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Using Serious Games for Learning British Sign Language Combining Video, Enhanced Interactivity, and VR Technology

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Abstract: One in every six persons in the UK suffers a hearing loss, either as a condition they have been born with, or they developed during their life. Nine hundred thousand people in the UK are severely or profoundly deaf. Based on a study by Action on Hearing Loss UK in 2013 only 17 percent of this population, can use the British Sign Language (BSL). That leaves a massive proportion of people with a hearing impediment who do not use sign language struggling in social interaction and suffering from emotional distress. It also leaves even a larger proportion of Hearing people who cannot communicate with those of the deaf community. This paper presents a Serious Game (SG) that aims to close the communication gap between able hearing people and people with hearing impairment by providing a tool that facilitates BSL learning targeting the adult population. The paper presents the theoretical framework supporting adult learning based on which a SG game using Virtual Reality (VR) technology has been developed. The paper explains the experimental framework of the study. It presents the creation of the research instruments to facilitate the study comprising of a SG that integrates video and conventional video-based educational material. It reports and analyses the study results that demonstrate the advantage of the SG in effectively supporting users learning a set of BSL signs. It also presents qualitative outcomes that inform the further development of the game to serve learning needs. The paper closes with conclusions, directions for further development of this educational resource, and future studies.

Keywords: Virtual Reality; Adult learning; Serious Games; Game-Based Learning; Video Learning; British Sign Language.
Categories: L.5.1**,** L.0.0, L.1.1**,** L.2.7**,** L.3.3**,** L.3.6

1 Introduction

British Sign Language (BSL) is a complete visual-gestural language with a unique vocabulary, construction, and grammar believed to be used by 151,000 of the UK population, 87,000 of which are Deaf [BDA British Deaf Association]. Increasing the number of Hearing people knowing BSL, would drastically reduce the barriers, discrimination, and plain ignorance that Deaf people face every day. Learning a visual language like BSL could be well supported by the use of highly visual resources, such as video, or a rich graphical environment. Shepard and Cooper [Shepard & Cooper, 1982] and Mayer and Gallini [Mayer & Gallini, 1990] made the connection between visual clues, the memory process, and the recall of new knowledge.

Virtual reality (VR) holds exciting prospect to accommodate the needs of people with hearing disabilities [Johnson, 2002, Adamo-Villani, et al. 2006, Zirzow, 2015] as it supports high motivation, it allows for greater control over one's environment, it facilitates repetition and self-pacing. To further motivate and engage the learning process and stretch knowledge retention and skills, VR can be coupled with gamification [Hamari et al., 2014], which is the application of game-design elements and game principles in non-game contexts. Gameplay stimulates brain activity, demonstrating retention of information and engagement that result in enhanced cognition [Wouters et al., 2013. The new genre of combining learning and gaming is called Serious Games (SGs). The term *Serious* refers to serving the purpose of learning and *Games* to maintain entertainment and attractiveness to learners [Arnab et al., 2015]. SGs demonstrate high potentials in providing the space where learners can actively participate in their learning [Lameras et al., 2016] changing their passive comfort zone to active learning and trying new approaches to reach knowledge [Prince, 2004].

The paper presents the creation process of a SG that uses VR and image processing technology to facilitate BSL learning targeting the adult population. Section 2, presents a background review of games that have been created to support learning BSL. Section 3, presents the theoretical framework that SGs should adapt to support adult learning. Section 4, describes the experimental framework of the study, while section 5 presents the creation of the research instruments to facilitate the study. Section 6, elucidate the experimental apparatus and it reports and analyses quantitative and qualitative results that demonstrate the advantage of the SG in effectively supporting the learning of a set of BSL signs. The paper concludes with directions for further development of this educational resource informed by the study output.

2 Related work

Several existing BSL educational games, using 2D technology and relatively low interactivity, target users who already hold some knowledge of the sign language aiming to engage them in activities to practice their knowledge. "*Sign language test"* [Sign language test] is one such game, that shows an image of a sign and 5 options to choose from. *"Finger Spelling Game"* [Finger Spelling Game], displays a series of signs and asks the player to recognize the whole word. "*Signing Time Kids"* [Signing

Time Kids] is a memory matching game with a countdown timer. Some other games attempt to teach novice players a sign language. Like *"Sign the alphabet"* [Sign the Alphabet], a learning by doing multiple choice game that displays a BSL sign and asks the player to recognize the corresponding letter. Answers are revealed as the game is played, users can be guessing, in which case their score is reduced. Similarly, *"What is this Letter Sign"* [What is this Letter Sign], alternates between displaying a written letter and three signs for the user to choose from, there is no scoring, but players are congratulated when providing a correct answer. The *"GreenBeanies App"* [GreenBeanies App], provides a short story with clickable words that trigger a short video playing the sign for the word performed by a person. *"Sign my World"* [Korte et al., 2012], is a mobile 2D video game to aid deaf children to learn the Australian Sign Language (Auslan) and familiarize themselves with the appearance of common nouns and verb signs. It contains several interactive objects that when clicked, an image and a word are displayed, as on a flash-card, followed by the video of the Auslan sign for the corresponding object.

