# Game Interface Design for the Elderly

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# Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Hagenberg, January 25, 2018

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# Abstract

This thesis aims to create a set of guidelines for interfaces that encourage and engage older adults to play video games. Often the main issue is that many elderly feel discouraged by complex UI systems and unfamiliar controls. The paper analyses basic standards and practices for established interface design and combines it with revelations from software device interface designs for elderly. The assembled guidelines is then tested in an prototype space exploration game *Co-Smonauts*. Its specifically compares three interface designs, two for touchscreen and one tangible controller. It was initially assumed that the tangible controls would be preferred because of its easy functionality, yet the results show that elderly are indeed interested in touchscreen devices and prefer them.

# Kurzfassung

Das Ziel dieser Arbeit ist es Richtlinien für Videospiel Interfaces zu erstellen, die ältere Menschen dazu bewegen mitzuspielen. Das Hauptproblem dabei ist, dass viele Senioren durch komplizierte Interface Systeme und ungewohnten Steuerungen sich oft nicht trauen ein Spiel anzufangen. Um dem entgegen zu kommen, werden in dieser Arbeit grundlegende Game-Interface Standards mit Richtlinien für andere Technikgeräte kombiniert. Das Resultat wurde dann mit dem Weltraum Spiel *Co-Smonauts* geestet. Es wurden drei verschiedene Interface Designs entwickelt, zwei für Touchscreen und ein materieller Controller. Die Vermutung war, dass der greibare Controller aufgrund seines einfachen Bedienung von den meisten Teilnehmern bevorzugt wird. Das Resultat zeigt jedoch das ältere Menschen Touchscreens bervorzugen und sehr and dieser Technologie interessiert sind.

# Chapter 1

# Introduction

As a child my parents often told me that video games would get me nowhere and that I should focus on the more important aspects of life. As an adult I was told that games are just for children and that they should not play. Now that I have started committing my life to games I can finally find a way to make them understand the enjoyment of video games by taking a step to making games more accessible to older people.

The experience of my parents, or the lack of, with video games is a common phenomenon in their generation and has become quite the problem since it leaves them out of touch with newer generations. Video games are ever prevalent with the children of this century and play a vital role in their lives. Due to this technological-difference of know-how, communication and exchange are rare between the older and younger generation. In order for the elderly to get up to speed with video games they need and opportunity to play games that are tailored to their needs.

This thesis will focus on game interface design for elderly people. The goal is to create an interface that encourages and engages the aged player to participate in video games. In order to do so this paper analyses various studies, guidelines and experiments and established a paradigm and used to to create interface prototypes for the intergenerational game *Co-Smonauts*. The game will serve as a testing platform in order to see if elderly people prefer a touch or tangible interface in their games and how well these interfaces are received by the target group.

However, first we have to determine what the term elderly entails.

## 1.1 Defining the Elderly and their Needs

The main focus group of this thesis are adults aged 60 years and above. However the principles discussed in this thesis can apply to many different ages especially since cognitive and muscular deterioration start at a different time for each person. Studies such as [4, 9] have found that cognitive decline is very closely related to the physical activity of a person. This can lead to poor short term memory, visual perception and sound judgement [45]. The following symptoms of cognitive ageing have been established and categorized in [6]:

- Crystallized intelligence describes knowledge and skills that are well familiar to a person because they have practiced and learned these many times over. They tend to be easy for older people to recall and use. Fluid intelligence refers to problem solving and reasoning often using unfamiliar information. Research has shown that these skills often degrade the older one gets [6, pp. 2–3].

- Processing speed, has been shown to decline during ageing even in health adults. It can cause the person to solve certain tasks slower and with less efficiency [6, p. 3].
- Generally speaking the ability to focus on a specific task does not decline too much. However, older people have had noticeable difficulties when it comes to selective and divided attention. The ability to focus on one piece of information or task while ignoring the others is referred to as selective attention. The other describes the ability to concentrate on multiple tasks at once [6, p. 3].
- A well known challenge for elderly are the memory problems. Harada et al. describe two major types of memory: declarative and nondeclarative. The first one describes the recollection of facts and events as well as life experiences. Nondeclarative memory describes information that a person does not collect purposefully. These can involve certain skills like riding a bike and remembering a familiars song. This type of memory generally does not degrade in adults unlike the declarative. Another factor that is bound to decline is the retrieval of new information. New memories are more difficult to retain than older ones [6, pp. 3–4].
- Many older people have difficulties in visual construction skills. This is the ability to put together individual pieces to form a whole, an example would be the ability to solve a picture puzzle. On the other hand visuospatial abilities, the skill to recognize and understand familiar real world objects and their relationship to each other, remains intact [6, p. 4].
- The ability to organize, solve problems and reason independently has proven to be challenging for ageing members of society. Elderly tend to have a more straightforward and have problems to "think outside the box".

