantitative data analysis has been performed using non parametric techniques in R to provide evidences about the main research questions. We have chosen nonparametric techniques for two main reasons. Firstly, because we have a sample with very little data (n=20) on which we cannot assume normality. Secondly, because we make a massive use of Likert scales in the design of our surveys and Likert scales uses ordinal measurement. The problem with ordinal categories is that they have a rank order, but the intervals between values cannot be presumed equal, therefore we have used the following instruments: (1) the median instead of the mean to characterize distributions of ordinal data, (2) the Kruskal Wallis test to compare medians and detect attributes that affect the measures (Table 3), and finally (3) the coefficient of Spearman to analyse correlations among variables.

We have used boxplot to illustrate the distribution of the data with the following settings: (1) central line corresponds to the *median*, (2) box limits correspond to the *quartiles q1* and *q3*, (3) whiskers limits correspond with the limits *q1-iqr* and *q3+iqr* where *iqr* is the interquartile range *(q3-q1)* and finally (4) *outliers* has been illustrated using points beyond the limits of the whiskers.

The qualitative data analysis has been performed using NVivo-10 to explain quantitative results. Data from [userSurveys] have been imported to Nvivo. The survey has been coded in three different ways. (1) We have used one node to code each participant and one node for each qualitative questions, (2) We have been used attributes and data classifications for each quantitative question and demographic data. (3) Finally, we have been designed a thematic hierarchy of nodes using as input the research questions and [FieldNotes] taken by 3 different observers. This hierarchy of nodes, containing information about (general perceptions, emotions, usability and reports), have been used to encode both each individual question (quantitative and qualitative), and also the students' answers for open questions. After coding all this material we have conducted different queries to analyze in-depth survey results and explain quantitative results. The tools used for data analysis have been selected taking into account the limitations imposed by the sample size (n=20) but it would be desirable to replicate the study with a larger number of participants to confirm the validity of the results.

4 Results and discussion.

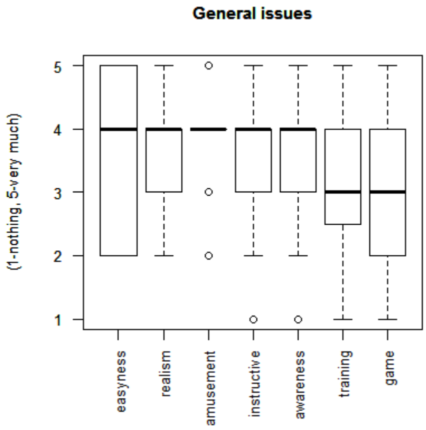
The results presented in this section are obtained mainly from the analysis of surveys [UserSurveys] and data obtained from the platform [physics3DOF]. Qualitative data such as [UsersInterviews] and [FieldNotes] has been used to clarify some findings obtained during data analysis, but more detailed and systematic qualitative data analysis, specially using [MultimediaReports] to detect micro-expressions of the users is required to complete the analysis about emotional states.

4.1 RQ-1: General characteristics and intention of use

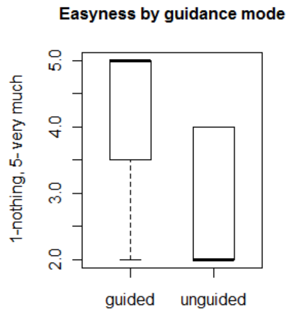
Findings about general issues confirm results obtained in previous experience [Fernández-Panadero, 13b]. Users consider the simulator "easy to use", "realistic", "amusement" and "instructive" (*median* =4 in a Likert's scale of 5 points) in the case of "amusement" (*deviation* = 0), see Figure 3a. They consider also instructive and helpful for awareness (*median*=4). However, their opinion about intention to use as training tool or a game is neutral (*median*=3). These results about intention to use are consistent with the design of the experiment. PhyMEL-WS have been designed for different target audiences with different objectives: (1) general audience to reach awareness, (2) wheelchair users for training and (3) medical staff to assess patients. This experience has been designed for target group-1 and users manifest that it is instructive and help to reach awareness but not show their intention to use as training or as game (functionalities designed for target group 2). Although students show no intention of using the simulator as a game, we thought it might be an interesting feature mainly for groups 2 and 3, in the first case to reduce the anxiety associated with training, and in the second one to experience errors in a pleasant way and without causing harm to patients.