Game technology combined with sign language recognition encourages deaf children to enjoy practicing the American Sign Language (ASL). Such an example is *"CopyCat"* [Henderson, 2005]. To play children wear colored gloves with wrist-mounted accelerometers and interact with a computer vision recognition system. *"Virtual Sign Game"* [virtualsign, Escudeiro et al., 2014], is a game for learning the Portuguese sign language (PSL) that combines 3D, Kinect, and gloves technology. The player controls a synthetic character that interacts with objects and non-player characters aiming to collect several gestures from the PSL that are performed by those characters helping the player to visualize and train existing gestures. *"MemoSign"* [Bouzid et al., 2016] aims to foster and promote the vocabulary acquisition for Deaf and Hard of Hearing (DHH) learners in both signed and spoken languages. MemoSign combines memory match game and avatar technology that renders sign notations content in visual-gestural modality.

A recent example of a game that combines VR, motion capture technology, and uses ASL to communicate with the player is *Moss* [Moss, 2017]. This is a storytelling adventure game with the main character a tiny mouse who guides the player through the game using sign language. The game is a mix of puzzle platforming and a fully narrated story built for PlayStation VR headset. A motion controller is used for movement and interaction in the world. Another example that uses fingerspelling as input passwords at several points throughout the game built for Windows PC and Xbox One is *Tacoma* [Tacoma, 2017]. Game experts commented on the growing interest in the authenticity of bringing sign language into games. However, an issue that arises here is that game design and development are driven based on the gaming experience. A SG contrarily should adopt an educational framework to address the educational needs of the intended learners.

3 Theoretical framework

For the needs of this study, the educational resource uses an instructional scaffolding approach in learning [Wood et al., 1976]. This is the *"systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize*

learning" [Dickson et al., 1993]. Similar to scaffolding used in construction, the SG puts in place temporary support structures to assist learners in the process of learning the BSL alphabet. It tailors the learning process to the needs of individual learners by enabling a self-paced exploration of the immersive environment. The structure of the scaffolded instruction implemented in the game is in three levels (see Figure 1):

- **Level 1 – the game and the individual does it**
  The game demonstrates how to perform the task of communicating using BSL in videos. The videos provide a realistic demonstration of the signing of the integrated BSL letters. Objects embedded in the game environment create a visual connection with the letters (see Section 5.1.2, Level 1 Learn). The learners explore the environment to uncover the hidden objects and watch the videos. Additional scaffolding (i.e., repetition of a BSL sign) enable learners to more efficiently and effectively learn the BSL letters.
- **Level 2 – the individual does it**
  In this practice stage, individual learners demonstrate their mastery of the BSL alphabet. Learners practice recognizing the BSL signs they learned in Level 1 automatically and quickly.
- **Level 3 – the individual is assessed**
  Once learners feel confident with their mastery of BSL, all scaffoldings are removed, and they can assess their knowledge by playing a game against a virtual enemy.

Figure 1: The scaffolded instruction implemented in the 3D interactive game platform.

4 Experimental framework

According to Mayer [Mayer, 2014], there are three types of experiments in SGs:

- *Value-Added Experiments*, to determine whether the addition of specific game features causes a useful change in the learner's knowledge;
- *Cognitive Consequences Experiments*, to investigate whether playing a game can improve cognitive skills related to learning;
- *Media Comparison experiments*, aiming to compare media and determine whether people learn better from games or conventional media.

The experimental apparatus of this study follows Mayer's *Media Comparison Experiments* to test/compare if players achieve better learning while playing the game and transitioning from Level 1 (learning) – collecting and watching the sign videos, to level 2 (training) – recognizing correctly the corresponding signs to letters – to level 3 (assessment) – recognizing correctly the corresponding letter to sign, rather than watching a series of videos signs.

Twenty-four (24) participants were recruited for this study. Figure 2 below, depicts the sequence of activities of the study, the research instruments used, and the data that has been collected at each stage. Participants used both a video-based resource to learn signing a set of BSL alphabet signs (see Section 5.2), task 1, and played a SG (see Section 5.1) that has been developed following the aforementioned theoretical framework (see Section 3), task 2. The style of the videos demonstrating the signing of BSL signs both in the video-based material and in the SG is exactly the same. To avoid distortion of the results having exposed the participants to the same set of BSL signs twice, a different set of signs are shown in tasks 1 and 2 (discussed in Section 5). In addition, the participants were randomly split in two groups and half of them completed task 1 first followed by task 2, while the other half completed task 2 first followed by task 1 (as shown in Figure 2).

Each video showing the signing of BSL signs takes a few seconds. The default time of repetitions the participants see the signing of each BSL sign both in task 1 and 2 is the same (2 times). However, in both cases, players/learners are allowed to watch the video as many times as they feel confident that they have understood and learned the sign (note that most of the players do not watch the video more than 3 times).

After completing each task participants have been given a questionnaire to assess their learning of the corresponding BSL signs (stated as Knowledge Assessment in Figure 2). These questionnaires collect quantitative binary data (correct or wrong answer). At the end of both tasks, participants have been given a questionnaire to gather quantitative and qualitative information related to their overall experience and satisfaction of the learning resources with emphasis on the SG (stated as User Experience Assessment in Figure 2). The study output generates both qualitative and quantitative data to evaluate their learning and the learning experience. To avoid bias half of the participants used first the video material and then the game, while the other half used first the game and then the video material as shown in Figure 2. The entire experimental session takes approximately 40 minutes (see Figure 2).

Figure 2: The study process, the sequence of the tasks completed, the duration of each task and, the type of collected data.

5 Research instruments

This section presents the material that has been created to support the needs of the media comparison experimental study. The following subsections describe the design of the research instruments that have been used.