While these point can be viewed independently it might be interesting to note that a lot of the groups are linked with each other. For example a lack of attention might affect short term memory [6, p. 3].

Another aspect of ageing involves motor skills and movement. It is well know that motor performance declines with age. Many older adults show a strong slowing of their physical movement. However, the also seem to value precise movements over speed [19, p. 2]. Coordination of multi-joint movements have proven very difficult and unstable. Repeating motions also seem to be exceedingly inconstant [19, p. 3].

## 1.2 Structure

In order to establish an interface paradigm for the elderly we have to first research common practices and standards of current games. Chapter 2 explains the base requirements and standards for modern interfaces in video games. The most prominent source for that chapter was Saunders et al. *Game Development Essentials: Game Interface Design* [18]. I recommend it for further reading as it dives into greater detail and specifics that many game interfaces have.

The third chapter dwells in to the subtleties and intricacies of interface design for elderly. Even though there were no established game interface guidelines for older people, other experiments testing games and guidelines built for digital devices proved to be invaluable as I assembled my paradigm guideline. The guideline itself was a combination of existing standards and practices paired with the cognitive needs and limits of the older population. The final chapter will be used for discussion, limitations and future research.

# Chapter 2

# Concepts of Interface Design

During the research for current standards in interface design, especially for elderly people, I came across a few different sources. At first I tried to accumulate most common guidelines for interfaces that had a more frequent player demographic such as [18].

While the age of personal computers and smartphones is relatively new, interface design has always been a part of it. This is due to the fact that communication of the user, in our case the player, and the device is managed by creating a functioning interface. Galitz [3] tells us that this includes "two primary functions: *output* (how the game informs the player also know as feedback [18, pp. 43]) and *input* (how the player informs the game of certain action, also known as control" [18, p. 43, 3, p. 4].

## 2.1 Feedback

The output of a game interface informs the player how their input functions and provides other useful information. Since older people have trouble learning new data [6, pp. 3–4] it is vital that these elements are as clear as possible. The first feedback a player receives when he or she plays a game is their status [18]. This refers to the their current situation concerning their success or failure in the game. This information can come in various ways as resources, camera view, location, etc. I will outline the most common information one comes across in a game.

The first would be, as mentioned before, the *location*. This does not only imply their position but also the information about where they can and cannot move to [18, p. 206]. Naturally, the need for a graphical explanation only occurs when the gameplay requires it. Common genres include open world, first-person shooters, metroidvanias, etc. A common way of expressing the current location is by using maps or even mini maps. Other methods include compasses way-point markers. Even simple arrows often do the trick.

A lot of games have some sort of variation on this feature. A good example would be the minimap of Nintendo's *Mario Kart 8* [35]. In the local "Battle" mode of the game, up to four players can fight each other in their racing cars to steal or destroy the enemy balloons. In order to do this players have to hit their opponents with a variety of items available. Finding your competitors is crucial to the success of participant. For the sake of fairness the map was placed right at the centre of the screen so all players have the


**Figure 2.1:** Local multiplayer of the "Battle" mode in *Mario Kart 8* [35].

equal distance to the information as seen in fig. 2.1. It is worth noticing that direction arrows on the minimap emphasize the player from non-player characters (NPC).

An other game also by Nintendo uses arrows to mark the players position. The game *Super Smash Bros. 4* is a 2D platforming fighting game, where up to eight players can participate simultaneously. Naturally such huge count of competitors can quickly cause confusion. Therefore the developers have added arrows to each player with a dedicated colour. This feature is supposed to help the player track their easier when the characters move too fast. An example of this can be seen in fig. 2.2.

Another important item is the current status of a player [18], p. 40. This implies multiple pieces of information as the current success rate of the player, are they on a winning path, what strategies could they follow next and how long would it take them to complete the game. This essential data can be expressed in multiple ways at the same time in one game.

A classic example of status expressed in a game is the health bar. An important information the player needs to access if they are losing or not. Most fighting games have, while sometimes slightly divergent, long bar at the top or bottom of the screen indicating their characters health situation. NetherRealm Studios' game *Mortal Kombat X* [24] uses a white bar at the top of the screen, while also changing the characters clothes and adding wounds to their body to indicate their well-being. An example of this can be seen in fig. 2.3. The health bar in this game also has an immediate damage indicator which is displayed in red over the usual white. This tells the player how much damage has been taken with each individual attack.

