Development and evaluation of serious games to assist nursing language acquisition of international students

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Declaration

I certify that this work does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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Abstract

The domain of serious games relates to the use of games and game mechanics for non-entertainment purposes. This thesis presents the development of two serious games followed by a pilot usability study. Both games were designed to help international students retain discipline language, specifically nursing students. The project aims to answer the question: Can Serious Games improve the discipline language for international students? With a focus in this thesis on the usability aspect. The developed games are Brevissima and Medicina. Brevissima trains students in recognising medical abbreviations, while Medicina trains students to become familiar with accurate medicine names. In Medicina, users are exposed to scientific and commercial medicine names. Both games make use of visual and audio exposure and employ educational theories.

The literature review of this thesis reviews serious game design concepts, game mechanics, and examples of educational games. Also, it reviews some related topics such as game design documentation. The thesis discusses each developed game from different areas such as the development, the educational-based theories, and concepts. The usability of these games will be discussed, and an evaluation of the developed games compared to existing games. The pilot study uses a quantitative research approach. The procedure of the study has three main steps. Firstly, a pre-test to the participants. Secondly, the participants play games for two weeks. Finally, a post-test is given to the participants. The participants study at the College of Nursing and Health Sciences at Flinders University. The pilot study questionaries were adapted from the system usability scale – SUS, a game evaluation scale and a game evaluation framework. The result of the pilot study shows a satisfactory usability level. However, game enjoyment and engagement may need improvement. Future work suggested includes evaluating the games with a larger group and developing the design elements that were subsequently removed from the pilot study prototype games.

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Chapter 1. Introduction

Computer games have been employed in multiple industries for purposes beyond pure entertainment, including knowledge transfer, social change, marketing, training, and simulation. Video games which are developed mainly for non-entertainment purposes are called serious games (SG). In training, SGs can both reduce the cost of the training, as well as increase the training's safety [3]. For example, training in chemical factories can be dangerous in the real-world environment, and a trainee's mistake can be costly both in resources and human lives, and may even halt a production process. The same risk can be seen in schools' chemical laboratories [48]. In contrast, the virtual environment removes these risks. Another advantage of using SGs is the increased accessibility. For instance, when working with large or expensive machines, SGs can provide access to simulated machines from home, and to more than one trainee at a time. Furthermore, SGs can be beneficial in education as they can increase learning motivation when designed appropriately, and in the health field, they can be used in rehabilitation, simulation, and staff training [3].

This thesis analyses and discusses the development of two SGs and includes a review of the related articles, experiments, and publications that represent guidelines and recommendations when designing a SG. Also, this thesis reviews some SGs that were designed for health education. By situating the research through a thorough literature review, the goal of the project presented in this thesis is to investigate the issue of **Determining the user experience of serious games developed to assist nursing discipline language for international students".** Presented in the thesis is the development of two games, Brevissima and Medicina. A description of the game design and implementation, followed by a pilot study consisting of two aspects: the usability of the games, and the educational outcomes, is presented for each game. This thesis focusses primarily on the game usability aspect, though it will conclude by analysing and discussing the study results also.

The developed games, Brevissima and Medicina, are not newly designed games. According to the development documentation, these games were part of a project called "inSONMia" which name was changed to "Automa-City". These games were developed at Flinders University using "Adobe Shockwave Flash", however, due to the limited accessibility and security concerns of this technology, these games could no longer be used. In the previous study, the games, as a whole, showed positive results. For the research project presented in this thesis, the development process did not include designing the games' graphics assets, these assets were re-imported from the old games. To enable play on modern systems the games were redesigned, recreated and developed using "Unity Engine" and as such can be exported to different platforms with the targeted platforms being web and Android mobile OS (other platforms such as iOS were left for future work). The project included building the games' database, API, and a web-panel. The database has been used to log the participants' data, while the web-panel is used for registration, login, and to download the games' Android version. The database and the web-panel were both designed to support future games.

Generally, the Automa-city family games shared similar game assets. Automa-city is a term referring to doing a task with less effort and less resources [2]. The games share the same avatars, audio effects, and UI design. This was considered when designing the new web-panel, thus one branding and visual feel will be used for all games. The Automa-city game family has four games: Brevissima, Idiomatico, Medicina, and Slanguage, all of which aim to teach international students, medical terminology. Each game has its own challenges, design, and goal. Brevissima's goal was to teach abbreviations, with the student being exposed to both visual and vocal abbreviations. The game offers seven levels that emulate through cartoon like, vector art, a real-life environment. The student was asked to identify the abbreviation by listening to either the full name or an abbreviation. In contrast, Medicina has only one level, and its goal is to train students on the names of medicines, both scientific and commercial. Again, through colourful cartoon style graphics, the game emulates a real-life situation where a nurse asks the student to bring a certain medicine, and the game trains students to catch the vocal names whilst challenged by accuracy and time. It allowed five seconds to pick the medicine and a limit of three mistakes. This thesis will describe each game in detail in the following sections.

The development of these games presented challenges from the game design perspective and technical challenges. There are usability improvements and changes made to the games, with the result being satisfactory, though the enjoyment of the developed games may need improvement. There were certain game elements that were not developed due to the short time for the project, but these elements may improve the engagement of the games. The decision, to not implement these elements, is discussed in the development challenges section (Chapter 5). The overall results will be discussed in four groups: engagement and enjoyability, realism and narrative, design, and ease of use. The results were used to motivate the study of the games on larger scale groups, as well as to continue the development and add in the eliminated elements.

The future work of this project includes developing the other two games in the family, studying these games in larger scale group, and developing the game elements that were not included in the final design.

1.1 Structure

The thesis structure is divided into seven sections: problem and motivation statement, literature review, methodology, system design challenges, Brevissima, and Medicina development, result and analysis, and conclusion. The following points list these sections and a brief description of each section.

1. The problem and motivation statement chapter presents the current state of the original games and why they need to be re-developed. It details the aim of the games, and what game engine was chosen for developing the SGs.
2. The literature review chapter reviews related articles and papers to SGs and other educational games. It starts by reviewing the system usability scale and game evaluation scale, followed by a review of topics related to SGs development such as designing the SGs and documentation management. It reviews related SGs examples, each with different technology, audience, and

level of application. Finally, it reviews related theories such as cognitive memory theory enhanced using SGs.

3. The methodology chapter gives an overview of the research goal. It lists the research procedures and questionnaires, and describes the design of the pilot study and its data collection.
4. The system and design challenges chapter focuses on presenting the system's architecture and the challenges in developing these SGs.
5. The Brevissima and Medicina development chapter presents each game in three sub-sections. It shows the game design, the design theories, and the implementation of the game. This is followed by a usability review which highlights some of the changes made to improve the usability of the developed games, and an evaluation of the re-developed games which present the developed features of the games. It highlights features from the original games that were eliminated, and new features and updates that were added to the re-developed games.
6. The result and analysis chapter starts by showing the participants' demographics, followed by the results that are presented in four groups: engagement and enjoyability, realism and narrative, design, and ease of use. This is followed by an analysis of the study results.
7. The conclusion chapter shows a summary of this thesis and future work.

Chapter 2. Problem and Motivation Statement

Many nursing students have reported difficulty when interpreting, understanding and taking medication names either in person or over the telephone, as nursing depends hugely on verbal communication [41]. This task is a challenge as they must identify the medication names and listen carefully to the handover information. Learning a new vocabulary for a native speaker often feels uncomfortable, and the nursing students may need to use the new vocabulary multiple times to get used to it. Certainly, the task is even more challenging for a second language speaker. Learning medical abbreviations is yet another challenge for nursing students, as the medical abbreviations appear in different forms and change according to whether they are written or spoken. There are six different ways to write abbreviations and four ways to shorten original words according to Muller, et al. [40]. These skills are not easy to learn yet are incredibly important for nursing students.

The School of Nursing & Midwifery at Flinders University employs SGs to improve these skills. They have created Automa-city SGs to support learning the English language for international students. These SGs target the listening skills and mitigate the challenges. The scope of the research presented in this thesis includes Brevissima and Medicina SGs, and the challenges and design of these SGs are discussed in more detail in the next chapters. These SGs have showed good results since they were developed [40,41]. However, they are not used as much as they used to be due to technical and accessibility issues. The Automa-city family of games were developed using Adobe Flash Player. At the time of development, the development team had a choice of four possible game engines: HTML5, Java, Adobe Flash Player, and Cross-platform game engines such as Unity, Torque, and Corona [41]. The HTML5 option was eliminated as it was slow and unreliable at the time, the Java option was eliminated because of compatibility and technical issues. The Unity and cross-platform game engines were eliminated because these game engines require installing software or plugins to the client's computer. For these reasons, the developers chose Adobe Flash player as the game engine which was a popular game engine for web games at that time [41].

Nowadays, Adobe Flash Player is not accessible on many platforms such as iOS mobile devices, and so this project aimed to improve the accessibility to these games by re-developing them using the Unity game engine. Currently, the Unity game engine does not require the installation of plugins for web versions as it used to, and it also has great compatibility with mobile operating systems such as iOS and Android. The developed games were exported to web and mobile platforms, and the games' development was followed by a pilot study that consisted of two parts. The first part was the usability study which aims to measure the accessibility and usability of these games, whilst the second part aims to measure the engagement of the game for players and how the players found the games from design and graphical perspectives.

Chapter 3. Literature review

This literature review is divided into five sub-sections, starting with a section dedicated to usability and game evaluation frameworks. It discusses the system usability scale (SUS) and related papers, followed by a framework to evaluate SGs. The second section gives an overview of SGs and presents several systematic reviews to give a general overview of SGs. The third section focuses on the pedagogical aspect of SGs, providing pedagogical theories and related studies. This section represents the motivation elements and how to build motivating SGs. The fourth section shows the SGs' development models and mechanics, some of which were proposed to ease the SGs development and maintain high communication between development groups. The last section shows examples of SGs, presenting two groups of examples: health SGs examples and related topics such as listening skills and cognitive memory.