This prototype intentionally does not include gamification elements; however, users express amusement and fun. This finding makes sense because the system has been designed to respect the four defining traits of a game described by McGonigal [McGonigal, 11]: (1) Challenging goals that provides a sense of purpose, (2) clear rules that place limitation about how users can achieve the goal, (3) real-time feedback to maintain motivation, and (4) voluntary participation. No specific feedback messages about user's performance are provided by the simulator, because this issue was one of the subjects of other phase of the study about reports, but visual and physical immediate feedback is inherent to the use of the motion platform and virtual glasses.

These results are the same regardless of the gender of the participants (Kruskal-test p>0.05). Most parameters are also independent of the guided mode, except "easiness" (see Figure 3b) that heavily depends (2.5 points difference in the *median*) of the guided mode. This result is expected: users in the guided mode considered the simulator very easy to use (*median* = 5) because they are automatically transported by the system, while those users doing the unguided tour consider it more difficult (*median* = 2.5) as they have to use the joystick to move the wheelchair through the virtual world and face different obstacles.



(a)



(b)

Figure 3: (a) General Issues. (b) Easiness by Guidance Mode

Dependent variable	Independent variable	Chi-square	Degrees of freedom(df)	P-value
Easyness	Guidance mode	5.1789	1	0.02286
Skills	Previous Mobility problems	3.8705	1	0.04914
Skills	Guidance mode	22.3387	1	2.286e-06
Difficulty	Obstacle	65.0358	9	1.420e-10
Difficulty	Guidance mode	6.5647	1	0.01040
Difficulty	Gender	10.8174	1	0.001006
Difficulty	Previous mobility problems	4.791	1	0.02861
Emotions 4median	Gender	4.7539	1	0.02923
Worry-Control	Gender	4.3379	1	0.03727
Anxiety-Relax	Gender	3.8587	1	0.04949
Performance feedback	Previous mobility problems	6.0873	1	0.01362

Table 3: Kruskal-Wallis

Spearman correlation coefficient has been used to analyze possible relationships among the measured factors but any significant relationship has been observed in most of them. Just found a slight correlation between realism and amusement (ρ=0.7298), which confirms previous findings in the literature [Conole, 04], [Dickey, 05], [Choi, 01], [Ibáñez-Espiga, 14] that emphasize the importance of representation fidelity on emotional state of the student and [Bulu, 12] who asserts that it is important to consider the realism feature of the environment to increase the sense of presence and therefore the satisfaction of learning.

4.2 RQ-2a: Measuring the flow state. Empirical and theoretical models.

According to the 9 factor model of Csíkszentmihályi, the balance between skills and challenge affect the students' state of flow (Figure 4a). To analyse the emotions experienced by the student during the simulation authors have perform two different tests. (1) On the first one (Figure 4b), students were asked about the level of skills and difficult experienced in each obstacle (before, during and after facing them), and the emotional state have been calculated according to the Csíkszentmihályi model (Figure 4a). (2). In the second test, we have followed the opposite approach. Students were asked directly about their feelings during the experience using bi-valuated Likert scale of 5 points. The results of the second test has been represented in Figure 5.

First test (Figure 4b) shows the most frequent emotions in descending order are: "neutral", "flow" and finally in the same level: "arousal", "control" and "anxiety". Most observations are positive emotions concentrated in the upper right quadrant: "flow", "arousal" and "control". But negative emotions are also present in the left side of the graphic and "anxiety" in particular is significantly represented.

However in the second test (Figure 5), when students were asked directly about their emotions, all the emotions expressed were positive (*median*=4) except in the axis "anxiety_relax" and "worry_control" that appears as neutral (*median*=3). Analysing in more detail emotions in these two axis we can conclude that this difference is due to a dependence of the emotions by gender that will be analysed in RQ-3.

Our preliminary results shows that emotions calculated using skills and difficulty (test-1, Figure 4b), and those expressed directly by the student (test-2, Figure 5) does not correspond exactly. These results confirm the findings of [Engeser, 08] that asserts that there are other factors beyond the Csíkszentmihályi's model that moderates the students' flow state. This quantitative analysis have been performed using only one of the 9 factors described by Csíkszentmihályi, so more research is needed on this point to complete the quantitative analysis of the theoretical model.