Klei Entertainments 2D stealth game *Mark of the Ninja* [23] uses an innovative approach to its stealth mechanic. The game revolves around a ninja who has pass through different levels while remaining undetected. The player can either be hidden or visible


**Figure 2.2:** A five player game of *Super Smash Bros. 4* [30]. Player 4 is outside of the screen but still indicated by an arrow on the edge of the screen.

and instead of showing and external indicator to show the player their current status it displays the hidden characters in black and white outlines while leaving everything in the light coloured as presented in fig. 2.4

The feedback received by the player is not only there to inform but teach the game. An intuitive interface design can help the user understand how the components are to be used without having to create a separate manual. This can be vital for the success of a game since many players often do not read instructions or skip tutorials and end up not understanding the rules and mechanisms. Simple hints as for instance a colour or audio cue at the right moment indicating the proper use of a component can have far reaching effects on how a game is being played [18, p. 43].

## 2.2 Control

This section deals with how the player interacts with the game. Input elements of the interface let the player best any impediments and helps them essentially *play* the game. Up until the late 2000s, where touchscreens became popular, most input methods were almost exclusively hardware items [39]. Naturally this means in order to find an appropriate interface one had to first consider which platform is being used.

This part will outline some common modern platforms and the Input methods they allow. In order to do so I have grouped the platforms in four groups: consoles, computers, mobile and virtual reality (VR). The first three categories are based on [18, pp. 86–122]. VR is a relatively new platform that does not fit in the other categories.


**Figure 2.3:** Screenshot of *Mortal Kombat X* [24]. The blood splatter is an additional indicator of damage being taken.

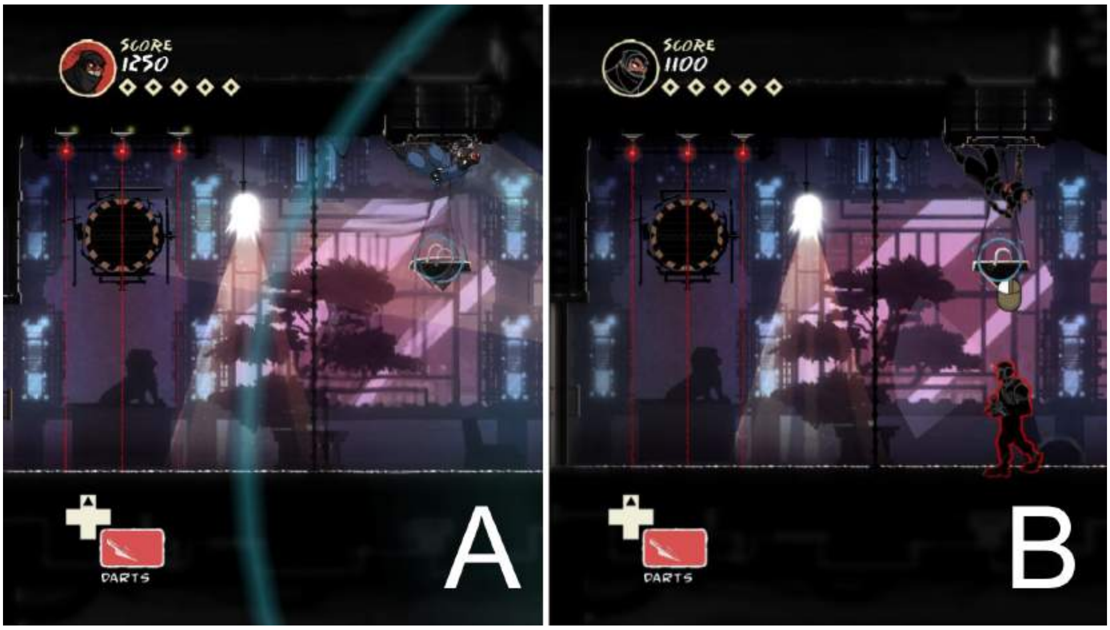


**Figure 2.4:** Two screenshots from the game *Mark of the Ninja* [23]. A: The character is in light and coloured. B: Here he is hidden in the shadows and outlined in white just as the guard walking beneath him. Notice how the icon on the top left also changes.

