Conducting a Usability Playtest of a Mathematics Educational Game with Deaf and Hearing Students

Lília Marcelino, Conceição Costa, José Carlos Neves, Andreas Melo and Fernando M. Soares

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Abstract. In this paper, a usability playtest to a pre-Alpha version of a video game namely "OtherWordly Math" is presented focused on Game-based Learning (GBL), Inclusive Design for deaf students and Games User Research. The present study aims to evaluate usability, understanding information and players' experience to improve gameplay. The sample is composed of nine participants, four being deaf and five hearing children, aged between 10 and 14, five girls and four boys. Three instruments were applied remotely using an online platform: a) participants' self-report on difficulties they may find in-game; c) an observational grid; and d) an emotional scale to assess the intensity of emotions felt by the players in-game. The results show that deaf and hearing children report the same playability constraints: a) the objectives of game challenge 2 were not clear; b) a user interface icon is ambiguous in challenge 3; and c) players expect more exploration in every challenge. Both groups felt "very" satisfied and "a little" confused during gameplay. A new level design and a new game layout were developed to fix the understanding and usability problems found in challenge 2. The usability problem related with challenge 3 demanded icon redesign. Regarding the playability issue mentioned in c) the solution points towards a game design review to balance the learning objectives with playability. Solutions are proposed concerning the main design problems reported by observers and by participants and a reflection about the value of User Experience Evaluation in the context of DHH students is provided.

Keywords: Research-based Educational Games, Deaf Students, Games User Research, Usability Playtest

1 Introduction

1.1. Games and Learning

The relevance of games in learning and cognitive enhancement has been increasingly studied [1]. Video games could be integrated into the educational process in several ways, such as by commercial games or the creation of games with previously defined learning objectives [2,3]. In good video games and good Game-based Learning (GBL) approaches, players and students are engaged and immersed in an activity when they receive no apparent reward except for the activity itself. Therefore, educational content is intrinsically integrated in the playability [4- 6]. In this matter, all game creation processes should focus on the very pioneer and actual concept of Huizinga [7]: "In play, there is something at play which transcends the immediate needs of life and imparts meaning to the action." (p.1).

In this perspective, good games designers managed to get players to learn and enjoy learning complex and challenging games [8], keeping the players motivating [9]. James Paul Gee (2003) [9] proposed thirteen "good" game principles as a checklist divided into three sections. Empowered Learners require that players feel active agents and use different ways to solve game issues. Problem-Solving with game challenges well ordered; and "pleasantly frustrating" meaning players' feeling that game challenges are demanding but at the same time achievable. Moreover, good games allow information "on-demand" when players feel they need it and "just in time" whenever players can put it in use. Additionally, problem-solving principles guarantee that game problems are integrated in simplified systems, namely "fish tanks" and "sandboxes" where game decisions feel like the real world, but risks and consequences are mitigated because of the safe sensation of sandboxes.

Deep Understanding is applied once players get a profound understanding of how each of the game elements fits into the game's overall system and genre, and when players give sense to the game action by concretely executing game experiences using images or activities.

The GBL principles proposed by Gee (2003) are particularly important for public-targets so-called "at-risk" learners - students who have little support for school-based literacy or who have fallen behind [8], such as deaf learners with low mathematics achievement [10]. As with hearing peers, the GBL principles may mitigate the unsuccessful educational experiences of deaf and hard of hearing (DHH) students [11].

Research also supports video games' potential to develop cognitive aspects crucial to the learning process, such as executive functioning or attention [12] (Ashinoff, 2014). For instance, behavioural and neurological investigations have shown that deaf people are more sensitive than hearing people to redistribute attention across visual space [13], and to the objects and movements in the peripheral visual field [14]. These response mechanisms to monitor and alert them about their environment changes are like video gamers behaviour. For instance, Gomez and Gellersen (2019) [15] have found a significant improvement in people's peripheral awareness who played computer games specially designed around using peripheral vision.

The current study was developed under the GBL4deaf – Game-based Learning for Deaf Students project [PTDC/COM-CSS/32022/2017] using a GBL framework where a video game was designed and developed from scratch. The project aims to evaluate the impact of an educational video game for mathematical learning (basic arithmetic and basic geometry) in particular, for deaf students.