3.1 System Usability Scales and Game Evaluation Frameworks

The System Usability Scales (SUS) was created in 1986 by John Brooke [43]. The SUS scale was defined as a quick and dirty usability scale comprising of ten questions. The questions alternate between negatively-worded; for example, "I found the system unnecessarily complex", and positive question; for example, "I thought the system was easy". The use of alternating question phrasing is to minimise bias in the results from the participant. The answer to these questions have five options scaled from "Strongly disagree" to "Strongly Agree". The SUS provides a guide on how to calculate the values at the end out of 100 [43]. According to a book titled "Quantifying the user experience: Practical statistics for user research", the SUS calculated value can be converted to a grade from A+ to F [45]. Another study showed through a review of 500 evaluations, that the average SUS value for suitable and usable software is 68, this is not a percentage value but rather a scale value for reporting SUS [46]. There are similar scales to SUS such as the standardized user experience percentile rank questionnaire (SUPR-Q) which has four factors to measure websites, these factors are usability, trust, appearance and loyalty. Another scale is usability metric for user experience (UMUX) which was developed to create a valid measurement scale out of four questions as well as the (UMUX-LITE) which consist of two questions only, but the SUS tends to be easiest and quickest when it comes to implementation and data gathering [46]. Appendix C contains the SUS questions used in the research presented in this thesis.

Developing an easy-to-use game does not make it a successful SG. For this, it must be evaluated and measured from the player enjoyment perspective and the educational outcome. EGameFlow is a scale for game enjoyment which consists of eight areas: immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement [44]. Each area contains several questions, with a total 56 questions. This scale could help the game designers and researchers to understand what the player enjoys about the play experience [44]. Questions used in the research presented in this thesis have been adapted from the EGameFlow survey, see Appendix D.

3.2 Overview of SGs and Systematic Review Papers

There are different proposed categories for SGs, one of which being the criteria of whether it is for defence, education, advertisement, health, recruiting, social change, or other non-entertainment focused activities. De Gloria, Bellotti, and Berta presented another categorisation is based on the psycho-pedagogical and the technical level of the game, which considers different dimensions such as purpose, reality, social involvement, and activity [7]. In addition, the study by De Gloria, Bellotti, and Berta suggests three components that must be satisfied to create an effective SG. Firstly, involving all stakeholders such as students, educators, developers, and researchers. Secondly, employing theories from relevant areas such as pedagogy, cognition, and learning. Thirdly, support for the SG and employing a mix of technologies such as Artificial Intelligence (AI), computer graphics, and Human-Computer Interaction (HCI) [7].

While the focus of this thesis is on developing an educational nursing SG, it might be helpful to see other available examples. A literature review conducted by Muller, Pront, Koschade and Hutton [2] on SGs shows there is in fact a very low number of SGs that have been designed for nursing education by using a comprehensive search of electronic databases, applying four criteria to filter the findings. These criteria are: 1) Games should be rule-based which makes players understand the environment; 2) Games should be responsive which means giving players the controls; 3) Games should challenge the players; and 4) The players must build progress to achieve the game's goal [2]. Based on these criteria, the study found only four games, and it is worth mentioning that two games out of the four are re-developed in this project. Muller, Pront, Koschade and Hutton's literature review was tightly constrained to just nursing education games, to the exclusion of other education domains. The paper highlighted some of the key advantages and disadvantages of SGs. It highlighted advantages such as increasing motivation and decision-making skills, while the disadvantages could be the high cost of development, time-consumption, and design complexity [2]. The study emphasized that there is not enough evidence on the effectiveness of SGs in nursing [2]. Moreover, another study failed to identify evidence for the impact of design elements on SGs for health education [3]. The study used a systematic review as its research methodology [3] in which design elements were defined as the leader board, hints, point, time pressure, and challenge-based mechanics [3]. Previous studies were able to identify the impact of design elements in health education simulation [3], but according to this study, using the same methodology was not helpful to identify evidence for the impact of design elements on SGs in health education [3]. Another systematic review stated the opposite; it found that educational health SGs appear to be more effective or equally effective to traditional education [25]. In addition, it failed to identify which type of SG is more effective [25].

However, many studies have highlighted that students' experiences were positive and very promising. A focus study group showed a high engagement [4]. The study focused on five elements: experiential learning, the learning process, personal versus professional, self-efficacy, and knowledge. Three sample groups of nursing students participated in the study and played a nursing SG for three weeks. All participants were women, of which there were 500 in total. Based on the study elements, the results were as follow: the game actively promotes experiential learning. The groups liked the safe guided learning process which they had commented, made them more

confident in future life. The decisions made in the game promoted self-efficacy. Finally, the study highlighted knowledge gaps, with students being able to see the impact of the work environment and gaps in their learning [4]. The study shows a high stratification, engagement, and self-efficacy based on clinical experience.

SGs could be engaged in nursing education as an evaluation tool. A study aimed to evaluate multiple-choice questions (MCQ) using SGs, showed the following results. The study targeted a total of 68 fifth-year medical students, with the SG being used to provide the student with the same questions but in a simulated environment. The results show that students did not feel any difference in the difficulties. However, the students believed that the SG was closer to clinical practice and they felt they learned more from the SG. The students were divided into two groups; One group started with the MCQ and then the SG, and the other group did the alternative. The group who started with MCQ obtained better results, but the overall MCQ test results were better than the SG results [5]. Considering the difficulty element in SGs, many games offer different difficulty levels, and others change the difficulty level based on player performance. Eichenbaum, Bavelier and Green have suggested that while video games try to find the balance between challenging and enjoyable, SGs and the learning process will be affected by the difficulty level [6]. Eichenbaum, Bavelier and Green stated that players do not like to master a game the first time of playing it [6]. Conversely, players do not want to play a game they cannot win [6].

Furthermore, research shows that video games release the same neurochemicals as a hungry human receiving food [6]. SGs can help people with Alzheimer's and similar mental disorders [6]. In addition, SGs improved the quality of life and the self-concept for elderly participants [6]. In training, a group of novice surgeons who were trained using SGs performed better than a control group that had no SG training [6]. It is worth noting that the type of game may have different cognitive effects [6]. For instance, researchers found that action games may improve multitasking and the ability to focus, and moreover, action games have been proven to help patients with "lazy eye" [6]. SGs may also have an impact on players due to anxiety or stress. For example, a SG aiming to teach a nursing student medical skills found a change in the student's vital signs when playing the SG, however further study is required to determine if this has a positive or negative impact from the teaching perspective [37].

3.3 Pedagogical Theories and SGs

The term "serious game" was first used in 1970 by Clark C. Abt [47], but the growth of eLearning and SG has attracted the pedagogical scientists' attention, as well as developers who wish to employ some educational theories in SGs. It is recommended that SGs should be developed by multidisciplinary groups [7,8]. However, creating these groups can be challenging [8], as can the issue of not having enough evidence on how to design and construct SGs [8]. This challenge can be seen in various studies [2,3]. The work with multidisciplinary is a challenge that might be caused by the lack of communication because different groups use different 'discipline' languages. The study [8] described some of the design tools and annotation systems that can help to overcome this problem. These models create a communication language that pedagogical and technical people understand, and the study suggests a model called ATTAC-L. The ATTAC-L could be described as a Unified Modelling Language (UML) with natural language annotation. The study

applied this model to two pedagogical theories. It was applied to Social Cognitive Theory (SCT) and Intervention Mapping Protocol (IMP) [8]. The authors claim the ATTAC-L model could be used to generate part of the code too. However, the model cannot describe the graphical specification. The model ATTAC-L was not the first model for SGs design; other models included LM-GM which focuses on the relationship between the game mechanics and the learning mechanics, WEEV which focuses on the storyline of the game, GLiSMo which also focuses on the storyline of the game, ATMSG focused on the relationship between the game components and the educational objective, and RETAIN which combine motivational and educational and design models [8].

Similarly, some theories were applied to the test phase. A study applied Kolb's experiential learning cycle when testing the SG [9]. Kolb described four abilities to have effective experiential learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Eight nursing students participated in the study [9] and played the game developed as part of Kolb's study in four sessions followed by an interview. The study [9] found that the Kolb model can usually be applied. In addition, the study found that students will sometimes experience the experiential learning several times in one scenario [9].

Usually, SGs are presented and marketed as a motivating tool for learning, and a study [10], tried to examine some of the claims around SGs including motivation. The Ryan and Deci Theory states the need for three physiological elements: competence, autonomy, and social connectedness [10]. Building a motivation system in SGs can be challenging for the following reasons. Firstly, SGs use a reward system that implements scores or point style mechanics. The student might concentrate on rewards more than the leaning outcome. For example, designing a game for teenagers is complex [11], and engaging them in the game design showed their ignoring of the game values [11]. Secondly, the rewards might be not motivated enough. Thirdly, the reward may lose its value over time [10]. For example, having the character dancing after getting each task done might be fun at first, but over time it might lose its motivation value, especially if it is the only motivation after the task. In a related study [12], monetary rewards were studied against social rewards and virtual points. The study had 36 participants aged between (12-24) years who played the game and answered simple mathematical tasks. After each task, the participant saw three rewards options. For the monetary rewards they would get 0.50€, for the virtual reward they would get five points, and for the social reward they would get a motivating message such as "Good Job!" attached to an image of a person who they might know. The study found that monetary rewards were more effective than social rewards and virtual points [12]. It was suggested that this type of reward could be helpful in mental health care and therapeutic tasks [12]. It was suggested not to use SGs for the goal of replacing normal education [13], but as an augmentation of learning that could be used when needed, it does not replace other types of learning experience [13]. It was suggested to be considered in the health education strategy as the cost and the complexity of these games makes it hard to build high quality and effective games easily [13].

A study [20] summarized the SGs design pitfalls into four points. Firstly, trying to create a SG for the sake of the game. Secondly, not thinking about the end-user when designing the SG. Thirdly, designing and using the SG as the only tool. Lastly, focusing on creating a fun game more

than the learning outcome [20]. Despite the complexity and the challenges, SGs could be deployed to new audiences, and the reusability advantage may increase ROI value. A nursing SG called VCLE was designed to target graduate and doctorate students. The game was able to target second semester undergraduate students successfully and was then modified to provide extra resources. This modification required engagement from stakeholders such as the faculty, however the result of the undergraduate survey showed positive feedback [21].

3.4 SGs Development Models and Mechanics

In the previous sections, different development and design challenges were presented. These challenges, such as having multidisciplinary groups and maintaining the SGs design criteria are complex, and so this section presents different studies about the relevant models used to design and develop SGs. The software design process is the roadmap for developing these SGs software, which has led some researchers to contribute to data collection while others may change the design process. In the study [14], the researchers included six data collection phases to designing a mobile SG. Another study proposed a protocol method for the SGs design process which included three phases [15]. These phases are pre-session, in-session, and post-session, with each phase consisting of different elements. The pre-session phase includes type of reporting, number of participants per session, participant selection, duration, creating design tasks, participant preparation, and environment setup. The in-session phase includes participant brief, recording and data collection, documentation and interview, and game evaluation. The post-session phase includes transcription, data analysis, coding, and validation of outcomes. This method aims to limit the gap between knowledge and the design process. It was claimed that this method can help to translate the content into game elements [15].