### 2.2.1 Computers

One of the first video games to grace the computer was *Spacewar!* [29] developed by Steve Russell for the PDP-1[1]. The interface consisted of various switches and analog sticks. However modern computers are generally equipped with a keyboard and a mouse. While keyboards and mice have various different designs with an inconsistent amount of buttons, the majority of video games only use core keys. Over the years games have established a few conventions such as using *W,A,S* and *D* for character movement and mouse for camera control. This platform is favoured for strategy and shooting games due to the precise handling of the mouse and abundance of keys on the keyboard [54].

### 2.2.2 Consoles

Consoles have a very special place in the gaming community because they are specifically designed to play games. Therefore the interface of the controllers are made for comfort and easy gameplay. The modern consoles have very similar gamepads [18, p. 91], however the feature certain additions that set them apart from their competitors.

#### Wii and Wii U gaming

Even though Nintendo's Wii U was the predecessor to the Switch, it has some innovative interface capabilities. The two part controller allows the player to control the game with motions and the infra-red sensors enable the user of pointing directly onto the screen. This interface scheme has often been praised to be a easy gateway for newer players, especially the elderly [12], to experience video games and exercise.

Ever since the *Nintendo Wii* (see fig. 2.5) was released in 2006 it has been a controversial console to say the least. Many developers thought that the lack of high performance hardware would discourage sales. However at the time the Wii was the first major console to feature an active interaction interface. The advertising where clearly targeted at a broader audience, most prominently senior citizens [48]. Its popularity grew so much that reportedly even Queen Elizabeth II of the United Kingdom had started playing [37]. As a result it became the best selling console of its generation [49].

Many sources value the medical capabilities of the Wii and report of health benefits in playing. In [17] reports that patients affected with cerebral palsy[2]. Santhanams research showed that the Wii controller could have beneficial impacts on cognitive and motor abilities [17, p. 304]. There are many other sources that report similar results such as [8, 12, 21].

Vero Vanden Abeele and Bob De Schutter [22] attempted to create a meaningful game for the elderly using the Wii controller with their mini-game *Atomium* [22, p. 7]. The game only uses the acceleration sensor and all other input methods are omitted. The gameplay involves screwing, cleaning dirty spots and swinging a ball with strong movements. The simple input methods bring a certain familiarity and ease of use to the game. The researchers state that using acceleration and motion controls increase the ease-of-use, equality-in-ease-of-use and visibility-of-player-action, which helps invite elder players [22, p. 9].

[1] A computer named *Programmed Data Processor-1* created by Digital Equipment Corporation.

[2] A medical condition containing multiple movement disorders also affecting cognitive abilities.


**Figure 2.5:** Picture of the Nintendo Wii [47].

### 2.2.3 Mobile

The first mobile video game console was established once again by Nintendo with their iconic *Game Boy*. A little computer with two action buttons and a D-pad for the very first mobile games. Ever since the mid 2000s, despite the success of the *Game Boy*, mobile gaming has more and more become synonymous with games for touch interfaces on a smartphone or tablet computer.

The touch screen has opened up a huge amount of possibilities. Since the control interface is simultaneously also the screen, games can create their own interface and are not dependant on the device. This has created an enormous variety of games with innovative gameplay and interaction. It versatility provides a chance to tailor the game interface to target groups, in the case of this paper elderly.

### 2.2.4 Virtual Reality

This group contains interfaces that have not yet been completely established. A promising technology are Virtual Reality headsets similar to the one mentioned above or the *HTC Vive [41], Oculus Rift* [50] and *Google VR* [40]. Using this technology the player can use their head to move the camera. The HTC Vive even allows the headset to be tracked in a room as it comes with to tracking sensors. A special trait of the VR headsets is that they are a platform and a interface simultaneously.

Another promising technology is the *Leap Motion Controller*. This device is capable of tracking individual finger motions that hover in front of it [44]. There have been various attempts at combining this technology with VR headsets to completely remove the necessity for a handheld interface as seen in fig. 2.6.

**Figure 2.6:** Picture of the HTC Vive with a mount for the Leap Motion Controller [44].

## 2.3 Supporting Gameplay

The main objective of an user-interface design in games is to support the gameplay [18, p. 191]. Ergo the worst that can happen is that your interface hinders the player of enjoying the game. This aspect becomes especially important in output interfaces for a game.

### 2.3.1 Classification of Elements

There are many ways to display feedback in a game. However not every interface can be used for every game. One has to consider whether the interface is part of the game world or static. Are the elements fictional or only for the player to see? These facets determine the immersion of the game and can elevate or lower gameplay enjoyment. Fortunately this issue has already been examined by Fagerholt and Lorentzon in [2]. However the terminology of these categories is still evolving and might me subject to change in future.