The video game characterisation can be done using the four-dimensional framework proposed by de Freitas and Oliver (2006) [16]: context; learner specification, processes of learning and mode of representation. The context for learning is a school-based environment where teachers can apply the educational video game as a curriculum-based intervention on primary math's (basic arithmetic and basic geometry). The learners are deaf students, aged between 10 and 14 years old, grades 5 to 9 with low primary mathematics achievement. GBL4deaf embed the full inclusion in the digital world of people with special needs, such as DHH students with an inclusive design. The learners are deaf students who speak LGP (Língua Gestual Portuguesa), aged between 10 and 14 years old, grades 5 to 9 with low primary mathematics achievement. The learning process is constructivist and focused on the relationship between mathematical competence development and game-based learning to increase the comprehension of how video games can strengthen mathematics learning [17,18].

1.2. **An Inclusive Design**

The current policy of Portuguese Ministry of Education for deaf children education advocates a bilingual education model, guaranteeing linguistic growth and social inclusion of deaf children, a strategy where the Portuguese sign language (LGP) is the first Language [19]. Therefore, in the video game "OtherWordly Math” a bilingual tutorial in-game was developed based on the concept of semantic triples. This means that for each semantic field there is a video with LGP instructions and text in Portuguese complemented by visual representation. For the LGP video a native speaker of LGP was involved, as well for Portuguese text revisions to better answer the deaf specificities, the video game main audience. Besides that, the written instructions are useful for the inclusion of hearing students, such as the ones who struggle with mathematics or those who play just for the pleasure of playing and to enable educators and parents there are not deaf to access the video game as a tool to support mathematics learning alongside the DHH children.

1.3. **Games User Research**

The video game development incorporates an iterative GUR process [2] and it is in the context of UX evaluation that the present study was conducted.

UX evaluation in video games is more complex and challenging when compared to the so-called productivity software. The ease of use and its well-known associated users’ productivity and satisfaction are not enough. Players are not only performing activities to accomplish goals in their personal or professional lives. Even in that type of activities the scope of analysis should be extended from tasks to a meaningful context of a subject's interaction with the world, including the social context [21] and emotions are involved [22,23]. Saying that, a video game is still a product, but a very particular product: one that engages and immerses users in a meaningful experience [2, 24].

Games UX considers the whole experience players have with the game itself - from interacting with menus and controls to the emotion and motivation felt during and after gameplay [25] and interfaces with the three big pillars of video game creation: Design, Art, and Programming [12]. However, to understand the players’ whole experience one cannot ignore usability; it is necessary to take in account the human limits in attention, perception, and memory; it also means anticipating design errors that can be made and being ready for them as well to know and work with the expectations and abilities of the audience [26]. Moreover, the game design process should be even more attentive to human factors when the audience is deaf and hearing students struggling with mathematics.

Taking this perspective in mind, the present study uses a three-layer model from Player Research [27]: *Understanding* - Do players know what to do in the game world and what is available to them?, *Usability* - Are players able to do what the game designers want them to do? And *Player experience* - Is the game enjoyable?. Therefore, a usability playtest was conducted to answer the following research questions:

1. Are the LGP (Portuguese Sign Language) video instructions based and corresponding written instructions in Portuguese clear for the audience?
2. Are there any playability constraints perceived by participants and observers during gameplay?
3. Is the WASD/Arrow Keys movement response fluid and as expected to different game actions?
4. Do Players' express positive emotional feedback after the gameplay?

2 Method

2.1 Participants

The sample was composed of four deaf students with a profound level of hearing loss and five hearing students. The participants, aged between 10 and 14 years old (five girls and four boys), attended fifth to seventh grade, except for a10 years old deaf boy who enrolled in the third grade. Deaf students' parents' level of education ranged between primary and post-graduate education while hearing students' parents' education level ranged between upper secondary and post-graduate education (see Table 1).

Table 1. Participants' characterisation by sample group

Variables	Group	
	Deaf (*n* = 4)	**Hearing (*n* = 5)**
Sex		
Masculine	2	2
Feminine	2	3
Age		
10	1	0
11-12	1	5
13-14	2	0
Mothers' level of education		
Primary	1	
Secondary	0	2
Graduation	1	1
Post-graduation	2	2
Fathers' level of education		
Primary	1	0
Secondary	1	1
Graduation	0	1
Post-graduation	2	3

Note. Level of hearing loss of deaf students is profound. Two participants are twins hearing brothers. Fathers' level of education = 1 missing value.