The game design document (GDD) is a useful document for SGs development. However, ~50% of game professionals believe it is not effective for communication and only 5% read the GDD [16]. The study [16], shows how they have transformed the GDD into a conceptual model which was then translated into a web-based system. The conceptual model was analysed and combined from different domains. They have analysed the influencing educational factors such as motivation, readiness for learning, and reward & punishment, and defined the game purpose attribute. For instance, players can play a game for the scenario, character, meaning, or the exciting visual presentation. In addition, the game design elements were defined including rules, challenges, and goals. The proposed conceptual model consisted of four main components game content elements, educational games, game design elements, and cognitive outcomes. As a result, their solution showed a positive result in solving GDD related problems. These problems are inconsistency, lack of GDD updates, and lack of communication. However, a further case-study is needed to validate their solution [16].

The GDD describes the game mechanics but designing the game mechanics may be challenging in itself. In order to create a unified language, a framework has been created that describes SG mechanics. The SG mechanics have been simplified into six categories: creating, evaluating, analysing, applying, understanding, and retention [19]. These categories aim to ease the game design work, however designing a SG is different to designing an entertaining game. As such, not all of the game mechanics work for the SGs [17]. Overcoming the pedagogical and game

design pattern gaps can be very challenging, and so a study [17] proposed an approach called purpose-processing methodology (PPSM). This approach aims to identify and evaluate the SG mechanics. In their earlier work [18], the results showed a positive shift towards identifying the SG mechanics. In summary, the above researches show efforts to overcome the challenge of design and identify SG mechanics. They proposed a unified language and framework to ease the work of SG mechanics identification.

3.5 SGs Case Studies and Examples

Searching for SGs examples yields thousands of results but, as presented in the first section of this literature review, there is a low number of available games based on suggested criteria [2]. This section shows examples of SGs that may have an intersection with the study games (Brevissima and Medicina). This review shows general related topics such as memory and listening skills, which is then followed by a sub-section of health SG examples.

3.5.1 Related SGs examples

The developed games for this thesis focus on teaching discipline language and this involves memory training. This section shows studies focused on the SGs' effect on cognitive tasks and an open world language teaching example. An example of how to use SGs in teaching languages was implemented using the virtual open-world [24], which showed some benefits such as the opportunity to provide brilliant lessons and increasing the trackability of students' activities.

The effect of SGs on memory, however, has proven to be debatable. One positive result was shown by a study testing the effect of gamification elements on memory. The study [22], gave two groups complex cognitive tasks, with both groups being instructed to solve the tasks using software. The first group used software that had some gamification elements such as progress bars and brain icons, whilst the second group used software with no gamification elements. The result showed that the game group achieved better result but both groups achieved the same number of tasks [22]. While another study on 119 US Navy recruits showed the opposite [23]. This study aimed to test the cognitive theory of multimedia learning versus resilient listening. The multimedia theory of learning states that presenting information in two modalities improves recall and retention. The resilient listening theory states that audio is better than text in training exercises [23]. The study tested these theories using technology and the result showed no improvement in recall and training outcomes. In fact, the study suggested that using human audio is better than synthetic audio in training exercises [23].

3.5.2 Health SGs examples

This section reviews SGs designed for health education and training. The examples show how SGs were used in simulation, value education, knowledge education, training, improving cooperation between students, and decision-making skills. The first study showed how SGs improved interprofessional learning between students [26], targeting pharmacy and medical students and categorising them into three groups. The first group was medical students working alone, and the second group was pharmacy students working alone, and the third group was pairs of pharmacy and medical students working together. The results showed a significant improvement in the third group and a slight improvement in the first group's result [26]. The study states that

SGs clarify the patient care role to students and demonstrate that they are ready to participate with other health disciplines [26].

The revolution of virtual reality (VR) technology will certainly have an impact on SGs. The SGs may reduce training's environment risk and cost, but the VR technology may take the simulation to another level entirely. A German study employed VR technology into SGs for training the process of ultrasound imaging [27]. Besides simply making a simulation of a real-world environment, the study decided to create a fun experience. The player was placed in a VR toy factory in which they needed to scan the toy boxed to find any mispacked packages. The player would use the ultrasound machine whilst scanning these toy boxes, and the game also provided a work environment and simulated an X-ray room [29]. The results showed an improvement in students' performance, but the authors suggested adding accurate tutorials. The game achieved high student satisfaction, with over 95% of students thinking the game was useful for medical education [27,29]. In addition, SGs improve self-confidence. A study on 97 nursing students showed that SGs had made them more self-confident [34].

Clinical reasoning and decision-making skills are very important for medical professionals. Poor clinical reasoning skills are one of the top three causes of diagnosis failure [38], and so the teaching of such skills were implemented into different SGs. The following discusses four examples of SGs targeting nursing students. The first game targeting nursing students was called CareME [30]. The game tried to promote clinical reasoning skills, with the player being in a work-simulated environment and being given questions based on the game scenario [30]. The second game aimed to promote both decision-making and clinical reasoning skills [31,35]. The game does not show a simulated environment, but instead showed a video of a nurse to a patient. The students would be ask questions, and the player would provide the patient with information about the diagnosis [31]. It is worth noting that the game designers found making the quiz questions incredibly challenging [35], and the results showed no significant difference between using this SG or other e-learning resources [36]. The third game was called VTEM, and it aimed to promote medical skills for responding to emergence cases [32]. The VTEM game allowed trainers or lecturers to add scenarios to the game. The game showed a simulated patient screen along with the vital signs, and the students would be given the scenario and option of actions and drugs. However, these scenarios could be edited or changed by the course's trainer or professor [32]. The fourth game was called mSTREET. It is more than a single SG; it was designed as a framework, allowing teachers to build their scenarios and teach through this framework. However, it is designed for nursing students. It aims to teach clinical skills targeting communities with high social interaction [39].

LISSA and DECIDIX are games designed to teach a specific topic. LISSA was designed to teach cardiopulmonary resuscitation skills for nursing students, with the results showing a significant impact on students' performance and motivation. Also, using LISSA showed better-obtained skills when compared to more traditional training [33]. In contrast, DECIDIX was a SG targeting adolescents in the field of sexual and reproductive health education [28]. The game scenario simulated an instant messaging website wherein the player would contact someone to discuss an issue or situation that they were having with another player. A total of 36 adolescents

participated in the study, and though authors believe it was a motivating environment for adolescents, it should not be used alone without any other type of education [28].

3.6 Summary of Literature Review

The literature review has shown that a low number of SGs are available for nursing education. It started by reviewing the SUS and related usability scales, as well as a game enjoyment evaluation scale. The review showed some design and development challenges such as the complexity of SGs development and the requirement to engage multidisciplinary groups. The challenges were followed by pitfalls that SGs may have such as designing a game for the sake of developing the game. Different theories and models were shown to easily improve development. A model was shown to improve communication between groups and GDD management. More than one theory was presented on motivational factors, including monetary factors. In relation to the developed games, a test of two theories relating to memory was shown. The last section shows different examples of SGs, with most of these games targeting nursing students. These examples were from different technologies such as VR, video-based, and simulation, some of which were followed by a study of usability or improvement. The overall results show improvement or at least neutral effects.

Chapter 4. Methodology

4.1 Research Overview

A quantitative research approach was used in this pilot study, which will in turn give feedback on what to improve and change about the games. The results might provide motivation to test the games on a larger group. The project's main investigator is Dr. Amanda Muller, a senior lecturer who teaches English for specific purposes in the College of Nursing and Health Sciences at Flinders University. Two co-investigators were involved in this project; one focused on the development and user experience (UX) of the games, and the other co-investigator focused on the educational outcomes. Organising ethics requests and recruitment were arranged by the main investigator.

4.1.1 Research Procedures

- Designed the questionnaire. The usability related questions were included in the post-questionnaire. The appendix E shows the questionnaire.
- Requested approval of the project ethics.
- Requested 60 participants from the College of Nursing and Health Sciences.
- 15 participants were recruited and commenced the study.
- A pre-test was taken to determine students' abilities in the form of a questionnaire before playing the games.
- The student's played the games for two weeks. During these 14 days, a minimum of 10 minutes each day and 7 days of playing was requested.
- Games session were tracked and players' activities during play were logged.
- Completion of the post-questionnaire which included the game evaluation and the UX. Five participants completed the study.
- Collected raw data and analysed the data.
- Worked on the quantitative data and analysing of the results.

4.2 Research Design

The project output is two re-developed SGs (Brevissima and Medicina). The SGs were developed to help students in language acquisition, with Brevissima focusing on the discipline of abbreviation, and Medicina focusing on learning medication names. These SGs were developed using the Unity game engine and were designed to target both Android and web platforms. As some participants may have limited access to an Android device or web platform, Android tablets were provided to participants. The chapters System Design and Challenges (Chapter 5), Brevissima and Medicina development (Chapter 6) describe the systems' designs and implementation in more detail.

4.3 Surveys Utilised

The research questionnaire (see Appendix E) included demographic information such as player gender, how many hours they played the games, what kind of devices they had, and what type of gamer they were. This was followed by a questionnaire section focusing on the educational outcomes and the UX, with the answer scale based on a value from 1 to 5 (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree). Some questions were formed as negatively worded

questions, but all of the questionnaire questions regarded the UX and the game evaluation, adapted from two sources. The System Usability Scale (SUS) and the EGameFlow game evaluation scale were employed [43,44], and the usability aspect which is the focus of this paper had the following questions:

- Engagement/Enjoyability
  - I found this game enjoyable and engaging to play
  - I think that I would like to use this game frequently
- Realism/Narrative
  - I don't think the game reflects the real environment
  - I felt as though the character could exist in a real environment
  - I don't understand the story behind the game
  - I was able to understand the game goal
- Design
  - I found the game interface and control engaging
  - I think the graphics need to be improved
  - I think the audio effects and sounds suit the game
  - I found the various element of this game well designed (e.g. controls, avatar, levels, audio)
  - I thought there was too much inconsistency with this game
- Ease of use
  - The game help information is easy to access when needed
  - I think navigating inside the game is complex
  - I found the game unnecessarily complex
  - I thought the game was easy to use
  - I think that I would need the support of a technical person to be able to use this game
  - I would imagine that most people would learn how to use this game very quickly
  - I found the game very awkward to use
  - I felt very confident using the game
  - I needed to learn a lot of things before I could get going with this game

4.4 Data Collection

The participants studied at the College of Nursing and Health Sciences at Flinders University in topics focused on the discipline of the English language and its related abbreviations. The study was to test the students' abilities after using these SGs. The games were to be played individually in sessions that were not monitored or controlled. However, the games sessions were logged automatically. Support for the study participants was provided online and in-person as this may have been required for installing the games or for technical issues. The study involved three stages: a pre-test stage which took about 15 mins to test the students' ability before playing the games and to fill a questionnaire, after which they played the games for a minimum of 7 days out of 14 for a minimum of 10 minutes per day. The post-stage took about 15 mins in which the participants were to fill in a questionnaire. The ethics of this project were approved under project

number 6275 by the Social and Behavioural Research Ethics Committee (SBREC) at Flinders University.