5.1 Signum Battle - the 3D interactive game platform

As part of task 2 of the study, a SG was developed using desktop VR interactive technology following the systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize learning suggested in Section 3. The game design, mechanics and technology used are covered below.

5.1.1 The game design

5.1.1.1 Genre

Signum Battle is a third-person hybrid action, adventure, and educational game, aiming to teach the BSL alphabet in a fantasy mythological world. The player/learner takes on the role of a heroine/explorer who needs to complete several learning quests to advance through the game. Adventure genre games usually require the player to solve a problem, but without much action happening, by action, we refer to encountering drawbacks in the form of enemies or battles. Action genres constitute mainly action derived activities and the game-play is very much based on the player using their reflexes and being in a heightened state of alertness to fight enemies. Problem-solving is essential for constructing links between information to reinforce learning. Also, negative and positive reinforcement strengthens the motivation for learning which is supported by the combination of action and adventure genres respectively.

5.1.1.2 Game Demographic

The target audience of this educational game is not children born with deafness, but people that learn sign language later in their life. Taking into consideration that after Level 2 of the game there is a suggestion to mild violence per the Entertainment Software Rating Board the band in which the game fitted best I s E10+ [Mitchell, 2012].

5.1.1.3 The Story

The review of educational games to teach sign language revealed that none of the existing games has an engaging story and/or an engaging environment usually found in popular games. Therefore, those educational games come across as uninteresting. The backstory of the Signum Battle is that mermaids have used their enchanting song to lure humans into the sea. The survivors left in this fantasy world lived because their lack of hearing has empowered them to be immune to the mermaids' chant. The mermaids have become aware of their limitations and have summoned walking sea creatures, minions, to come into the land to protect their territory and the humans they have trapped. A young heroine has stumbled into this world and decides to go on a mission to help them. To do so she needs to pick up the skills and magical powers of this language to attack the minions, reach the mermaids' lair, and rescue the humans. The language to be learned is the BSL. The backstory is used to: provide a framework for a mission-based game structure; and help the players submerge themselves in a game they experience *"Suspension of disbelief"* [Safire, 2007] to be entertained.

Furthermore, it was important to tackle the subject of deafness in an inclusive and non-patronizing way. Thus, deafness is presented as a positive and empowering element in the story of the game. This has been the case in many superhero stories; as for Marvel who included a deaf super-hero in their comics, which according to Callis [Callis, 2017] for deaf children this pop culture representation is affirming. Hence, the people of this game world survived the evil song of the mermaids which lured men to sea, because they were immune due to their lack of hearing.

5.1.1.4 Game Controls

The game is controlled by mouse clicks to move around and interact with objects in the environment. Gestures, using a Leap Motion Controller (an optical hand tracking module that captures hand movement and let users interact with digital content using bare hands), are used to practice the signs that have been learned or make selections in Level 2. The keyboard is used to recognize signs. This game aims to be inclusive; therefore it includes audio but is not reliant on it. Audio is used to engage able hearing players, but for every sound cue, there is equivalent visual feedback.

5.1.1.5 The Game Environment

The game environment depicts a forest where stone ruins (see Figure 3(a)) reflect the magical theme of the backstory and the destruction that had come before (see Figure 3(a)). The backstory has been described earlier (see The Story above). The game environment of each Level is explained in more detail in Section 5.1.2.

The heroine of the game models a young female modern character that players could relate to. The enemy in Level 3 was inspired by a collection of sea monsters. The enemy is bigger than the player's avatar and fearsome to add to the fear factor of the game [Mitchell, 2012].

5.1.2 The game Levels & mechanics

5.1.2.1 Level 1 Learn

Level 1, familiarizes the player with the BSL signs. Signs drawn on stone tiles like ancient hieroglyphics are scattered in the environment among the forest ruins for the player to discover (see Figure 3(a)), supporting exploration, engagement, and immersion in the game. To create a visual connection between signs and corresponding letters, objects have been integrated into the Virtual Environment (VE) and placed near the signs to be found the name of which begins with the corresponding sound of the sign (see Figure 3 (c), (d)). [Ralby, 2017] presents a successful example of using mnemonics and building memory palaces (an imaginary location in people's minds where mnemonic images are stored) in VR to aid information retention and retrieval in learning languages. To better support player learn and memorize the signs, when the player's avatar reaches a sign this is magnified covering most of the user's field of view and the video of the sign plays consistently until the users click the "got it" button to collect the sign in the inventory (see Figure 3 (c), (d)). The style of the videos that show each BSL sign in Level 1 is

the same as the ones that have been used in task 1 (see Section 4), which is explained in detail in (Section 5.2).

(a) (b) (c) (d) (e) (f)

Figure 3: (a) The forest environment in Level 1 where the players collect the BSL signs; (b) inventory of the collected BSL letters and the video showing the BSL signing of each letter; (c)(d) video demonstration of the BSL signs accompanied by mnemonics; (e) the teleportation area after completing Level 1; (f) the area in Level 2 players arrive after their teleportation from Level 1.

Each video showing each BSL sign takes a few seconds. Most of the players in this study did not watch a video more than 3 times (however, this is only based on observation, the study did not keep such a log). The player's avatar performs an animation indicating that the sign has been collected and the panel with the sign, the

related object, and the video disappear from the VE. The User Interface (UI) displays a message that the sign of the corresponding letter has been collected. When the players activate the inventory they can play all the signs' videos until they are confident they have learned them (see Figure 3 (b)). By default, each sign is played twice. Currently, in the version of the game, only 8 signs of the BSL alphabet have been implemented, specifically letters F, B, A, H, G, C, D, E.