2.2 Materials

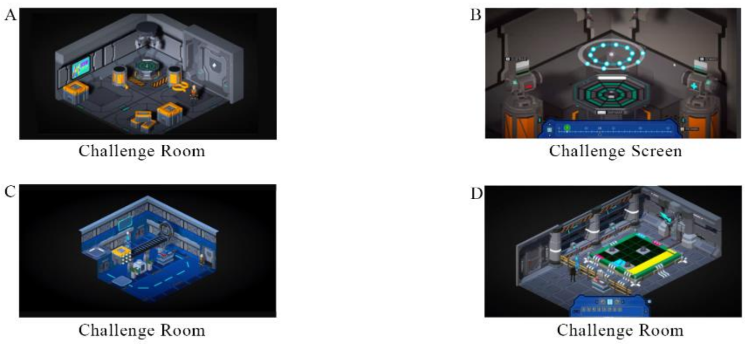
"OtherWordly Math" video game. The software used is an alpha version of a standalone game, produced with the Unity game engine. The OtherWordly Math game is a third-person camera game, single-player with a cooperative multiplayer option and with a fixed orthographic perspective. The type is Adventure/Puzzle/Arcade. The game art style contains a low-poly design, pure colours and sci-fi design defined in a consultation with a sample of students [28].

The game is designed to be a mathematical educational game for formal and informal learning. The player must use mathematical abilities to solve four challenging puzzles to build a space base, but only three challenges are under study. Each challenge has three difficulty levels designed to provide the player with the use of progressively advanced mathematical knowledge and reward them with the resources necessary to build and upgrade their space base.

Challenge 1 consists of an addition and subtraction puzzle in which the player must add or remove particles of an 'atom' to create a resource (see Fig 1. A & B). Challenge 2 consists of a multiplication and division tasks in which the player must decide the number of cars needed to transport the produced gears. Still, they must determine the total amount to be made each round by using multiplication reasoning (see Fig. 1.C).

In challenge 3, the player applied algorithmic thinking and notions of angles and rotations in a type of game known as turtle geometry to complete a plan in a 5 x 5 grid by using step-by-step sets of instructions: turn to the right, turn to the left, step left, step right, step forward, step backwards (see Fig. 1. D.).

Fig. 1.
Game Challenge Rooms



Note: (A) Challenge 1: Addition and Subtraction - Challenge Room & (B) Challenge 1: Addition and Subtraction - Challenge Game Screen. (C) Challenge 2: Multiplication and Division - Challenge Room. (D) Challenge 3: Algorithmic thinking, angles and rotations - Challenge Room.

Electronic Device. Laptop with Windows 10 software and a Mac OS X.

Media Usage Questionnaire. The questionnaire collects information about participants' video games preference, consisting of six applied before playing the game. The pre-game questions are: (1) Do you play video games during your spare time?; (2) How many hours do you play games during the week? (none; 2-3; 5-7, 8-10; more than 10); (3) What games do you like most?.

Usability Questionnaire. The survey, made in Google Forms**,** collects information about usability and understanding reported by the participants. It consisted of three post-game questions: (1) Did you feel any difficulty while playing the video game? If yes, in which part?; (2) Do you think that it was easy to control the game character?; (3) Did you understand what the character was doing?

Observational Grid "Got it/Don't got it" (Swink, 2008) [29]. The observational grid is composed of 36 items for the four-game menus: introduction (items 0.1 - 0.9), challenge 1 (items 1.1 - 1.9), challenge 2 (items 2.1. - 2.9) and challenge 3 (items 3.1. - 3.9). The following nine items are incorporated into the introduction and in each challenge: (1) To start the game/challenge; (2) To navigate the level or reach the challenge level; (3) To observe the LGP (Portuguese Sign Language) tutorial; (4) To follow the instructions of the first stage gameplay tutorial; (5) To follow the instructions of the second stage gameplay tutorial; (6) To understand the objectives of the challenge; (7) To be able to play the first stage of the game with the tutorial help; (8) To be able to play the first stage of the game without the tutorial help; and (9) To successfully conclude the gameplay. Each item is rated using a dichotomous scale (got it/do not got it) to rank the performance of participants in each item. Also, a 5-item Likert scale is used to observe participants' experience (1= very low; 5 = very high).