4.5 Experiment Process

The main process can be described in four main sub-process which are the following:

- **Pre-Registration**
  - Around 20 tablets were ready to collect by the students who need an android tablet, the devices were provided by the thesis supervisor Dr. Brett Wilkinson and handed to the project main investigator Dr. Amanda Muller. The games were installed in the tablets and they were ready to start the experiment.
  - Setup the project database and adding the students' data.
- **Registration**
  - A brief introduction about the study was given to the students by the project main investigator about the study.
  - Email was sent to the students to register for the study.
  - The Android tablets were provided to the participating students, if they need one.
  - Support on registration and installing the games were provided.
- **Playing the Games**
  - Students start to play the games for two weeks.
  - Track and log the game sessions.
  - Continue to provide support if needed.
- **Collecting Surveys**
  - Filling the questionnaires by the participating students.
  - Processing and analysing the questionnaire results.
  - Export the game sessions records.

Chapter 5. System Design and Challenges

5.1 System Design Overview

The developed games aim to target both smartphone devices and web platforms. The system design includes four components: website, application programming interface (API), database, and the smartphone application (App). Figure 1 shows how these components are linked together. The website will be used for user registration, login, and playing of the web version of the games. In addition, the website will provide links to download the app games. The API was designed to serve iOS and Android apps, even though we only have an Android version currently. The API collects each play session and sends it via API, allowing us to record each session without losing any data in case a player switches between the game and other apps. With each main menu load, the app updates the highest score and the leader board data. Finally, the database stores users' data and session records. Figure 2 shows a sample of session records.

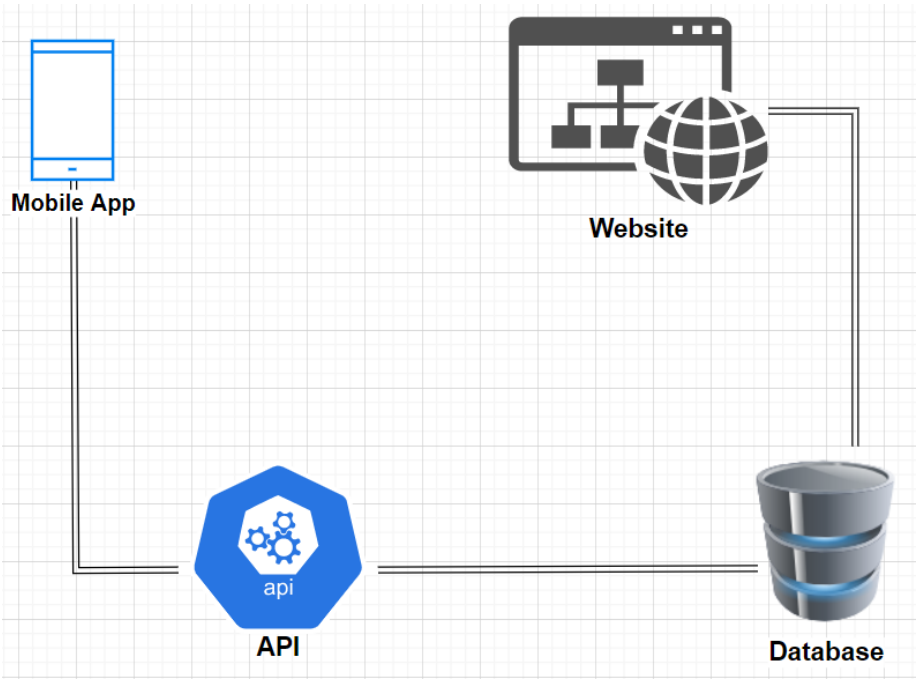


Figure 1 - System design and structure

id ▲ 1	UserID	StartTime	EndTime	Score	sessionScore	recordtimeStamp
30	Jimmy	2019-08-06 17:39:08	2019-08-06 17:39:24	250	250	2019-08-06 17:39:24
31	Qin	2019-08-06 17:40:08	2019-08-06 17:40:22	0	0	2019-08-06 17:40:56
34	Tony	2019-08-06 17:55:54	2019-08-06 17:56:26	1000	1000	2019-08-06 17:56:26

Figure 2 - A database record sample of the play sessions

The games have been developed using the Unity Engine from scratch meaning scripts, animation, and databases were either unavailable or not used. Some of the graphics and audio were available and others needed to be extracted from old games developed using Adobe Flash. By

using the Unity Engine, the games were easily deployed to Android and web. The iOS app was excluded due to the difficulty in getting the app onto the AppStore or to install it directly on the students' Apple products. However, the web versions of the games had some issues with compatibility between different screen sizes and platforms, though this has since been fixed. Though the game does not allow offline play mode, in case of network disconnection the app stores the offline data temporarily to be sent when the player is next online.

5.2 Development Challenges

It was assumed that the games' resources were available and documented, but there were challenges to the development and understanding of the design of the previous study's games. Firstly, we were not able to run the games in order to understand how they were designed. There was a gameplay video for each game, and one of the games had the GDD but it was out of date and required many sections to be revised or omitted. As a result, the work process was to view the gameplay videos and simulate the games. Secondly, there was a stark lack of media documentation, and importing the media and audio posed some challenges. One of these challenges was trying to locate an image or an audio clip, and the only solution was to dig through the available files or by decompiling the Adobe Flash files. In case of not being able to locate the resources, it was replaced with alternative resources from other games or from an online open-source library. Some of the text was not available, so an image was taken directly from the gameplay, which was then converted using OCR. Thirdly, the lack of a complete GDD documentation led us having to simulate the games from the gameplay videos, and in case of any unclear feature or mechanics, the game designer was available to consult with the research lead. Some other challenges were from the development side, such as targeting different screen sizes when the available graphics were designed for one screen size only. Similarly, targeting the web version was a challenge due to the different browsers' web engines. For instance, in some cases, Apple Safari does not allow the playing of audio. The games were not designed for touch screens, but as the new games targeted smartphones, the design had to be modified when needed. Another challenge was not having a database of the question bank and user data. Designing the database data was easy but the question bank was far more time-consuming because it meant having three versions of the database, and some of the audio files were not available. One of the databases was chosen based on manual matching, and the unavailable audio file issue was solved programmatically by checking the file availability. If it was not available, the app would get another question. Also, this would allow for the adding of the missing audio at a later stage without redevelopment. It is worth noting that the question bank and audio database were stored in JSON files to allow offline mode and give the ability to update the question bank. Finally, the original game offered four avatars to allow for a more personalised game experience, but only one avatar was available so, it was animated and used as the sole avatar. In conclusion, most of these challenges could have been easily dealt with if the documentation of the game design and resources had been maintained but engaging one of the game designers was a big help in getting past these challenges.

Chapter 6. Brevissima and Medicina Development

6.1 Nursing Games Website

The aim of the website was to handle the login, sign up, and playing of the mobile-based games. The website holds the APIs and was used to get around an issue with Unity's player for web mobile version. In addition, the website also provided links for downloading the Android version of the games. Figure 3 shows the main screen of the website.

Figure 3 - Nursing Game Website

An administration website was proposed for future work, which would allow teachers to observe students' game sessions without technical assistance. The nursing games administration section in Appendix shows the mockups for the website design.

6.2 Brevissima Game

6.2.1 Game Design

Nursing students find difficulties during handover because of dependencies on verbal communication and the number of medical abbreviations [40]. The Brevissima game aims to get students used to these abbreviations by automating the recognition process [40], and this is achieved by providing player's with exposure to these abbreviations visually and phonetically. Brevissima has 380 unique medical abbreviations imported from the Australian Nurse's Dictionary and the Australian and New Zealand version of Mosby's Medical Dictionary [40]. In each play session, the player would hear a sentence in the background 5 times, and each sentence would have abbreviated words. However, the background audio may pronounce the abbreviation or the full term, which in turn would make players aware of the abbreviations and what they stand for. The background may show a request or a medical description. For example, "He has a past medical history of Ischaemic heart disease and MI so we need to ensure that we do an ECG post-op". This sentence shows three abbreviations, and the player would need to recognise these abbreviations. In the game, these abbreviations would be falling from the top of the screen in the shape of pills along with other irrelevant abbreviations.

The game design shows an avatar holding a container. The player's role is to collect the correct pills and avoid incorrect pills. The player would see their score and a pills container that would get filled with each correct collection. Players would collect the correct pills which they had heard in the background audio. In the case where the player caught an incorrect pill, the pills container would lose its collection and the score would be reset to zero. In addition, a hospital bed randomly falling from the top was added to make more of a challenge and increase enjoyment to

the game. If the falling bed hit a player, the bed would be destroyed, and the player would fall to the ground with their score reset to zero. If the falling bed hit the player three times, the player would lose the game session. Collecting a correct pill would give the player a score of 50 and collecting the correct pill three times would give the player a bonus multiplier. For example, a x2 multiplier would make the correct pills worth 100 rather than 50.

After the game session, the game would show the written sentence which the player was hearing including the score and how many times the falling bed crushed the player. Also, it showed the "next" button which opened the next level. Completing level seven would take the player to level one, allowing the player to play the different levels without exiting to the main menu.

6.2.2 Brevissima Design Theories

The game was designed based on cognitive psychology-based instructional design. This approach claimed to be the best approach for the Brevissima content as it deals with the memory process in the first point [40]. The following presents three groups of theories that influenced the game's design.