One of the evidences found in our study is the fact that there are other factors beyond the skill-challenge balance that may improve the student's satisfaction and flow state. Although the model predicts a high state of anxiety in students (Figure 4), however the emotions expressed by the students are positive or neutral (Figure 5). Our first hypothesis based in [FieldNotes] and [UsersInterviews] point in two directions: (1) the importance of making the error a fun experience and (2) the importance of offering students mechanisms to get out of conflict situations when needed. An example of this factor is the respawn button (Figure 7). These mechanisms provides the students confidence to tackle more difficult challenges because if they find stuck, may jump to a secure position and retry the challenge. These factors are closely related four defining traits of a game described by

McGonigal [McGonigal, 11] and mention in RQ-1, but a more detailed analysis of qualitative data is necessary at this point to confirm the hypothesis.

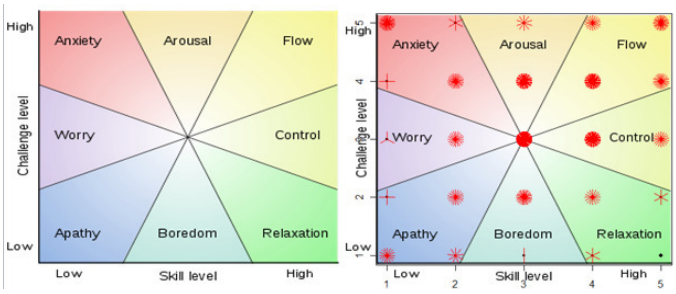


Figure 4: (a) Mental state in terms of challenge level and skill level according to Csíkszentmihályi zentmihalyi's flow model (src:wikimedia commons). (b)Mental state calculated using difficulty and skills expresed by the student in a Likert's scale of 5 points. Multiple points are plotted as 'sunflowers' with multiple leaves ('petals'), one for each observation.

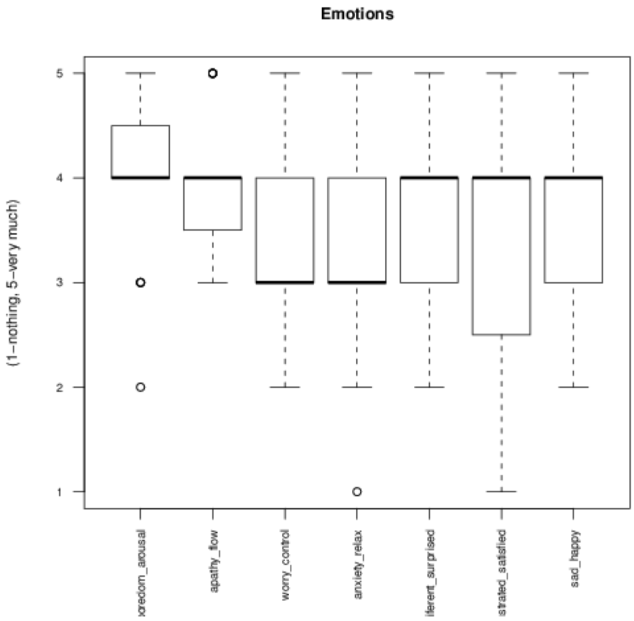


Figure 5: Emotions perceived by users. Number indicates the intensity of the emotion from high intensity of the negative emotion to high intensity of the positive emotion incrementally. For example for the axis apathy-flow: 1-high apathy, 2-low apathy, 3-neutral, 4-low flow, 5-high flow)

4.3 RQ-2b: Balance between skills and challenge per obstacle.

In previous section we have analysed how the balance between skills and challenge (difficulty) affects the students' flow state. In this section we will analyse deeply this parameters according to the different architectonical barriers.

Our results indicates that users' perception of their own skills to face different obstacles are independent of the stage (before, during, after), gender or whether the user has or not previous mobility problems (Kruskal test with *p-value* >0.05). Students perceive only a change in their skill level when the obstacle to face is considered very difficult to overcome (*median* ≥ 4) (See Figure 6). The perceived skill level increase when the challenge is repeated until the obstacle is overcome successfully and decrease in two other cases: (1) when user retries and fails or (2) when he does not try again. There are 3 situations in which the student experiences a change of skill level before and after the obstacle. The first one is in the case of stairs, after passing the obstacle user feels skillful (skillsBefore=3, skillsAfter=4). The other two are related to maneuver inside the bus and get off of it, in which the student experiences a decline in the perceived skill level (skillsBefore *median*=3.5, skillsAfter *median*=3). Students in the unguided tour usually get stuck at some point in situations such as those illustrated in Figure 7. This forces them to eventually press a button (respawn) that returns them to a stable situation in the scenario.