At this Level, the game mechanics used is exploration, discovery, and collection of signs to advance to the next Level. There is no time constraint, rewards, or penalties. Once all the letters in this Level have been collected the players can proceed to Level 2. To highlight that the teleportation is active when all the objects in Level 1 are collected, the UI message bar instructs the user to go to the teleportation point. An animation with blue halo plays above the teleportation point to indicate that the teleportation is active (see Figure 3 (e), (g)).

5.1.2.2 Level 2 Practice

In Level 2, players are transported on a bridge (see Figure 3 (f)) where they can decide to go to a training house (see Figure 4 (a)), or the battle Level (Level 3, see Figure 5). Players transition from an open environment to a closed sheltered area where they can practice at their own pace the signs they have learned in Level 1. The system displays a letter and prompts the player to correctly recognize the corresponding cube on the tabletop with the BSL signs they have learned in Level 1 (in the form of a multiple-choice questionnaire) using hand gestures. Players select one of three cubes that appear on a tabletop in the training room using the Leap Motion Controller (see Figure 4(b)). Initially, it was planned to use a BSL recognition algorithm for Leap Motion, but this was too difficult due to the use of two hands for signing each BSL sign. The letters are presented randomly until the players perform well, indicating they have learned the signs. There are no time constraints, rewards, or penalties at this Level. When the players feel confident that they know the signs they can progress to Level 3.

(a) (b)

Figure 4: Level 2 (a) The sheltered environment for practicing the BSL signs; (b) The user recognizing the BSL signs using a Leap Motion controller.

5.1.2.3 Level 3 Assess

Level 3 is the battle Level where the player's knowledge of the BSL signs is assessed. To win this level the players have to correctly recognize the BSL signs shown on top of the enemy/minion by hitting the respective key on the keyboard see Figure 5. Correct recognition of the BSL signs keeps the enemy in distance (see Figure 5) right image), while failing to recognize them reduces the players' health, that after few wrong attempts die and the Level starts again. There is no time constraint at this level, the players play for as long as they can last.

Speech recognition could support faster identification of signs. However, selecting the respective key of a sign on the keyboard might serve to learn better, as it helps the conceptual connection between letters and signs.

Figure 5: The battle, the players have to correctly recognize the BSL signs shown on top of the enemy/minion by hitting the respective key on the keyboard to keep the enemy away.

5.1.3 The technology

The game has been implemented in Unity [Unity]. For the creation of the VE and textures, 3DsMax and Photoshop have been used, while for the game characters, Adobe Fuse CC and Mixamo (an online tool with an extensive library of animations that can be attached to 3D characters). Gestures are recognized by a Leap Motion Controller.

5.2 The video-based material

The conventional video-based resource designed for this study consists for a sequence of videos that demonstrate a series of BSL signs. Specifically, signs corresponding to letters L, I, J, N, O, M, K, P. The videos are the same style as those integrated into Level 1 of the Signum Battle game. Each videos showing a BSL sign takes a few seconds and then it moves to the next sign. Each video plays by default twice. The players are allowed to play a video as many times as they need until they feel confident they know it. Thus, the entire task 1 (see Section 4) takes approximately 3 minutes. The video-based material has been created using Adobe Animate.

5.3 Questionnaires

Three questionnaires have been created for the needs of the study. The first two assessed the participants' knowledge of the BSL signs they have learned using either the video-based material or the SG, shown as knowledge assessment following tasks 1 & 2 (see Figure 2) and collect binary data (correct, or wrong recognition of the sign). The third questionnaire allowed the collection of information related to participants' experience and satisfaction of the learning resources they used. Due to the type of questions asked, the small sample of participants in this study, and the data interpretation at descriptive level, the quantitative data this questionnaire collects is binary (agreeing or disagreeing with the asked questions). It also collects qualitative information as it allows participants to justify their answers with free text.

The knowledge assessment part of the questionnaire has two parts. The first presented the sign and requested participants to write the represented letter (assessing the knowledge stored in memory), the second part showed the letters and the signs and asked the learner to match letters to corresponding BSL signs.

The UX part of the questionnaire gathers information about the:

- clarity of the story and the UI;
- game functionality and features to support the participants in completing their tasks;
- clarity of the role of the player;
- design of the environment and the characters;
- navigation in the environment; the ease of completing tasks and the available support;
- game pace, and;
- participants' preference of the activities at different levels allowing them to compare different game mechanics.

6 Experimental apparatus

As stated in Section 4, 24 participants have been recruited to the study. They were Computer Science Undergraduate and Postgraduate students and members of staff at the University of Westminster aged between 19-53 years old, with higher concentration in ages between 19-30 years old. Two of them knew BLS at a beginner level, while the rest of the participants did not know BSL. Nineteen out of 24 participants played games, and 13 of them classified their game-play skills as good or experienced gamers.

All participants used both the video-based resource and the SG to learn a set of BSL alphabet signs. Half of the participants used first the video-based material and then the SG, while the other half used first the SG and then the video-based material as shown in Figure 2.

6.1 Learning

The hypothesis formed and tested in this study to evaluate the effect of participants' learning depending on the educational material that has been used is as follows:

- H_1: there is a difference in learning BSL signs using conventional video-based educational material or the Signum Battle SG.