Exposure

The cognitive-based instructional design stated that "*extended practice is needed to develop cognitive skills*" [40]. Brevissima exposed students to vocal and written abbreviations, and it was found that 10 exposures to a word improved the remembering of it [40]. In a confusing environment, the brain looks for patterns in human cognition [40]. Brevissima designers stated that games make students search for patterns and evaluate their knowledge by identifying the abbreviations, resulting in constructive learning and produces long-term skills [40]. The game design promotes interaction by having a time limit, and insufficient engagement causes failure in the game [40].

Feedback and scoring

The theories on feedback and scoring recommended using technology to provide practice feedback, and having rewards that increase students' motivation [40]. The game provided feedback after a correct or an incorrect answer, as well as additional feedback which was provided at the end of the game session. The game designer believes that instant feedback gives the students a clear idea of the knowledge level and the responsibility of their actions. The students' score presented their learning progress and the leader board compares them against other players which can add an element of competition and challenge. The instant feedback tells the students how much they have personally improved each time [40].

Multimodality and working memory

Providing vocal and written abbreviation names in Brevissima was driven by a multimodality recommendation which emphasises the importance of multimodality in working memory. An example of multimodality would be showing a picture of something while talking about it, which leads to greater learning [40]. In addition to employing the vocal and written

abbreviations, the game designers simulated a natural environment in the form of graphics and audio which is recommended to improve the expansion of the working memory [40]

6.2.3 Implementation

The game starts by loading the login screen. The students could either join or login, with the join button opening a web page for registration. After the login screen, the game shows the main menu which has four menu items: play, how to play, scores, and learning tips. Figure 4 shows the login and main menu screens.

Figure 4 - Screenshots of Brevissima Game

The play screen shows a list of available levels which students could choose between. Each level was designed to simulate an area of the hospital environment. For instance, level 1 simulated emergency, level 2 simulated reception. Levels presented different types of sentences groups and difficulties. Some sentences had only one abbreviation, whilst others may have had more. The "How to Play" button shows written instructions before playing, in-game instructions as well as link to email the game designer for any help. The "Scores" screen shows the player's current score and the top ten players including their scores. Finally, the "Learning Tips" screen describes the game's aim and how to make better use of the game.

6.3 Medicina Game

6.3.1 Game Design

Medicina's goal is to get the student used to medicine names by exposing them to commercial and scientific names. The students were exposed to the names visually and phonetically with the player being asked to pick a specific medicine from five options. Medicina's database has 250 medicine names and these names are placed into groups, with each group showing similar names e.g. Zentel, Zestril, Zyrtec, Zabel, and Zerit. These names were imported from the Australian Prescription Benefit Scheme (PBS) list [42]. The player would be challenged by the time factor and number of errors, as they had to make a choice within five seconds. If they failed to choose in time, the game session ended. Also, if they made three incorrect choices, the

game session would end. Players challenge their top score and other players' top scores. Medicina is not as cumulative as Brevissima; each game session will start from zero building the top score.

In each question, the nurse would appear in the background and ask the player for a specific medicine. The request was proposed in different phrases e.g. "Could you give me Zabel?" and clicking on a medicine container would enlarge that choice and show a happy or sad patient, in addition to phonetical feedback such as "Zabel, that's right", "That's not right". When the game session ended, it would show their score, and if they achieved a new high score a high score badge was shown.

6.3.2 Medicina Design Theories

The game's designers employed cognitive and linguistic theories while designing Medicina. These theories were maintained when redeveloping the game, and are grouped in the following parts

Exposure

The paper [42], presented different studies emphasising the importance of exposure. These studies have different exposure rates, but more exposure is likely to show a better result. The game designer believed that 10 exposures should make students more familiar with the words as well as them being able to recognize its spelling. It should be noted that evidence to support this claim from Müller was not presented in the paper. Medicina achieves this rate in less than an hour of playing. Half an hour more will expose students to ten vocal exposures [42]. Medicina has 50 groups of names and each group has 5 names. So, 50 multiplied by 10 equals 500. If each group took 5 seconds this would be 2500 seconds which is 41 minutes.

Cognitive load theory

Students playing the game are exposed to vocal and written names. This is claimed to improve the automaticity of processing the medication names [42]. Moreover, exposure multimodality should improve the processing speed and strengthen the links between the written and spoken words [42].

Sweller's (2010) cognition-based instructional design

There are two aspects of this theory: intrinsic cognitive load and extraneous cognitive load. The intrinsic cognitive load is described as "anything that needs to be or has been learned" and the and extraneous cognitive load is defined as "non-optimal instructional procedures" [42]. The first aspect is considered highly in this SG. The second aspect comes in the form of background, distracting sounds which aims to simulate the same level of hearing difficulty as in the work environment [42].

6.3.3 Implementation

Medicina's login screen is similar to that of Brevissima, which makes for a similar UX. Players can use the same game name (player identifier) for both games. Medicina has three main menu items. "Scores" shows the player's best score and the top 10 highest scores, "Help" shows

the information on how to play the game and a link to the game designer email for any technical issue, and the “Play” button starts the count down to the game.

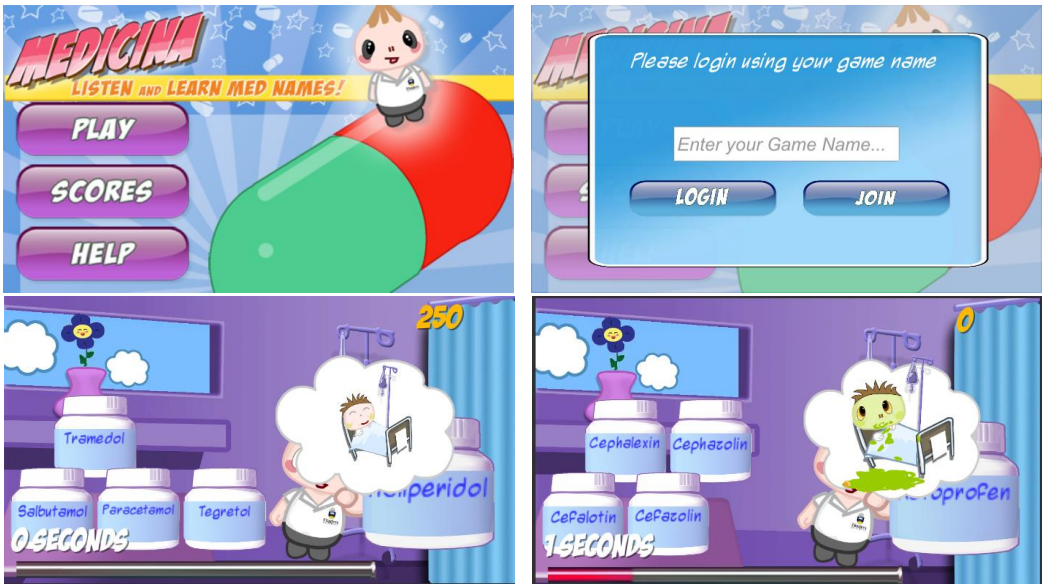


Figure 5 - Screenshots of Medicina Game

6.4 Nursing Games’ Usability

The games were originally designed for a desktop screen, whereas in the new redevelopment, they are targeting smartphones as well. As such, some modifications needed to be made to the design of the game in order to enhance the UX. Firstly, the game was modified to have a similar UX; both games share the same login and join screens. Once the player creates a username for Brevissima, they would be able to play on Medicina and vice-versa. However, the login screen is different in the mobile web version. It was seen in Figure 4 & Figure 5 that the login screen has a text field for user login name, but this is not possible with the mobile web version. This is due to an issue with Unity web mobile preventing popping the keyboard when clicking the text field. This issue was avoided by taking and sending the user data outside of Unity’s player. The login website was designed to share a similar UX with the games.

The two games place the scores at the same place on the screen, and the top 10’s screens for both games are very similar. Both games offer a support email address in case of technical issues and a brief statement about the game and how to play. In Brevissima, it was noted that users cannot go back to the main menu while playing, so a back button was added to remedy the issue. The same button was not added to the Medicina game because Medicina play sessions are shorter as making three errors or waiting five seconds will end the session. In Brevissima's original version, an instruction was shown to the user directing them to use the left and right arrows to control the avatar. In the redeveloped version that text was removed, as the game now supports arrows keys as well as standard game direction control letter (WASD) keys. In addition, touching the right half of the screen would also make the avatar move right and the left half of the screen will move left. The overall design tries to maintain “Next” and “Back” buttons in the bottom of the pop-up windows and the left-top corner in the game session.

Some audio effects can be seen to improve the UX and the learning feedback also. In Brevissima, when the player collects an incorrect pill, an audio clip saying 'No' is played, as well as the falling bed crash audio clip and unloading the pill container. In Medicina, audio effects were used in a similar way. Whether the user picked a correct or incorrect medicine, they would hear the medicine name in relevant phonetical feedback along with a happy or sad patient image. In Medicina, each play session shows a countdown which gives a sense that time is a challenge too.

6.5 Nursing Games' Evaluation

This section lists the aspects and the elements of the developed games. This is followed by listing the elements in the original games. The original games list avoids repeating items from the developed games and focuses on the eliminated items only. It has been justified that some of these game elements have been eliminated because of missing game assets, but most of the features of these games were implemented as they were in the original games. However, some of these features were edited as per the game designer's requirements.

6.5.1 Developed games

The Automa-City family of games share several features. The following list, details the shared features between the games, followed by each game's specific features.

- Shared features:
  - Top 10 leader board which shows the highest ten scores.
  - "Join" in both the web and mobile versions will lead to a web page join link. This is a new idea implemented to have a unified username for all games and platforms.
  - Login screen using the username only.
  - Help screen that shows how to play the games with a brief description.
  - Logging of game sessions data which includes start time, end time and the game session score.
  - Allowing the controlling of the games using the touch screen and keyboard as well as the cursor.
  - Feedback screen after each game session.
  - Showing the current level and score during the game.
  - Playing the sentences in the background for different times.
  - In the help screen, a link to an email address was added for support if needed.
- Brevissima:
  - Learning tips is similar to the how to play screen but provides more detail. It gives information on how this game will help and what the player is required to do.
  - Looping between levels and starting from any level.
  - A capsule container simulates the collected points.
  - An animated hospital bed falling from the top was added to add some distraction for the player.
  - If the avatar was hit by the falling bed, the avatar would fall to the ground and the bed would crash and disassemble. Also, the player would lose the current score but not the game session as a whole.
  - Avatar movement animation.