Emotional Questionnaire. The questionnaire is a researcher-based scale in reference to the Positive and Negative Affect Schedule short-version (PANAS) [30] that evaluates the intensity of emotions felt by the players while playing the video game. Five positive emotions were measured: satisfied, relaxed, involved, enthusiastic and excited; and five negative emotions: confused, bored, agitated, unsatisfied, and disappointed. Players asked to answer a 5-point Likert scale (1 = not at all; 5= extremely) to the following statement: "How did you feel while playing the video game?".

2.3 **Procedure**

In consequence of the evolving COVID-19 pandemic, the in-person work field with deaf and hearing students was cancelled and our sample stayed out of contact. In this context, it was decided to recruit participants on the project site and social media networks as well to contact directly with deaf associations. Besides all the efforts, only four deaf student participants and five hearing students were recruited. Informed consents were gathered from parents and children as well as questions about the participants (e.g. age, birth date, level of hearing loss, parents' educational level) and the study was approved by the university ethics committee. Game download instructions were sent by email to the parents, and the usability playtest sessions took place on Zoom platform for a one-hour mean duration, approximately during three months. A PC and MAC version were available. Before the gameplay, a media usage questionnaire was administered using Google Forms to gather information about the participant's video games preference. During the gameplay, the observers used the observational grid to take notes and rated the participants' performance. In the case of deaf students, a sign interpreter helped the test administrator to communicate with the deaf children. After the gameplay, a usability questionnaire and an emotional questionnaire were applied to participants.

3 Results

3.1. Media Usage

Asking to participants if they play video games during your spare time and how many hours do they play games during the week, seven participants reported that they played video games except a deaf girl with 13 years of age and a hearing girl with 12 years of age. Five participants stated five to seven hours per week of playing video games: two deaf and three hearing children with different years of age. Only one hearing girl informed that she plays more than seven hours per week. And none of them reported playing video games at school (see Table 2).

Table 2. Number of participants' playing videogames by sex, age and sample group.

Variables	**Play video games**		**Hours per week playing video games**			
	Yes	**No**	**0 h**	**2-3 h**	**5-7 h**	**8-10 h**
Sex						
Masculine	4		2		2	
Feminine	3	2		1	3	1
Total	7	2	2	1	5	1
Age						
10	1				1	
11-12	5	1		1	3	1
13-14	1	1	2		1	
Total	7	2	2	1	5	1
Group						
Deaf	3	1	1		2	
Hearing	4	1	1	1	3	1
Total	7	2	2	1	5	1

Table 3 presents the most referred games played by participants. The deaf children seem to be interested in games with a lower PEGI age rating, except Brawl Stars, which are video games that do not require a lot of quick reflexes to multiple stimuli on a screen. For instance, Wii Tennis is a video game that focuses on physical movement with a single focal point (the tennis ball). Minecraft has some environmental dangers, although the sandbox nature of the game means that the player can easily avoid them or build not to deal with them.

On the other hand, hearing children show preference in games like Tomb Raider, Rocket League and Fortnite. These video games are all fast-paced and require the player to be alert of multiple different sources of threats and opportunities which demands more time to master. In terms of platforms, both groups report the use of smartphones and consoles to play video games. Even though one hearing girl states playing more hours per week (8-10 hours), gender differences are not present. For instance, girls declared to play games as often as boys did. Differences between deaf and hearing in the number of hours playing video games was minimal, with deaf children playing slightly fewer hours per week.

Table 3. Video game type, age rating, and electronic device by sample group

	Type of video game	PEGI age rating	Video game name	Electronic device
Deaf	Adventure, Sandbox	7 +	Minecraft	P.C.
	Sports, Simulation	7+	Wii Tennis	Console
	Shooter, MOBA	10+	Brawl Stars	Smartphone
Hearing	Sports, Simulation	E	FIFA 19	Console
	Adventure, Shooter	PG-13+	Tomb Raider	Console/PC
	Adventure, Role Playing	9+	Harry Potter	Console/PC
	Shooter	12+	Fortnite	PC
	Shooter, MOBA	10+	Brawl Stars	Smartphone
	Racing, Sports	E	Rocket League	PC

Note. MOBA = Multiplayer Online Battle Arena; PEGI = Pan European Game Information; E = Everyone; PG = Parental Guidance.