H_1: $\mu_{video} \neq \mu_{SG}$

The dependent variable being tested is the participants' knowledge of BSL signs following tasks 1 and 2, where:

- in Task 1, the participants use conventional video-based educational material;
- in Task 2, the participants use the Signum Battle SG which contains video material integrated into an environment that engages learners in a gamified experience to support their learning.

The independent variable is the use of the educational material to learn the BSL signs. The data collected based on the participant's knowledge assessment of tasks 1 and 2, is either correct (1), or wrong (0) identification of the BSL sign to the corresponding alphabetical letter.

A chi-square test of independence was performed to determine whether there was a significant correlation between the educational material to learn BSL signs and knowledge of BSL signs, determined by the number of correct/wrong answers. The chi-square test showed a significant correlation between the two variables (X^2 (1 N = 27) = 22.222, $p < .05$). The Phi and Cramer's V test showed a strong association between the two variables ($\varphi = .241$, $p < .05$; Cramer's V = .241, $p < .05$). The results show (see Figure 6) that users correctly identified a BSL sign 85.4% of the time when using the Signum Battle SG, while only 64.5% of the time when using the video resource. Also, users incorrectly recognized a BSL sign 14.5% of the time when using the Signum Battle SG compared to 35.4% of the time when using the video resource.

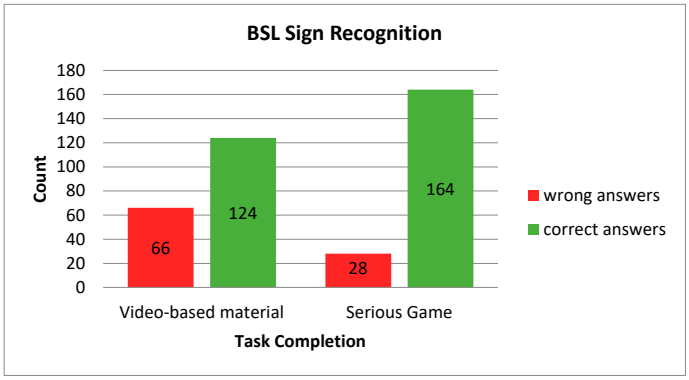

Figure 6: Distribution of participants by their BSL sign recognition

The results confirm our hypothesis (see H1). The use of the Signum Battle SG supports learners to learn, practice, and assess their knowledge more effectively than conventional video-based educational material.

6.2 User Experience

The UX part of the questionnaire at the end of the activity gathered both quantitative and qualitative information related to the participants' overall experience and satisfaction. It focused mainly on the SG and helped to compare the user experience interacting with the SG and the video-based material. The reported results are based on the 24 participants that took part in the study (see Section 4). The participants' feelings are captured by agreeing (Yes) or disagreeing (No) with simple questions or statements and the data is interpreted using descriptive statistics as the sample is relatively small. The Signum Battle SG is still at the prototypical stage of development and thus at this phase qualitative data related to UX helps gaining valuable insights from the targeted users regarding why and how the product is used and how it could be improved.

Figure 7 below depicts a set of questions asked related to the game design overall. Generally, the users found clear:

- the instructions in all three game Levels;
- the game menu;
- the story and their role in the game.

Twenty-one out of 24 participants liked the Signum Battle SG environment and some of them mentioned that it gave them a genuine feeling of being in a mythological world. They liked the variety of environments offered in the 3 game levels and stated that this resembles an open-world space with different environments to explore, so the levels do not seem short.

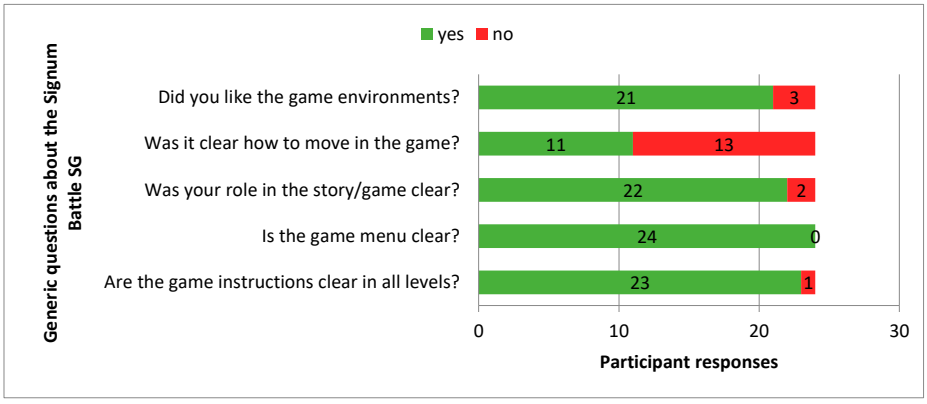

Figure 7: Generic questions about the Signum Battle SG

Some constructive comments to be considered to improve the VE design in Level 1 were:

- that the forest did not show clear boundaries of how far the player's character could go;
- the background was busy and distracting user attention from learning the signs;
- the player's movement, the player's character would walk towards an area by clicking with the mouse within this area. Particularly in Level 1 where the

environment was busy with many objects to be collected this way of movement was problematic.

Figure 8 below captures the questions that participants have been asked related to Level 1 of the Signum Battle SG (see Section 5.1.2 Level 1 Learn), where the participants had to collect the BSL signs and watch corresponding videos to learn them and the participants' response. Although, most of the participants (17/24) said that the signs were easy to find in Level 1, some found it quite tricky to move around to find (7/24) and collect the signs (8/24). Some (11/24) said that the signs were a bit hidden. Some participants said that it was not clear where their avatar was in the environment and suggested that the integration of a map would help the user orientation.