- Collecting capsule plays an audio clip for incorrect and correct capsules.
- Bounce rewards system when collecting more than a correct capsule.
- Falling capsules have different speeds.
- After the game session, the background sentence is shown in the feedback screen for review.

❖ Medicina:

- A count down appears on the screen before starting the game session.
- Noise sounds are played randomly to add distraction when the player is hearing the sentence. This is to simulate a hospital environment.
- In the game session, a countdown is shown which forces the player to choose an answer within five seconds.
- The nurse will show in each question in the background.
- Relating animations for each question such as the avatar movement, the nurse movement, and the intravenous poles.
- The feedback on choosing a correct medicine will show a happy sleeping patient, whereas the wrong medicine will show unhappy patients.
- The player has three chances and the progress is shown at the bottom of the screen presenting how many chances are available.

6.5.2 Original Games

This section will focus only on the omitted features of each game. All the shared features were implemented, and the eliminated items are listed for the specific games.

❖ Brevissima:

- The player can choose a custom avatar on a screen called “Me”. It was eliminated as there were only one avatar asset available.
- The original game had two playing modes. The learning mode and full mode. The learning mode would be easier for the player by showing the sentence in the beginning. The learning mode was eliminated due to limited time and missing graphical assets and the final developed game has only the full mode.
- Under each level, there was a rounds screen (sub-levels). The rounds screen was eliminated, and the sentences are played randomly. The related button was removed too.
- The falling capsules in the game had different moving directions depending on the round. So, one direction was used as the round screen was removed.

❖ Medicina:

- The player can choose a custom avatar on a screen called “Me”. It was eliminated in the developed game at the game designer's request.
- After each question, there was a curtain animation. It was removed due to an animation issue with different screen aspect ratios.

Chapter 7. Results and Analysis

There are various learning outcomes from the pilot study and its evaluation. The evaluation of the serious games that assist international nursing students in discipline language acquisition will start with the demographic information, followed by the game evaluation and user experience.

7.1 Participant Demographics

The participants included two males and three females. There were five undergraduate nursing students from China, Japan, Hong Kong, and Hungary, and their ages ranged from 19-44 years. The participants have spent differing numbers of years in Australia. Two participants spent five years, whilst the other three each spent one, two, and three years in Australia. The study showed that 40% played videogames for less than 1 hour/week, and 40% spend 1-4 hours/week. Only one student spends 5-9 hours/week. The results showed that 80% of the participants use computers and mobiles to play videogames, with one participant who did not play games on any device. None of the participants played video games on consoles or handheld devices, and none of the participants considered themselves an expert gamer. They considered themselves as 40% novice gamers, 20% as casual gamers, and 40% as intermediate gamers.

7.2 Game Evaluation and User Experience

This section presents the UX questions from the pilot study. There were 14 questions grouped into four groups. The first group is engagement and enjoyability which focuses on the participants' feedback as to whether the games are enjoyable and if they would use them frequently. The second group is realism and narrative which focuses on how the sense of real environments had helped to realise the games' goals. The third group is the design which focuses on graphics, animation, and audio. The fourth group is the ease of use which focuses on the usability aspects such as navigation, help information, and how to use the game. Each group shows its questions and its results. In addition, it presents the group's overall average result.

7.2.1 Engagement and Enjoyability

To gain feedback on the game enjoyability and whether the game would be used from time to time for the learning purpose by the participant, the study posed two questions. The first question was "*I found this game enjoyable and engaging to play*". The result of this question showed an average of 3.6. The second question was "*I think that I would like to use this game frequently*". The result was an average of 3.2. The average result, shown in figure 6, was 3.4. The correlation between both group questions was 0.973.

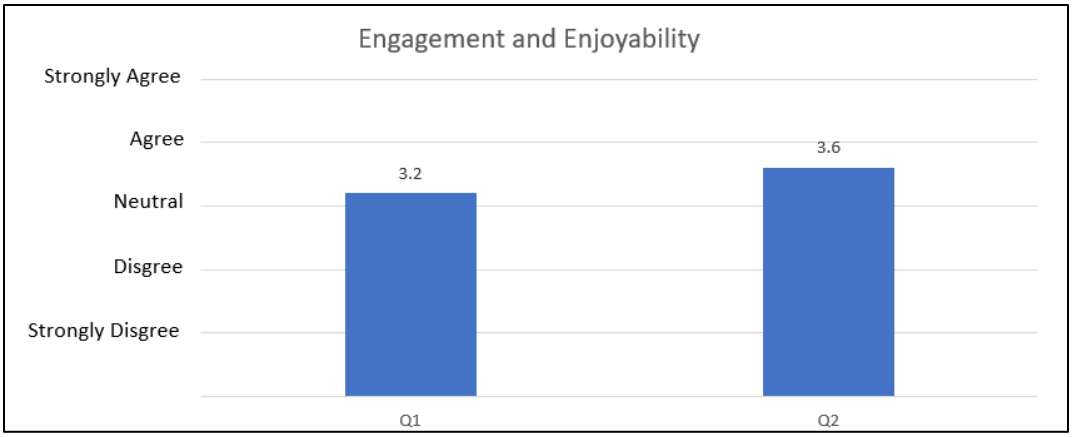


Figure 6 - Engagement and Enjoyability

7.2.2 Realism/Narrative

This group has four questions. Two are formed as negatively worded questions. The first pair of questions focus on the realism of the environment. The second pair of questions is concerned with the game goal understanding. The first question was *"I don't think the game reflects the real environment"*. The reversed average result of this question was 3.4. The second question was *"I felt as though the character could exist in a real environment"*. The average of the results was 3.4. The third question was *"I don't understand the story behind the game"*. The reversed average of this question's results was 2.6. The fourth question was *"I was able to understand the game goal"*. This question had an average of 3.6. Figure 7 shows the group's overall results. The correlation between the first and the second question was 0.763. The last pair of questions had a correlation of 0.649. The first pair had an average of 3.4 and the last pair has an average of 3.1. The overall average of this group is 3.25.

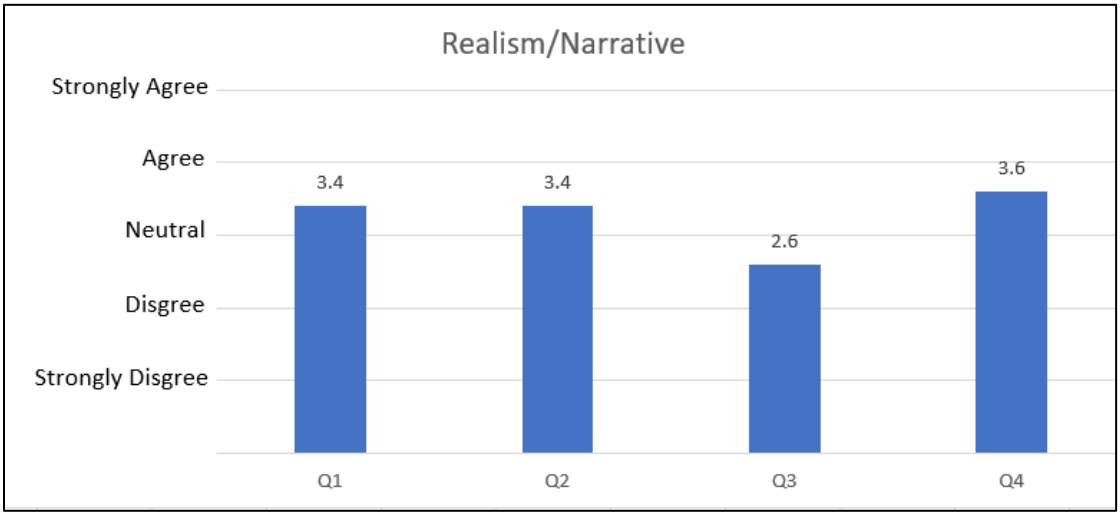


Figure 7 - Realism and Narrative

7.2.3 Design

The design group has five questions. The first question was "*I found the game interface and control engaging*". The average result for this question was 3.6. The next question, phrased in a negative-wording format was "*I think the graphics need to be improved*". The reversed average result was 3. The third question was "*I think the audio effects and sounds suit the game*" and gave an average of 4. The next question concerned the game elements. The question was "*I found the various elements of this game well designed (e.g. controls, avatar, levels, audio)".* This gave an average of 3. The final question of this group focused on the consistency of the game elements. The question was "*I thought there was too much inconsistency with this game*" and gave the reversed average of 3.6. The overall average of the design group was 3.44 and Figure 8 shows the results. The design group and the realism and narrative group shows a correlation of 0.872.

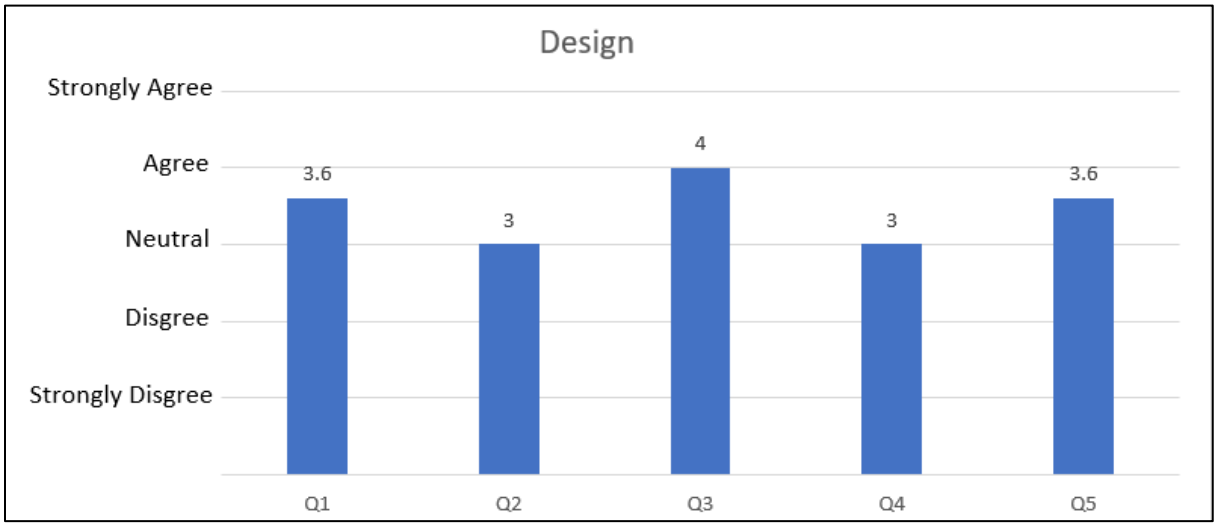


Figure 8 - Design

7.2.4 Ease of use

The usability study questionnaires used were the System Usability Scale (SUS) [43]. The questions were posed in positive and negatively worded formats. The first question was "*The game help information is easy to access when needed*" and gave an average of 4. The second question was "*I think navigating inside the game is complex*" and the reversed average was 3.6. The third question was "*I found the game unnecessarily complex*" give a reversed average of 4.6. The next question was "*I thought the game was easy to use*" and the average result was 4.8. The fifth question was "*I think that I would need the support of a technical person to be able to use this game*". All participants did not need any support and strongly disagreed with this statement so, the reversed average result was 5. The sixth question was "*I would imagine that most people would learn how to use this game very quickly*" which gave an average of 4.8. The next question was "*I found the game very awkward to use*". This negatively worded question had a reversed result of 3.6. The eighth question was "*I felt very confident using the game*" and its average was 4.4. The last question was "*I needed to learn a lot of things before I could get going with this game*" which gave a reversed result of 3.2. The overall result was 4.2 and Figure 9 shows the results.