They developed a design space map to categorize interface elements in a game which have been adopted by others (see fig. 2.7). It concludes that there are four categories for an element to fit in by considering the criteria mentioned in the previous paragraph.

#### Non-Diegetic

These elements are neither in the game environment nor in the fictional world. It is the "traditional" classification for interfaces [18, p. 80]. It describes elements that for example layer above the game world as health bars or speedometers. Even though these informations are important to the game they can not directly be interacted with by any character and are not recognized in the story [51]. An example can be seen in *Rocket League* [32]. This football-racing game shows the score, time and boost amount of the car (see fig. 2.8).

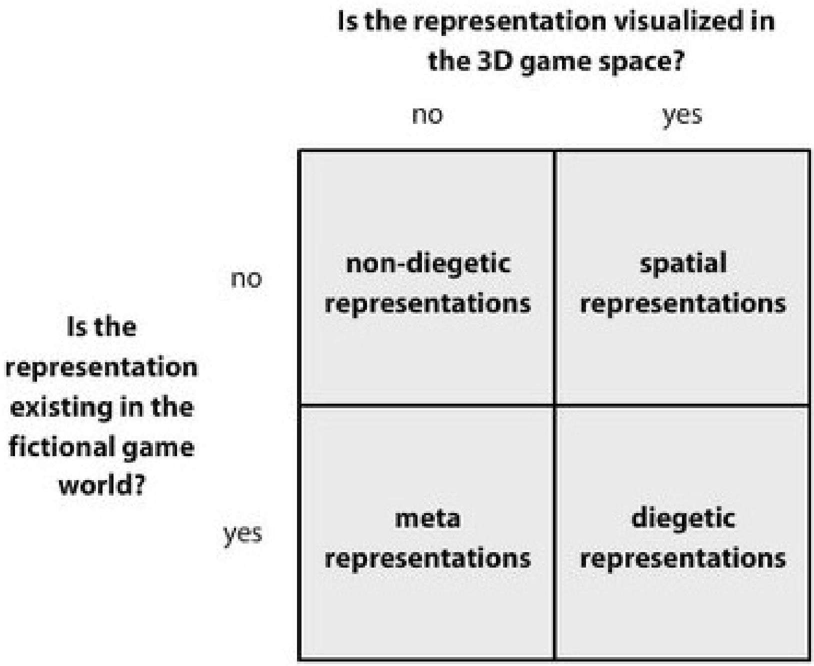


**Figure 2.7:** Design space as envisioned by Fagerholt and Lorentzon and adopted by Marcus Andrews in [36].


**Figure 2.8:** Screenshot of the Psyonix *Rocket League* [32]. The interface elements are static and placed on the top and bottom-right corner.


**Figure 2.9:** Screenshot of *Alone in the Dark's* inventory system [28]. The player character opens their jacket and looks down. The items in the inventory are attached to the jacket.

### Diegetic

Elements that are both in the game world and in the story are called diegetic. This method of showing interface items is often hailed as the most immersive because its conveys the information without breaking the fourth wall [[2], p.75]. Most games feature some form of diegetic interface such as animations of characters that indicated their current status or the armour and weapons a character is equipped with. Atari's *Alone in the Dark: Inferno* [28] applies this when showing the players inventory. Instead of have a separate window open the character opens there jacket and looks down. Now the player can see all of the items that they possess and additionally every crafting action is animated accordingly (see fig. 2.9).

### Spatial

The spatial interfaces are represented in the game world however the characters in the game are unaware of these items. A typical example would be an outlining of an object or character in the game. The outline helps the player identify certain items without recognized by the games story. Blizzard Entertainment's *Diablo 3* [38] does something similar by circling the characters on the ground and showing the enemies in a different colour to differentiate them from the players (see fig. 2.10).

### Meta

A meta interface describes the elements that do not appear in the game world but are part of the games story. These interfaces often have the purpose of adding immersion


**Figure 2.10:** Screenshot of *Diablo 3* multiplayer mode [38].

to a player by only affecting them [2, p. 74]. A classic example of said category would be blood splatter effects in modern first-person shooters. The effect is presented as an overlay over the camera and vanishes after a few second out of combat. While the effect is indeed part of the story, it is not tangible for any of the characters in the game world. The game *NieR: Automata* by Square Enix [33] has set up an interesting approach to its HUD interface. The main character in the game is and android capable of upgrading themselves using plug-in chips. This allows them to increase their attack and defence statistics and also includes the ability to show and hide HUD elements. Traditional items such as the health bar, mini map and experience are integrated into the games story, however since the character is played in third-person view it is clear that the elements are not in the game world itself (see fig. 2.11).