3.2. **Participants' self-report on difficulties found in-game**

Eight participants answered to the usability questionnaire, five hearing students and three deaf students. One deaf participant (deaf girl, 14 years old) gave up playing challenge 3 and did not answer to the post-questions.

When asked "Did you feel any difficulty while playing the video game? If yes, in which part?", a common difficulty reported by children was the use of WASD keys to move the character in the isometric, third-person view. Two hearing students answered that "at the beginning no, but then yes" and one deaf and one hearing student answered "more or less".

Four participants in eight reported that they found it easy to navigate with the game character, two indicated that they found it 'somewhat easy' and the other two said that it was not easy at first. Still, it became more manageable after a while. No user stated that it was difficult to control the game character. Concerning the answers to the post-question "Did you understand what the character was doing?", participants show knowledge about the game character actions. For instance, they stated that the game character was working, building something, a space base, chips, sprockets, etc. (n = 5), or collecting materials (n = 1) or answered "*Yes, I know.*".

3.3. **Observation of participants during playtest**

From the participants' observation, researchers identified five design problems in playability:

Lack of understanding of the objectives of the challenge 2. The goals of the challenge were not sufficiently clear to the player (Items 2.6 - 2.9). The "Got it" observers rating of the Item 2.6 *Understanding of the objectives of the challenge 2* was 56.25% with a mean "Experience" of 2.9 points. Some observers' notes sustain the quantitative results: Observer 1. "Failed three times." - Deaf girl, 14 years old - Item 2.9; Observer 2. "Took a few tries, but she managed." - Hearing girl, 12 years old - Item 2.9.; Observer 3. "Only understood with (administrator's) help. She looks frustrated." - Item 2.7- Deaf girl, 13 years old; "Took a while to finish it. When he did, it was a sum. Player achieved the right result only because the 'sum' happened to be the same result as the desired multiplication (2+2 and 2x2)" - Item 2.7 - Hearing boy, 12 years old.

Video game instructions in Challenge 2. The sign language interpreter displays and interprets the transcribed written language. However, the tutorial written language was not clear enough and could be confusing. The tutorial frequently skipped without being fully watched. Participants did not press the key Q to skip the tutorial instructions and often ended the tutorial without seeing the second and third instruction *(see Fig. 4)*. The "Got it" observers rating of the Item 2.3. *To observe the LGP tutorial* was 68.75 % with a mean "Experience" of 3.1 points. Some observers noted the attempt to skip without watching the tutorial: Observer 3. "Tried to skip with the mouse" - Item 2.3. - Hearing girl, 12 years old.

Fig. 4. Challenge 2 tutorial. First instruction: "You will transform metal in sprockets. The red light indicated the quantity of metal blocks that will get out of the machine."

The gameplay is too punitive in mistakes/failure. In challenge 3, the gameplay was long and challenging, and the player lost too much progress with each error, which was a source of frustration. Some observers noted frustration. Two players quit the game at this level (Items 3.5 - 3.8). Observer 1. "Failed twice and gave up." Item 3.8 - Deaf boy, 12 years old; Observer 3. "Always looking frustrated" - Item 3.5 - Deaf girl, 14 years old; Observer 4. "Gave up" - Item 3.8 - Hearing girl, 12 years old. When asked "What is the less positive part of the game?" the answer was "Challenge 3." - Deaf boy, 12 years old.

Ambiguity in the meaning of rotation icon. In challenge 3, many players made the same incorrect assumption over the function of a given UI (User Interface) object meaning the icon used for it was not clear enough. Frequently, observers noted the confusion and errors regarding rotation. In some cases, the player traces a plan which rotates 360 degrees without a step forward/right/left/backward (see Fig. 3). The "Got it" observers rating of the item 3.9. *The rate of participants' success in concluding the gameplay* was 68.75 % with a mean "Experience" of 3.6 points. Observers notes mentioned the UI icon ambiguity: Observer 1. "She did not realise that the arrows were for rotation only. She tried to execute the program as if the arrows would for rotation and move forward." - Item 3.7 - Hearing girl, 11 years old; Observer 3. "The rotation is confuse. The player makes a 360 degrees rotation when it is not necessary". Item 3.7 - Hearing boy, 12 years old.