Most participants found that the use of the mnemonics (linking the signs with artifacts in Level 1) helped them to identify the signs (21/24) in the scene and to memorize them (18/24). However, some (6/24) had an opposite view, they did not realize the relation between the embedded artifacts in the scene and the signs, thus those did not work as a memory aid. Some said that it was easier for them to search and identify the BSL signs based on the glowing engraved with the sign stones.

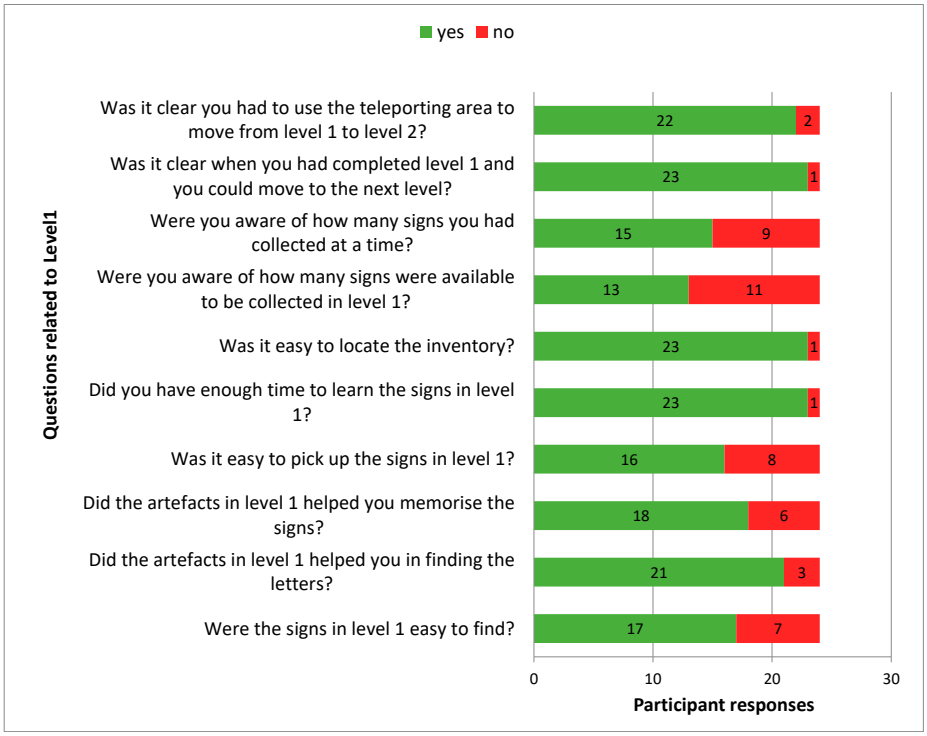

Figure 8: Questions related to the design of Signum Battle SG Level1

Twenty-three participants found that the time they had available in Level 1 to learn the signs was adequate, but some commented that Level 1 was long. That was interesting because there was no time restriction in exploring the environment to

collect and learn the signs. The video sequence demonstrating a BSL sign plays continuously once a sign is picked (see Section 5.1.2 Level 1) and it is up to the user to decide when they feel they understand the signing and thus stop playing the video sequence and collect it in their inventory. However, difficulty in movement and navigation in Level 1 may have prolonged the time of collecting the signs, and thus some might have felt that the level was too long.

When the participants were asked if they were aware of the number of signs, they had to collect in Level 1, 13/24 replied that they were aware, while a considerable number (11/24) had the opposite view. Also, 15/24 participants were aware of how many signs they had collected in their inventory at a time, while 9/24 were not. This was due to lack of a progress bar, or a count displayed on the screen to keep track of user progress in completing the level. One participant commented that although they could check the inventory to find how many signs they collected; it would be preferable to have this information displayed on screen all the time.

Regarding the clarity of Level 1 completion and progression to the next Level, most participants (22/24) said that they were aware that they have selected all the signs and they had to go to the teleportation area to progress to the next Level.

Figure 9 below illustrates the questions participants have been asked related to Level 2 of the SG where they were being teleported, upon completion of Level 1 and the participants' response. In Level 2 participants landed on a bridge that led either to a house where they could train the signs they have learned in Level 1, or to Level 3. Twenty-three participants agreed that it was easy to find (23/24) and enter (22/24) the training house. Two participants that had difficulties entering the house said that they had to go around it several times and one mentioned that the red and green lights triggered their attention to enter the house.

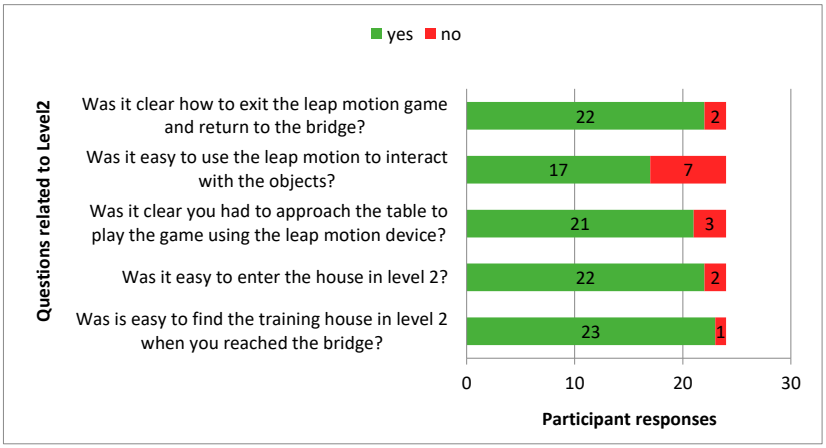

Figure 9: Questions related to the design of Signum Battle SG Level2

The part that the players had to switch from using the keyboard into using the Leap Motion device was in Level 2, when participants entered the house and approached the table on which cubes were laid displaying BSL signs. A pop-up window prompts a letter of the alphabet and instructed the players to select the cube