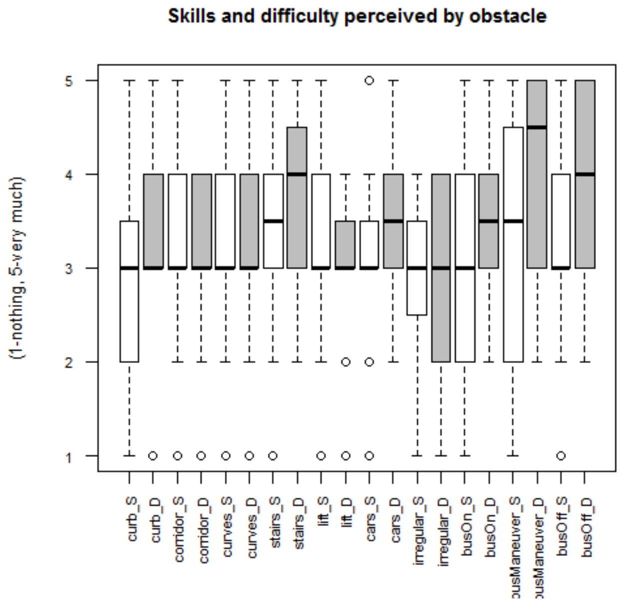


Figure 6: Skills (white) and difficulty (grey). Average value calculated with students' perceptions before, during and after the obstacle.

However, the behaviour of students after clicking respawn-button is different in the case of the stairs and bus. In the case of stairs students retry the obstacle until they successfully complete, however if the bus they do not retry the obstacle after they press respawn. Thus in the first case, the result is that they have overcome the obstacle and feel empowered and more skilled, while in the second case they feel frustrated and less skilled.

More research is needed at this point to determine the cause of this behaviour and to foster first behaviour (retry) that empowers the user. Possible factors involved are: the time spent in the obstacle before respawn-button is pressed, the position in which the student is located after respawn-button is pressed, the overall difficulty of the obstacle, and the obstacle situation in the whole activity that can influence student fatigue when facing it.

Figure 7: Main problems maneuvering in narrow spaces, curbs and stairs.(1) The corridor is bounded on one side by the wall, and the other by columns. When users maneuver backwards, they can fall or get stuck between columns. (2) It's difficult to reach the center of the platform without falling down if the the lift does not have safety measures. Implementation of a Respawn button allows users exiting for conflicting situations situating them in a safety point near the obstacle.

Analysing the difficulty perceived by obstacle (Figure 6) we can see that the distribution of difficulty measures fits nicely the experimental design according to the PhyMEL framework [Fernández-Panadero, 13a] using three difficulty levels and a narrative structure in 3-acts (4 stages). The results show that no obstacle is considered especially easy this contributes to avoid boredom and apathy (Figure 4a). Obstacles are perceived by the students in three difficulty levels: Normal difficulty (*median* = 3), medium difficulty (median = 3.5) and high difficulty as (*median* = 4, *median*=4.5). The order in which the obstacles are distributed in the scenario is the same as that shown in x-axis Figure 6. The orchestration of the perceived difficulty for students fits very well the design in 3 acts and 4 stages as described in PhyMEL framework:. (1) simple obstacles presents a first step to motivate the student (2a), in the midterm the difficulty increases to test the skills learned, (2b) after 1st test difficulty decrease temporarily to give confidence to those who failed and provide a rest to those who succed (4) finally at the end of the tour, when the student has already acquired some skill in handling simulator, the most difficult obstacle is presented and the student has to use previously acquired skills to overcome it.

Analysing in depth difficulty we observe that there are no dependency on the phase (before, during after) or previous mobility issues (Kruskal test *p-value* >0.05). However, there is a significantly dependency on guidance mode and gender (see Table 3 and Figure 8 for specific values).