Lack of Undo game function in challenge 2 and 3. In both challenges 2 and 3, the absence of a 'undo' feature was reported by players. The "undo" function allows the player to correct their mistakes before 'testing' their solution. In challenge 3, players inquired the test administrator how to 'undo' or to erase in challenge 3 and how to return carts. In observers notes one 11 years old hearing girl asked "How can I erase this?" - Item 3.6.

Bugs. During the gameplay tests, the observers encountered three bugs (programming errors), but no exploits noted. On challenge 2 and challenge 3, there was a bug in which, after several attempts to solve the game tasks, the game would fail to reset appropriately for a new effort. This bug was no longer noted in all gameplay attempts, only a small number of them and all in which there were more than five failed attempts. On challenge 3, the observers noted that the tutorial failed to update even as a player performed the right actions correctly.

3.4. **Players emotional feedback**

Post-questioning players how they felt while playing the video game, most of the deaf and hearing children reported positive emotions like feeling "very" satisfied, enthusiastic and excited. On the contrary, they did not feel unsatisfied or disappointed. However, their emotional feedback in negative emotions indicated that they felt "a little" confused despite of being deaf or hearing children (*MD* = 2.3 and MD= 2.0, respectively), and "a little" bored (*MD* = 2.3) and "more or less" agitated" (*MD* = 3.0) in the case of the deaf children.

The children' feedback in opposite emotional states such as unsatisfied and satisfied are consistent. They felt "not at all" unsatisfied and "very" satisfied independently of the group (see Fig. 5).

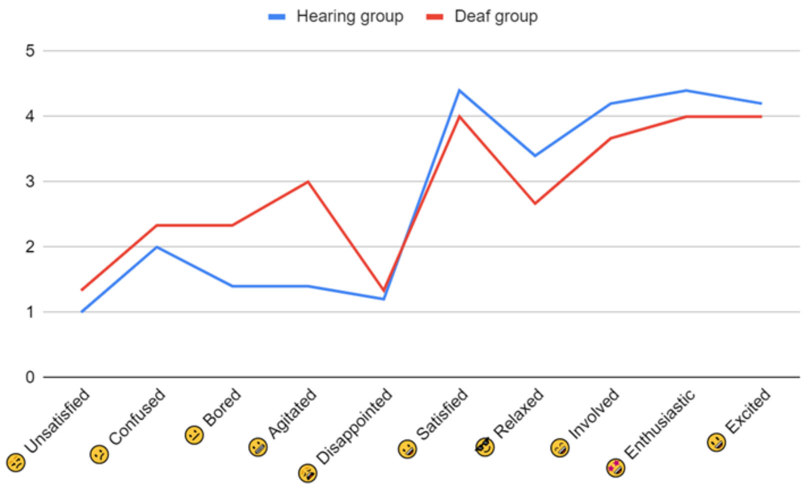


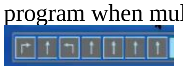
Fig. 5. Emotional feedback reported by hearing and deaf participants after playing the video game (mean values). Vertical axis: 1 = Not at all; 2= A little; 3= More or less; 4= Very; 5= Extremely.

4 Discussion

The present study uses a usability playtest to gather usability and understanding information about game experience of "OtherWordly Math" in order to improve the game. From the results, the following solutions were proposed to the development team (Table 4) and implemented.

As a first conclusion, both deaf and hearing participants felt "very" satisfied and "a little" confused during gameplay.

Table 4. Design problems and proposed solutions

Design problems	Solutions
1. Confuse instructions on challenge 2 tutorial	To redesign the tutorial to give more clear and concise instructions.
2. Lack of understanding on challenge 2 objectives	To redesign the Challenge 2 with more visual clarity and more contextual leads for the player.
3. Icon meaning ambiguity on challenge 3 	To create a new rotation icon to reduce the ambiguity. 
4. Challenge 3 too punitive of mistakes/failure.	To allow players progress to be saved inside the same program when multiple connections are necessary. 

5. Lack of "Undo" function on Challenges 2 and 3	To introduce the game function "Undo" to allow the player to change the game action.