displaying the BSL corresponding sign using hand gestures (see Section 5.1.2, Level 2 Practice). Twenty-one of the participants (21/24) agreed that it was clear that they had to reach the table in the middle of the room and use the Leap Motion Controller to complete the task of matching the displayed letter to the cube with the corresponding sign. One said that perhaps it would be better if the character entered the room directly across the table and not from the side of the room.

Regarding the use of the Leap Motion, although most of the participants said that it was easy to interact with the objects using it (17/24), a considerable number of participants had issues with its use (7/24) and mentioned issues such as:

- the Leap Motion picked up movement before they really moved their hand, or accidentally touched the wrong cube, which led to making a wrong selection;
- users that never used a Leap Motion before did not find it easy to interact with objects using it and took them time to figure out the distance they should keep between their hands and the Leap Motion to pick up their hand movements;
- the height they had to place their hand above the Leap Motion to pick up their hand motion was tiring;
- they could not see the point of using a Leap Motion for this task, while they could complete it more effectively using the mouse.

Figure 10 below captures the questions that participants have been asked related to Level 3 of the SG and their response. In Level 3 participants' knowledge gained in the two previous Levels was assessed by confronting enemies that brought BSL signs above their head that the participants had to defeat and keep them at a distance by hitting the correct corresponding letter on the keyboard. Twenty participants found that the signs above the enemy's head were easy to read (20/24). However, four mentioned that distant signs were unclear and that once the enemies where in line behind each other, only one sign could be seen. One participant stated that this made the game more challenging and exciting. Although most participants (19/24) responded that the time they had to recognise a sign and type the corresponding letter on the keyboard was enough, some (5/24) found the pace of the game too fast. Nineteen participants (19/24) agreed that the UI element (progress bar, see Figure 5) showing their health status was clear.

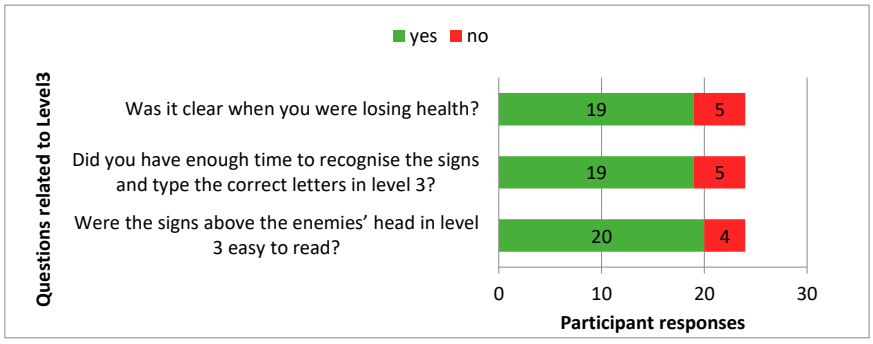

Figure 10: Questions related to the design of Signum Battle SG Level3

As for the question, which game Level did they find more interesting and why (see Figure 11), 10/24 participants responded that they liked Level 3, the assessment Level, where they had to confront the enemy and test their knowledge of the BSL signs. They stated that the reasons they liked this level because they instantly understood what they had to do, and it was interesting. Eight participants (8/24) showed preference for Level 2, the training level and stated that this was mainly due to the use of the Leap Motion Controller that introduced an interesting and enjoyable interaction style. Only 3 participants (3/24) said they liked Level 1 and they explained that this was because it introduced the game in an engaging and entertaining way. Three participants (3/24) did not answer this question and mentioned that all Levels were interested in their own way.

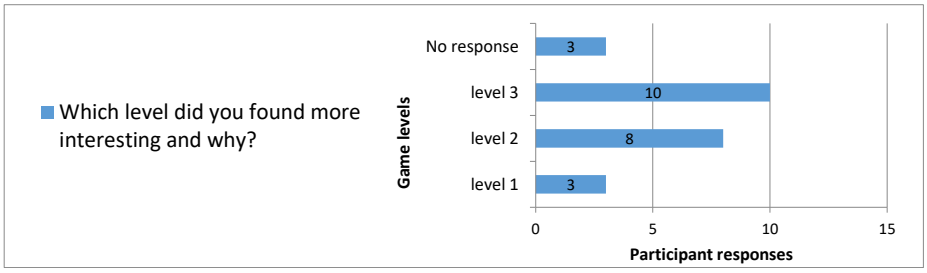

Figure 11: Questions related to the Level preference of the Signum Battle SG

Figure 12 illustrates a set of general questions participants have been asked related to their overall experience using the game to learn and their response. Twenty-three of them (23/24) agreed that the game helped them to learn and apart from the navigation and interaction issues in Levels 1 and 2 it was an enjoyable experience. Half of the participants (12/24) said that they expected more features like:

- more advanced use of the Leap Motion, like the detection of the correct signing of each sign;
- the possibility to spell small words;
- the integration of a map in Level 1 to help orientation and discovery;
- imposing time constraints to collect letters, a restricted number of attempts and, gaining power while learning.