The calculated SUS value was 81 which, according to paper [45] the SUS value is equivalent to an 'A' grade. Using SUS to determine the usability of an application if the calculated SUS score is 68 then this reflects an average, acceptable software system [46]. Having achieved a calculated score of 81 suggests the game was designed with excellent usability, based on the small numbers from the pilot study. The correlated result of the ease of use group with the other groups was as follows: the engagement and enjoyability group was 0.811, the realism and narrative group was 0.791, and the design group was 0.730.

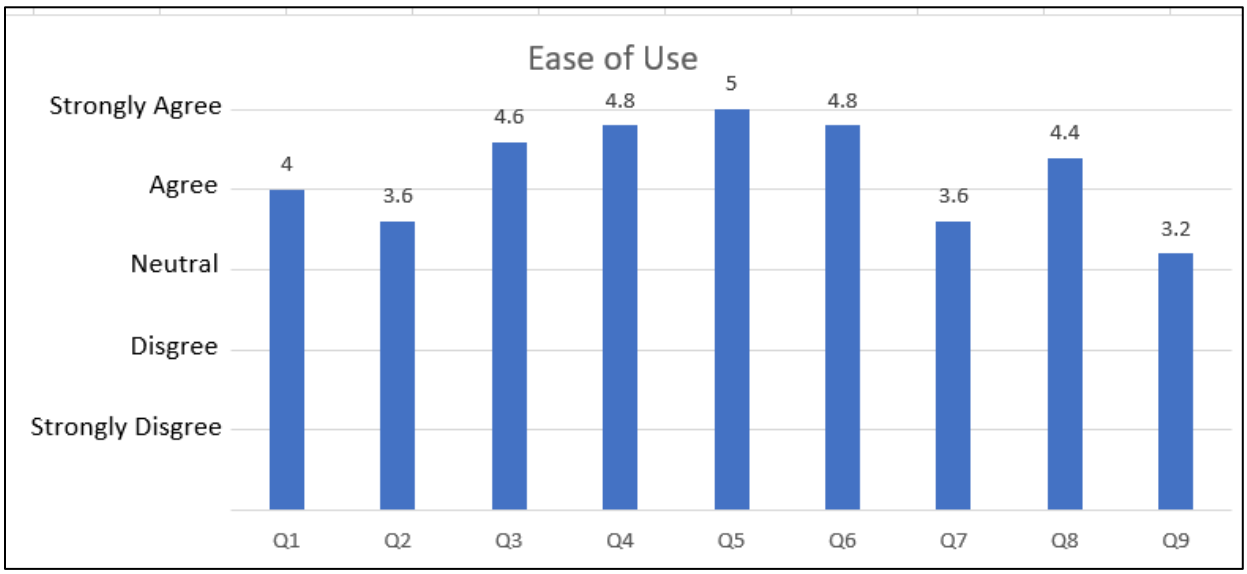


Figure 9 - Ease of use

7.3 Result Analysis

The study had a mixture of participants' that varied in culture and gender. The participants' ages ranged from 19 to 44 years, and the inclusion of international participants from different countries may have had a positive impact on the study. The study recruited 15 participants, however only five participants completed the questionnaire due to a hospital placement that students had to go to. The participants considered themselves novice, casual, and intermediate but no one was considered as an expert gamer and, furthermore, the study lacked console gamers and handheld devices gamers. The results showed a low correlation between the number of hours playing games and all the other elements. While this pilot study has a mixture of participants, applying the study on a larger group should ensure the group is more diverse.

The original games were designed for different screen aspect ratios and different resolutions. Adapting these game assets may affect the UX and game engagement, and one of the biggest game development challenges was missing some of the original game assets (audio, graphics, animation). Due to these missing items and the available development time, some aesthetic and gamification elements were eliminated. For example, having different avatars was available in Brevissima's original game, but were omitted from the re-developed game. Therefore, adding engaging game elements may have a positive impact on game engagement and other

attributes. The engaging elements ideas can be imported from the eliminated items or by the game's educational designer.

The original games were not designed for mobile devices; they were designed for the web only, but adapting these games without modification may cause an unsatisfactory UX. The ease of use had an overall average of 4.2 and the calculated SUS was 81. This might be due to the simple tasks in the games, but also it might be because of the modification made to the games such as unifying the registration process between the games and the platforms and the changes to the games such as adding navigation controls such as the "back button" inside the Brevissima game. The usability of the original games was not available when reviewing the publications [2, 40, 41, 42] which are related to the original games, neither was access to the original games available. However, having the original games may need a dedicated study to compare the UX of the original games against the redeveloped games. The shown usability result was good, as the players did not have issues understanding how to use the games.

In summary, the participants' average results show that participants would agree that the games were easy to use. Therefore, the game usability is satisfied at this level as the SUS value is 81. However, more elements should be added to improve the enjoyability and engagement of the games. Also, applying the study to a larger group is recommended to get more diversity.

Chapter 8. Conclusion

The re-development of Brevissima and Medicina had many different challenges. There were challenges that affected the user experience such as the different platforms and the different resolution and screen aspect ratios, though the changes made to the games may limit these effects. The results show a satisfactory usability level. The SUS shows an excellent grade compared to the average. The pilot study shows low engagement and enjoyability levels which might be due to the elimination of certain game elements. It is recommended to add these game elements and features.

The developed games had the main features of the original games, though some features were eliminated due to missing assets or by request from the game designer. The game targets the Android platform, mobile web, and web platforms. Different updates and adjustments to the game design were added to enhance the UX and the compatibility with these platforms. The system architecture includes a web platform that handles the registration process and web games. Also, it has an API to support the Android apps and a web-based database. The main development challenges were technical, missing documentation, and missing assets.

The developed SGs share the same aim which is to help international nursing students in discipline language acquisition. However, each game focuses on a specific goal. The first game Brevissima focuses on the nursing abbreviations while the Medicina game focuses on the medicine names and includes both scientific and commercial names. The games are designed based on educational theories. The three presented aspects in Brevissima were the feedback and scoring, the exposure, and the multimodality and working memory. In the Medicina game, the design aspects are exposure, cognitive load theory, and cognition-based instructional design.

The UX and game engagements usability questionnaires for this pilot study were adapted from the SUS and a game evaluation framework. The ethics of this project was updated to include this questionnaire, followed by the defined research procedures. The literature review of this project shows examples of nursing games. which had different technologies, levels of application, and audiences. Related aspects to SGs development such as GDD management were investigated, as well as examples of SGs designed for memory enhancements and memory-related theories.

The focus of this thesis was on the UX aspect of the developed games. The games achieve satisfactory usability as the results shows that the ease of use had an overall average of 4.2 and the calculated SUS was 81. The motivating result from the original game based on the published papers leads to re-developing these games. The technology which the original games were using was obsolete, and thus students could not benefit from these SGs. Therefore, using the same game design and assets to re-develop these SGs using the Unity engine was advised. In future work, the re-developed games need a graphical design engagement to cover the missing items and testing these SGs on larger scale groups.

Appendices

Appendix A: Nursing Games Web Administration

The developed games use a unified authentication system. Each logged game session is stored in the database for all games. Thus, an idea to provide a system that allows viewing and exporting these data. Figure 10 shows the system main screens. However, this idea takes a low priority as the data can be exported directly from the database and the game has not reached a final level.