### 2.3.2 Gameplay Genres

Even though every game has a individual approach to their user interface design, yet many games share gameplay elements which have led to the establishment of certain practices that have been proven to work well. In his book *Fundumentals of Game Design* Ernest Adams defines five major genres of games. He describes a genre as following “Genres are categories of games characterized by particular kinds of challenges, regardless of setting or game-world content.” [1, p. 67]. It is essential to look at these categories to determine current conventions of the UI design [18, pp. 126]. Naturally games are not set in stone and can contain multiple genres in one. It might also be worth noting that there are a multitude of subgenres, but they mostly follow the same interface principles. The following paragraphs will outline major categories with an examples of games and interfaces [1, pp. 67–78, 18, pp. 128–154].

**Figure 2.11:** Screenshot of *NieR: Automata*. Note that health bar, minimap and sound wave elements [33].

### Action and Arcade

This genre is one of the biggest and most versatile groups. First-person and third-person games such as fighting and shooter games find their place here. According to Saunders there are many common interface design elements [18, p. 128]. For example *enemy differentiation* is a key point in action games. Due to the active and intense nature of action games it sometimes can be difficult to determine enemy characters. Elements such as special audio cues, outlines or distinguishable silhouettes are common practice. Another aspect is high level control responsiveness. It is critical that every input has an instant feedback since the pace of the game is often very fast [18, p. 130]. A good example of an action game is Blizzard's *Overwatch* [26]. It uses different audio cues for friendly and enemy players and colour codes them in red and blue (see fig. 2.12).

### Adventure

Adventure games are a story driven genre. The player hast to solve a multitude of puzzles and combat can or cannot be added. It has no interface specific characteristics [18, p. 138].

### Role-Playing

Role-playing games (RPG) generally defines by three characteristics [18, p. 139]:

- A character power advancement system,
- An strong emphasis on story and dialogue and
- A loot or inventory system.


**Figure 2.12:** Screenshot of *Overwatch* gameplay [26].

Dialogue has a big part in role-playing games. Some feature systems in which the player can choose how to interact with a non-player character and can thereby influence the story of the game. Another common practice within RPGs are quest logs and journals. Players are capable of tracking failed, completed and active missions [18, pp. 140–141]. All these advancement systems are often accumulated in one multi-faceted menu interface where the player can control all aspects of their characters. A good example can be found in the Bethesda's game *Fallout 4* [25] and its famous *Pip Boy* menu (see fig. 2.13). Due to the massive amount of information that one player must have, RPGs are often seen as the most challenging to a developer.

### Simulation

Simulation games consist mostly of vehicular, sports and construction simulation games. As the name implies the category is defined by imitating the real world to the dot. There are games in this group that focus on entertainment, especially in sports, however most simulation games try to create interfaces that are true to its real life equivalent [18, p. 144]. Especially vehicular simulation games have a variety of hardware input gear that can be purchased in order to get the best experience.

### Strategy

Strategy games defined by how time passes in them. *Turn-based strategy* (TBS) describes games where a players make their moves one after the other similar to board games. In *real-time strategy* all player move simultaneously. This often requires a lot of micro managing or multiple units [18, p. 147]. Interface HUDs for RTS games have become increasingly complex over the years and so has the gameplay. These games are


**Figure 2.13:** Screenshot of *Fallout 4* "Pip-Boy" [25].

often hailed as the most difficult games to understand and master both mentally and mechanically therefore they are suited for beginners. A critical interface for RTS games are minimaps. The provide essential information about various locations at the same time, which is helps player make educated tactical calls.

TBS games on the other hand allow for a calmer pace and do not require incredible motor skills. They can offer strong mental challenges while also being fairly easy to use. Nintendo's *Fire Emblem Heroes* [27] is a mobile TBS game that is easy to understand due to its low unit count and limited map space (see fig. 2.14). Traditional interfaces in strategy games allow you to select units move them and order them to perform combat actions [18, pp. 148–149].