To improve understanding of challenge 2 objectives, the written instructions and LGP tutorial were simplified, explicitly showing to the player the amount of metal blocks (see Fig. 4) enabling a more direct communication. More importantly, the layout level of challenge 2 was redesigned to improve players' feedback. The rail with transportation carts was changed to a straight line, making cars counting more perceptive (see Fig. 6).

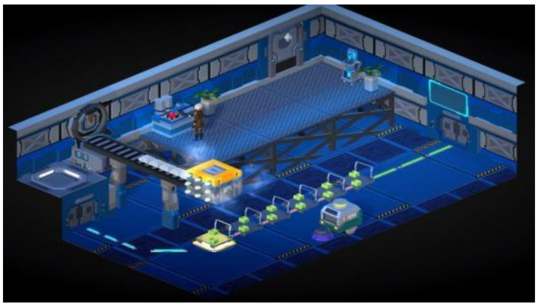


Fig. 6. New layout of challenge 2 (see previous layout, Fig. 4).

The ambiguity in the UI symbol for 'rotation' on challenge 3 can be solved by changing the icon to represent more clearly a quarter-circle rotation.

It was found that the challenge 3 was too punitive for players in case of failure, what certainly is related to the levels of *frustration* perceived by participants. In this challenge the players were expected to successfully create three plans (with several steps each) using the 'programming' to command a robot to follow a path. In the original game design, the challenge is complete only when the three plans are correct. During the gameplay, some participants asked the test administrator how to erase their solution because they realised they have made a mistake. The game had no "undo" function. The players merely were advised of failure and then should restart for the correct solution. The new version of the game has a UI function included in every challenge to allow players to 'undo' actions in each challenge.

The solutions proposed on challenge 2 may improve the emotional feedback given by deaf and hearing participants concerning feeling "a little confused". The fact that some deaf students reported feeling a "little bored" and "more or less agitated" during gameplay may be related with the problems detected. The in-game tutorial was redesigned to remove ambiguity, moreover the possibility of saving the progress of step-by-step instructions, and the opportunity of using the "undo" function in all challenges may reduce boredom and stress.

From the results of this usability playtest, the major problems found are related with lack of clarity in challenge objectives and instructions (Table 4.) and are commonly shared by deaf and hearing participants. Such could be an indicator that "OtherWordly

Math" development process strategy is adequate to deaf and hearing students and should be maintained. The usability Playtest, as expected, gave important insight for game design improvement.

The present study has some limitations that are important to mention. First, conducting a usability playtest with a remote context might influence the results. One explanation for deaf students feeling "a little bored" and "more or less agitated" may be concomitant to the online platform option for usability playtesting due to Covid-19 restrictions. Although having a sign interpreter in the usability playtesting sessions and the Zoom observers' windows kept without video and sound during playability, online conditions may influence deaf students' emotions during playability. Some sign language may be unclear to deaf players because of the small Zoom platform's windows' size, therefore some information can be lost in the process of translation or even influence the emotions reported by deaf students.

Secondly, some limitations might be found in learner specifications. The fact that deaf players reported "more or less agitated" compared with hearing players might be explained by the cognitive differences between deaf and hearing students [13,14]. Deaf students tend to be more alert, and visually distractible relative to hearing age-peers despite the observers' windows in Zoom platform being kept without video and sound during playability to reduce interferences. As a third aspect, the absence of interviewing deaf participants to understand better the "bored" and "agitated" emotional aspects of the video game is another limitation of the present study. Besides interviews with players, retesting the solutions proposed with the same conditions is necessary.

Finally, the study cannot be generalised. A larger sample is needed even though results can come from testing with no more than five-10 users as proposed by Nielsen and Landauer (1993). The authors use a mathematical model with the proportion of usability problems found with increasing number of subjects and they observe that after five to ten test subjects/evaluators, the number of usability problems becomes flat [31]. Nevertheless, as a future study, we hope to recover the GBL4deaf sample that stayed out of contact due to the evolving COVID-19 pandemic and evaluate the video game with a homogeneous sample regarding deaf and hearing children, age and grade.

As a final consideration, playing the "OtherWordly Math" video game was enjoyable and immersive for both deaf and hearing students, notwithstanding their solving mathematics challenges what, again, is very promissory in terms of achieving a balance among playability and learnability.

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