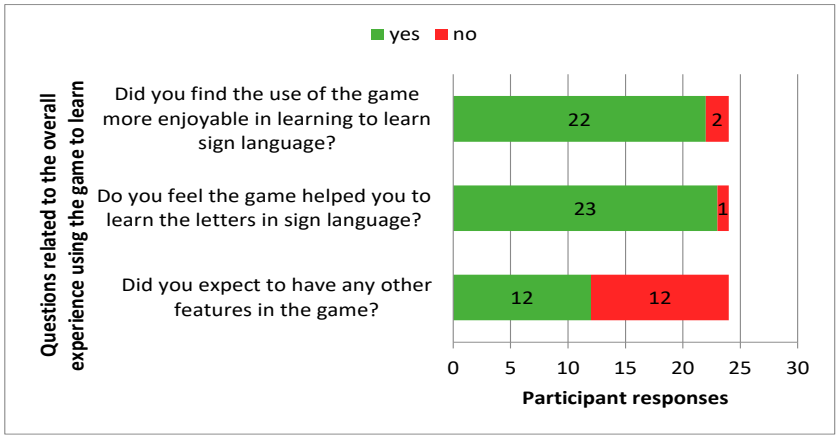

Figure 12: Generic Questions related to the design of Signum Battle SG

Eighteen of the participants (18/24) found the game more preferable as a learning tool (see Figure 13) and the following features made the experience enjoyable:

- the gamification of the learning experience, the sense of progress, while learning and having fun;
- the game concept for learning sign language, the story, the narrative, and the historical setting;
- the use of different interaction styles and their ease of use;
- the ease of use of the UI, the tutorials and the game controls;
- the integration of video within the game to demonstrate the signs;
- the inventory was a useful tool for revision;
- the use of the mnemonics;
- the opportunity to revise the content they have learned;
- performance under pressure at Level 3.

However, a considerable number of participants (6/24) preferred the video resource due to its clarity and simplicity.

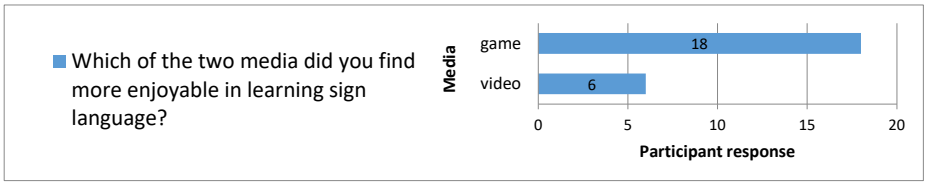

Figure 13: Participants preference of the video material vs the SG

The following section closes with discussion, directions for future work, and conclusions.

7 Conclusions & future directions

This paper presents a first attempt of providing a valuable resource to support people to learn the BSL alphabet enjoyably and effectively way with the use of video coupled with advanced technologies and gamification. The resource uses a scaffolded instructional approach in learning by offering temporary support structures to assist students in their learning process and tailoring the learning process to the needs of individual learners enabling a self-paced exploration of the learning content. The paper presented the design of the first version of a prototype SG which is used to evaluate the educational approach compared to conventional video-based educational material. This study supports this work in progress, by allowing an informed revision of the prototype based on 'real' user feedback.

The paper presented the experimental apparatus, it reported and analyzed research output based on a study partaken by 24 participants comprising of quantitative and qualitative data. Quantitative data demonstrates the advantage of SGs in effectively supporting the learning of a set of BSL signs. Qualitative data suggests various improvements to the SG design focusing on refining movement in the environment, enhancing interactivity, and improving the game mechanics to make the experience more memorable.

The future direction of this work focuses on further improvement of the SG, as well as on repeating and extending the study with a larger sample of participants. Specifically, to allow the collection of reliable data about users learning, one main update to the game will be the implementation of all 26 signs. At the moment Level 1 contains only 8 signs, which is close to Magic number 7 (plus or minus two) of the proven capacity of human short-term memory [Peterson and Peterson, 1959, Miller, 1956]. Most adults can store between 5 and 9 items in their short-term memory. Increasing the number of signs to be learned and memorized may increase user performance gap between those playing the game, compared to the ones watching the video resource, where preliminary results revealed no big difference. Possibly the first level of the current prototype needs to be extended to 3 levels each holding 9, 9, and 8 letters respectively to cover all the BSL signs. New environments would need to be created to maintain the user's interest and perhaps each Level would add several lives to the player's health before progressing to Level 3. Also, it would be possible to experiment with slightly different conditions in those environments in Level 1 to evaluate their effect on learning. For example: busy versus plain surrounding environment to test if very rich visuals obstruct the learners' attention instead of helping them to learn; time constrained versus unlimited time spend in a Level; empowering versus losing health. Level 2 would be more challenging for the players/learners as there would be a larger volume of random selections of letters to be recalled. Certain logs need to be integrated into the game to collect more precise information related to the number of times users watched a video of a BSL sign, the period of time they spend training each sign and, their final performance. In addition, to collect reliable unbiased data the experimental framework should change from exposing the same sample to both conditions (task 1 and task 2, that so far exposed the participants to different BSL signs), to running a two-sample test where users would split in the control group using the video material and the experimental group

using the updated SG. This would ensure avoiding learners being exposed to the signs twice and demonstrating preference towards a medium.

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