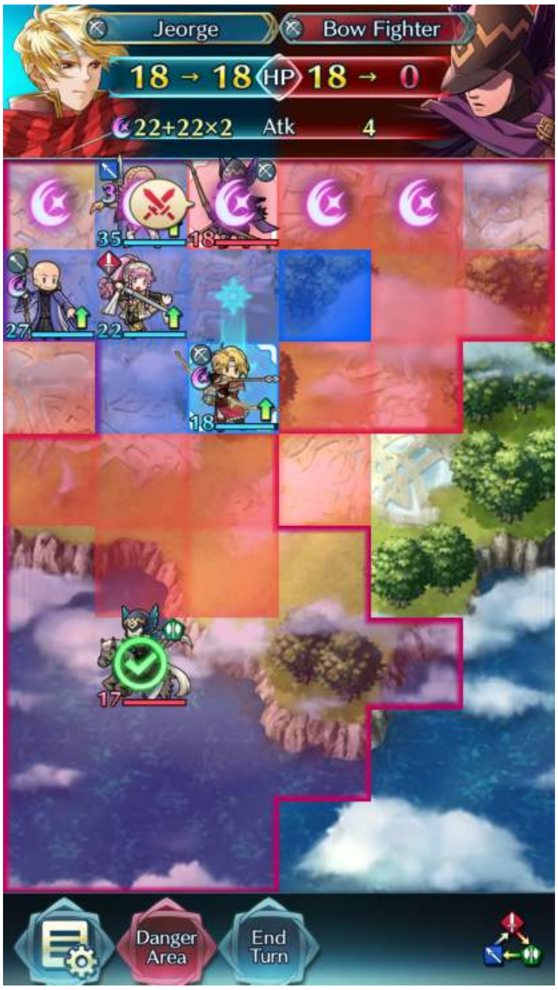


**Figure 2.14:** Screenshot of *Fire Emblem Heroes* [27]. Note the use of the colour as a way to distinguish between movement and attack fields.

# Chapter 3

# Interface Design for Elderly People

In order to design an interface for the game described in chapter 4 I have analysed various studies and games to accumulate a set of guidelines that helped me create the interface for said game. There have not been many attempts to examine game interface design for elderly specifically, which is the reason why some of the studies included in this chapter refer to interfaces for other products. It can be reasonably assumed that these elements can be directly translated to the gaming industry, since the share similar feedback elements and input methods.

## 3.1 Heuristics and Studies for Interface Design for Elderly

In this section I will describe several projects that attempt to study interface design outside and inside of games. Some of the guides and rules may overlap with the other studies as they come across similar results.

### 3.1.1 The ALTAC-Project

This project was an attempt by the Altec Inc., an American electric utility and telecommunications company, to investigate how elderly people cope with technical machines in their daily life [16, p. 165]. They categorized the machines in to groups. One for apparatuses used in the public, such as a ticket machine or a ATM. The other group describing appliances used in a household, for example a television set or washing machine.

The project consisted of two experiments. One on a ticket machine in public and one for a TV set and video recorder held in a private laboratory type situation. As they observed that most elderly have an increased difficulty to operate the machines they developed the following set of guidelines for user interface design [16, pp. 169–170].

- *Reduction of complexity:* This concept describes that information which is rarely used or unnecessary should be omitted in order to avoid confusion.
- *Clear structure:* The starting point and sequence of use of an apparatus should be easily recognizable.
- *Consistency of information:* Labels and colours of elements should not contradict or be inconsistent

- *Rapid and distinct feedback:* When the user is operating the interface they need to receive instant feedback in order to understand the use of that element. This also indicates the positive or negative outcome of the item.

### 3.1.2 Touch based User Interfaces

Touch based interfaces have been around since late 20th century. In 1985 the Japanese company *SEGA* released a video game console called the *SG-1000* capable of touch interaction [52]. However the first device to reach a widespread audience was *Apple's iPhone*.

Atsuo Murata and Hirokazu Iwase of the Hiroshima City University conducted two experiments in order to determine the usability of touch-panel interfaces for older adults [14, p. 1]. In the first they compared touch interfaces with traditional mouse usage. The intent of this comparison is to determine weather a direct to indirect interface should be pursued. The experiments tested the speed and reaction time of the elderly participants [14, pp. 6–8]. The second examination only tested the touchscreen and which areas where optimal for interaction. The results showed a clear advantage for the touch-panel interface. The researchers developed following guides for the touchscreen use [14, p. 9]:

- The target size for an item should be at least 16.5 x 16.5 mm.
- The moving distance of the hand should not be above 33mm from one element to the next.
- Interactive elements should be located at the centre or slightly to the left of the screen.

Researchers in Italy have developed a prototype interface directly at elderly people named *Mobitable* [13, p. 845]. The aim of the Mobitable was to address the special needs, skills and interests of older people. The project attempted to create an interface for elder people to use ICT[1] software in order to help their health and cognitive skill. After undergoing multiple prototypes they developed a movable table consisting of a touchscreen interface that was embedded in, a touch pen, a web cam, wifi connection and a keyboard underneath attached to it (see fig. 3.1). Touch gestures where the main input method while the keyboard merely optional.