The distribution of difficulty per guidance mode is significantly different (*p-value* <0.05) but present the same median value. It is particularly curious that women perceive the difficulty of the obstacles one point ahead of men (on a Likert scale of 5 points). However, they feel equally skillful than men to face them. This fact will affect the balance between skills and difficulty perceived by women and consequently the flow state according to Csíkszentmihályi. this fact will be discussed in more detail in RQ-3.

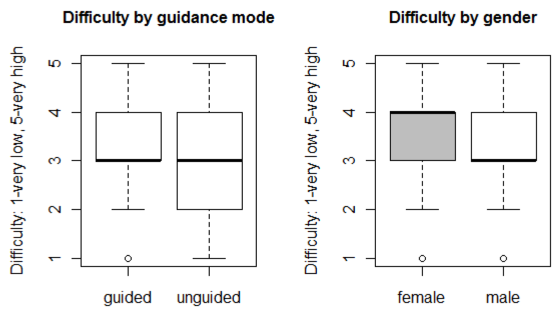


Figure 8: Difficulty perceived by guidanceMode (a) and gender (b)

4.4 RQ-3: Other factors that affects the flow state: gender and guidance mode

Analysing in detail the results of the first test (Figure 4b) using Kruskal-Wallis we can conclude that the emotion experienced by students is neutral (*median*=3) for most of the obstacles and only in the stairs and inside the bus the students experience flow state. This finding is also directly deductible from the information obtained in the analysis of difficulties and skills (Figure 6).

Analysing more deeply the result of the second test (Figure 5), we can conclude that the median of the emotion expressed by the students depends on gender (Figure 9) and guidance mode (Figure 11). The dimensions that shows significant dependency (Kruskal-test *p-value*<0.05) are "worry-control" and "anxiety-relax" (Table 3, Figure 9, Figure 10)

Averaging the degree of the 4 emotions represented by Csíkszentmihályi (Figure 10a) we can see how women tend to feel less positive emotions than men (negative emotions represent low levels and positive emotions high level in the Likert scale). It is important to note that the fact that women experience emotions significantly less positive (*median* = 3.25) than men (*median*= 4), no depends on how skillful they feel internally, but rather on how they value the external circumstances. Women in the study perceived obstacles as more difficult than their male peers what causes them feelings of anxiety and worry.

Although these results show statistical significance using Kruskal Wallis test it would be necessary to conduct an experiment with a larger number of students to confirm this point.

Regarding the guidanceMode, the two most affected dimensions are anxiety-relax and indiferent-surprised. Students from the guided tour expressed to be more relaxed than their fellows in unguided tour, mainly because their participation in the process were more passive. They also were more surprised by the experience because they had no control over the movement of the wheelchair (position-x, velocity-v, and acceleration-a), and how to approach different obstacles.

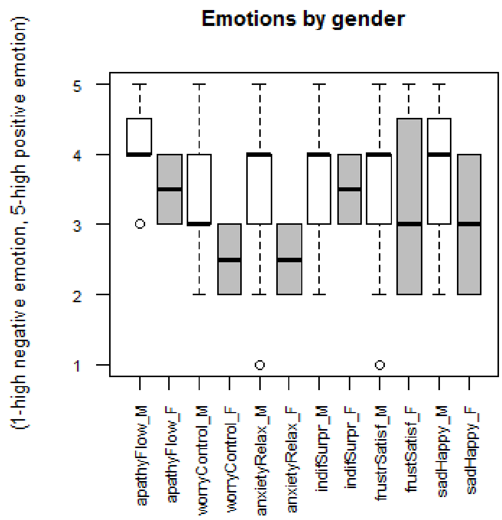


Figure 9: Emotions by gender.

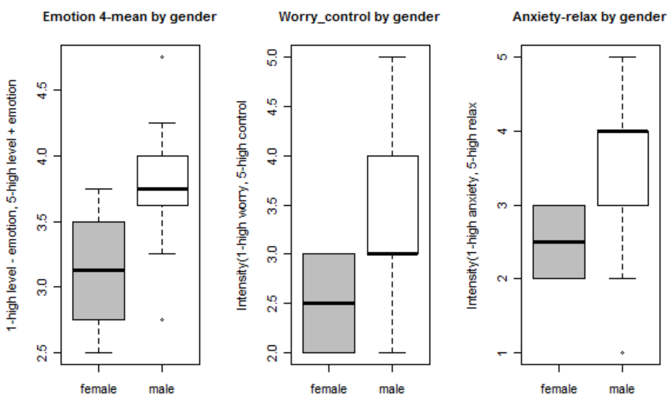


Figure 10: Dependency of emotional state according to gender white-men, grey-female. (a) Median of the emotions expresed in the 4 axis. (b) Emotions expressed in the worry-control axis, (c) Emotion expressed in the anxiety-relax axis.