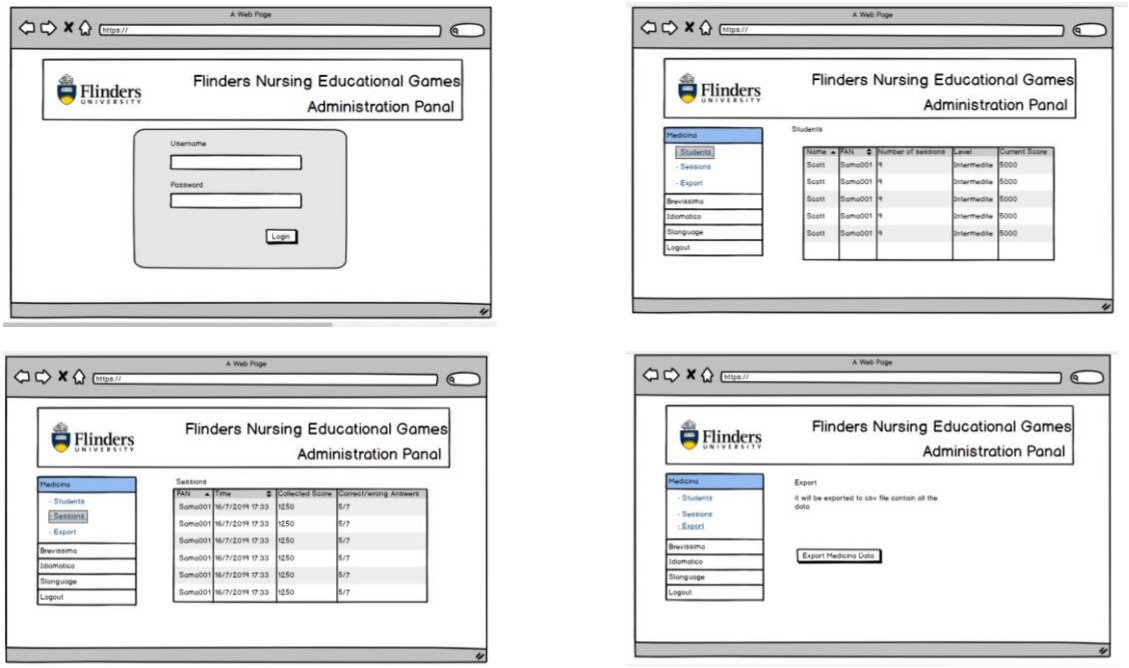
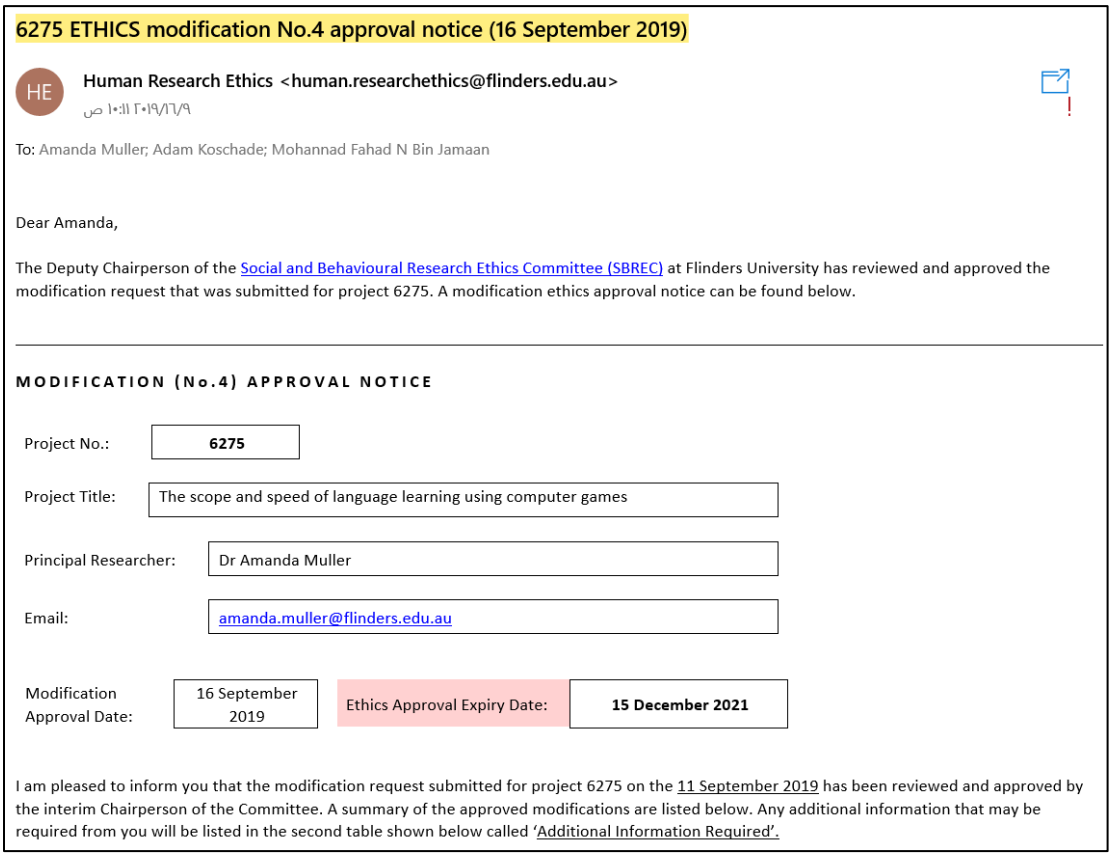


Figure 10 - Nursing games administration

Appendix B: Ethics Modification Approval

The ethics was approved before starting this thesis. The ethics was modified to add the system useability scale SUS and the educational game evaluation questions. The modification and approval were done by the main investigator of the project.



6275 ETHICS modification No.4 approval notice (16 September 2019)

HE Human Research Ethics <human.researchethics@flinders.edu.au>
٢٠١٩/١٦/٩ ١٠:١١ ص

To: Amanda Muller; Adam Koschade; Mohannad Fahad N Bin Jamaan

Dear Amanda,

The Deputy Chairperson of the Social and Behavioural Research Ethics Committee (SBREC) at Flinders University has reviewed and approved the modification request that was submitted for project 6275. A modification ethics approval notice can be found below.

MODIFICATION (No.4) APPROVAL NOTICE

Project No.:	**6275**
Project Title:	The scope and speed of language learning using computer games
Principal Researcher:	Dr Amanda Muller
Email:	amanda.muller@flinders.edu.au

Modification Approval Date:	16 September 2019	Ethics Approval Expiry Date:	**15 December 2021**

I am pleased to inform you that the modification request submitted for project 6275 on the 11 September 2019 has been reviewed and approved by the interim Chairperson of the Committee. A summary of the approved modifications are listed below. Any additional information that may be required from you will be listed in the second table shown below called 'Additional Information Required'.

Figure 11 - Ethics modification approval

Appendix C: SUS

The SUS was adopted from the original system usability scale [43], the original questions were as the following:

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

Appendix D: EGameFlow

The game enjoybility questionair was adapted from the EGameFlow, the EGameFlow scale has the following questions:

Table 2
Scale of EGameFlow

Factor	Item no.	Content
Concentration	*C1*	*The game grabs my attention*[a]
	C2	*The game provides content that stimulates my attention*[a]
	C3	Most of the gaming activities are related to the learning task
	C4	No distraction from the task is highlighted
	C5	Generally speaking, I can remain concentrated in the game
	C6	I am not distracted from tasks that the player should concentrate on
	C7	I am not burdened with tasks that seem unrelated
	C8	Workload in the game is adequate
Goal Clarity	G1	Overall game goals were presented in the beginning of the game
	G2	Overall game goals were presented clearly
	G3	Intermediate goals were presented in the beginning of each scene
	G4	Intermediate goals were presented clearly
	G5	*I understand the learning goals through the game*[a]
Feedback	F1	I receive feedback on my progress in the game
	F2	I receive immediate feedback on my actions
	F3	I am notified of new tasks immediately
	F4	I am notified of new events immediately
	F5	I receive information on my success (or failure) of intermediate goals immediately
	F6	*I receive information on my status, such as score or level*[a]
Challenge	*H1*	*I enjoy the game without feeling bored or anxious*[a]
	H2	*The challenge is adequate, neither too difficult nor too easy*[a]
	H3	The game provides "hints" in text that help me overcome the challenges
	H4	The game provides "online support" that helps me overcome the challenges
	H5	The game provides video or audio auxiliaries that help me overcome the challenges
	H6	*My skill gradually improves through the course of overcoming the challenges*[a]
	H7	*I am encouraged by the improvement of my skills*[a]
	H8	The difficulty of challenges increase as my skills improved.
	H9	The game provides new challenges with an appropriate pacing
	H10	The game provides different levels of challenges that tailor to different players
Autonomy	*A1*	*I feel a sense of control the menu (such as start, stop, save, etc.)*[a]
	A2	*I feel a sense of control over actions of roles or objects*[a]
	A3	*I feel a sense of control over interactions between roles or objects*[a]
	A4	*The game does not allow players to make errors to a degree that they cannot progress in the game*[a]
	A5	*The game supports my recovery from errors*[a]
	A6	*I feel that I can use strategies freely*[a]
	A7	I feel a sense of control and impact over the game
	A8	I know next step in the game
	A9	I feel a sense of control over the game
Immersion	I1	I forget about time passing while playing the game
	I2	I become unaware of my surroundings while playing the game
	I3	I temporarily forget worries about everyday life while playing the game
	I4	I experience an altered sense of time
	I5	I can become involved in the game
	I6	I feel emotionally involved in the game
	I7	I feel viscerally involved in the game
Social Interaction	S1	I feel cooperative toward other classmates
	S2	I strongly collaborate with other classmates
	S3	The cooperation in the game is helpful to the learning
	S4	The game supports social interaction between players (chat, etc)
	S5	The game supports communities within the game
	S6	The game supports communities outside the game
Knowledge Improvement	K1	The game increases my knowledge
	K2	I catch the basic ideas of the knowledge taught
	K3	I try to apply the knowledge in the game
	K4	The game motivates the player to integrate the knowledge taught
	K5	I want to know more about the knowledge taught

The scale figure was retrieved from paper [44]

Figure 12 - EGameFlow Scale

Appendix E: Questionnaire

The following shows the questionnaire which shows the demographic and the usability sections.

Questionnaire

About You:

Gender (M/F/X/Prefer not to say) .....

Age .....

How much time have you spent in Australia? .....

What country do you come from? .....

What is your first language? .....

What year of your course are you currently studying?

First year / Second year / Third year / Fourth year or higher

On average, how many hours per week do you spend playing videogames on any device (such as smartphone, tablet, computer/laptop, console or handheld device)?

- Less than 1 hour
- 1 to 4 hours
- 5 to 9 hours
- 10 to 19 hours
- More than 20 hours

Which of the following devices do you FREQUENTLY use to play videogames? (select all that apply)

- A computer device (e.g., desktop, laptop)
- A mobile device (e.g., smartphone, tablet)
- A console device (e.g., Playstation, Xbox)
- A handheld device (e.g., Gameboy, Nintendo DS)
- None of the above

What type of videogame player do you consider yourself?

- Newbie/novice
- Casual
- Core/intermediate
- Hardcore/expert

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I found this game enjoyable and engaging to play					
I found the game interface and control engaging					
I think navigating inside the game is complex					
I like being able to customize the character					
I think the graphics need to be improved					
The game help information easy to access when needed					
I don't think the game is reflecting the real environment					
I felt the character in a real environment					
I don't understand the story behind the game					
I was able to understand the game goal					
I think the audio effects and sounds doesn't suit the game					
I think that I would like to use this game frequently					
I found the game unnecessarily complex					
I thought the game was easy to use					
I think that I would need the support of a technical person to be able to use this game					
I found the various element of this game well designed (e.g. controls, avatar, levels, audio)					
I thought there was too much inconsistency with this game					
I would imagine that most people would learn how to use this game very quickly					
I found the game very awkward to use					
I felt very confident using the game					
I needed to learn a lot of things before I could get going with this game					

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