5 Discussion and conclusions

This paper has presented a case study with 20 students between 21 and 36 years using a wheelchair simulator to reach awareness about the difficulties that people with disabilities face daily. The objectives of this experiment were focused on three main research questions: (RQ-1) know the general opinion of students on the simulator and their intended use, (RQ-2) confirm the discrepancies pointed out by literature between measurements of the students' flow state obtained (a) operationally or (b) empirically and analyse the possible factors behind these differences and finally (RQ-3) investigate how other demographic factors (such as age, gender or previous experience) or related to the experience settings (as the guiding mode) influences the students' flow state.

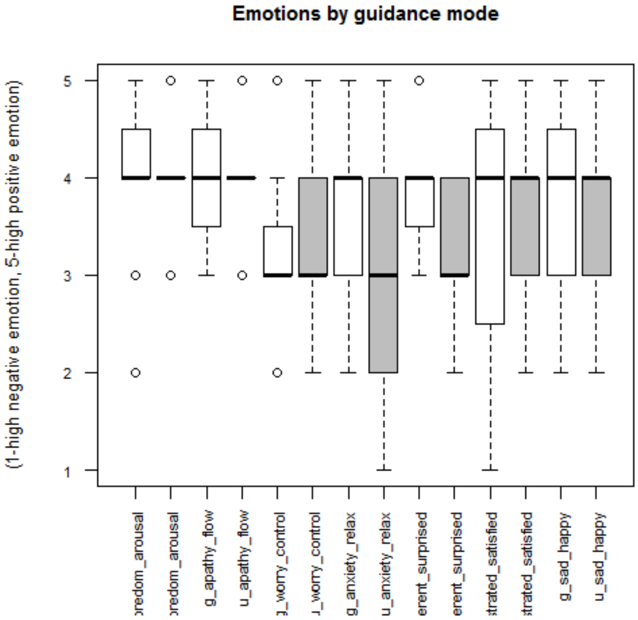


Figure 11: Emotions by guidanceMode. White-guided, grey-unguided

Regarding the first research question users consider the simulator "easy to use", "realistic", "amusement", "instructive" and "helpful for awareness", (*median* =4) in a Likert's scale of 5 points, but they are not interested in using the system as a game or for training. The correlation between realism and amusement confirm finding by [Bulu, 12] that asserts that it is important to consider the realism feature of the environment as well as course design to increase presence and satisfaction of learning.

Regarding the second question, we have confirmed quantitatively the hypothesis of [Engeser, 08] that asserts that operational and empirical measurements does not match and it's necessary to include other factors to moderate the theoretical values based con the balance between skills and difficulty. Qualitative analysis reveals that some of these moderating factors could be related to the four defining traits of a game proposed by [McGonigal, 11]: challenging goals, clear rules, real time feedback and voluntary participation).

Finally, regarding the third question, although the present analysis present significantly evidence according Kruskal-Wallis test about the influence of gender and guidance mode in the students' emotions, it would be recommendable to replicate the study with more participants to confirm this asserts.

6 Future Work

Regarding future work we are working on different lines: (1) on one hand the analysis of emotions using other measures and compare them with the measures proposed in this paper. We are considering different techniques: (a) Facial micro-expressions recorded during the experience. (b) Psychophysical test using minimally invasive sensors such as skin conductivity and temperature. (c) Theoretical measures traditionally used in HCI to calculate emotion from some operational factors such usability and time spent per task. Each one of these techniques offers different challenge about how measurement process affect the result of measurement.

(2) The second research line is related to a study to corroborate the influence of the four defining traits of a game proposed by McGonigal in the students' flow and quantify this influence.

(3) Finally the third research line is to include in the experience some of the elements of gamification and storytelling proposed in PhyMEL framework and analyses their impact on students' emotions.

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