The article writes that even though most test subjects initially started using they switched to using their finger on the touchscreen after getting used to the interface. Dragging motions where not as easily understandable, similar to flicking motions as these required a minimum speed and precision that proved difficult. The easiest motion to understand was the tap gesture due to its simplicity [13, p. 847–848].

Another lesson learned was that each element should have a single purpose. Overloading an item with capabilities causes confusion and misunderstandings. These functions should also have redundant feedback in order to emphasize the usage [13, p. 849].

### 3.1.3 Tangible Interfaces

Tangible interfaces as the name implies are input methods that can be touched in the real world [7, p. 17]. While this theoretically applies to any and all hardware input, it

[1]Information and Communication Technology.

**Figure 3.1:** Picture of the final *Mobitable* [13, p. 847]. The touch screen is slanted to ease the use. A camera is placed on the top facing the user and a keyboard underneath.

is usually differentiated by gamepads, keyboards and mice by also showing the output on the hardware.

*TanCu* was a tangible interface project developed by Wolfgang Spreicer in order to determine weather tangible interfaces resulted in a higher acceptance rate by the elderly [20, p. 314]. The apparatus consist of a small base, two cubes and a device with three OLED[2] buttons. The cubes have different pictures on each side and placing them on the base will create a message. The user can then send this message using the three buttoned device. Spreicer conduced numerous workshops and concluded that tangible objects do increase the acceptance rate of new technologies [20, p. 315]. The vital characteristic being that the interface is simple and easy to use. He determined that technology design hast to meet user needs and expectations.

Meeting user expectations in interface design can sometimes prove difficult in modern technologies, especially when dealing with elderly. A Swedish research team tried to solve this issue using familiarity and nostalgia. They developed a prototype MP3 player that featured and interface similar to a vintage radio, fittingly named *Nostalgia* [15, p. 964]. As the introduced the prototype to the seniors they noticed great interest and curiosity toward the machine. The participants started working on the apparatus by their own volition and were sometimes even emotionally invested [15, p. 965]. Using these familiar designs is also a key element in the prototype game discussed in chapter 4.

[2]Organic Light-Emitting- Diode.

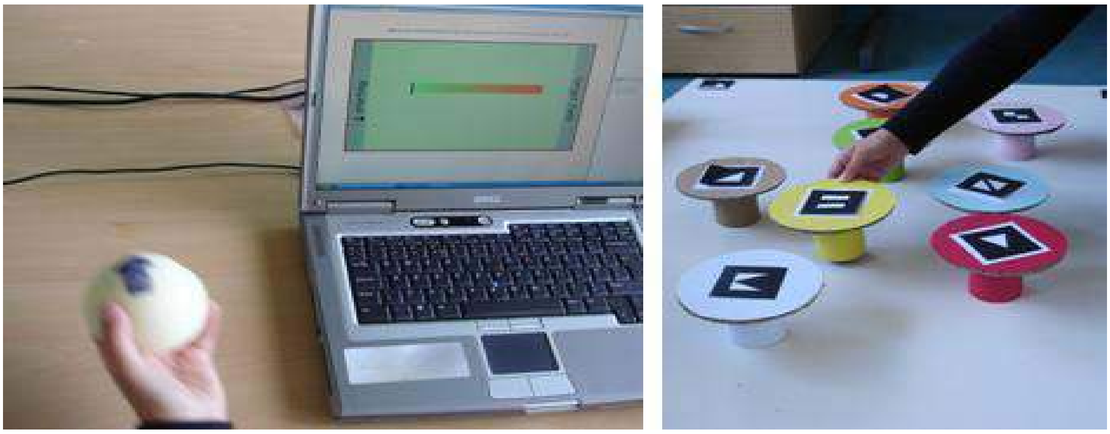

**Figure 3.2:** Photograph of the *Curball* prototype [11, p. 3]

## 3.2 Analysis of Game-Interfaces for Elderly

This section will concentrate on existing experiments with games for elderly. Video games have not yet had a widespread popularity among the older adults, which prompted many researcher to prototype games that might appeal the demographic [46]. The games discussed here are mostly prototype experiments, however they have come across significant success an provide useful information on the preferences of the elderly.

### 3.2.1 Tangible Gaming

There have been quite a few attempts to combine tangible interfaces with video games. One such attempt was the game *Curball* [11, p. 1], an intergenerational ball game. Both players are in two different locations. The aim of the game is to roll the ball to a certain goal without hitting any obstacles. The younger player is in charge of placing the obstacles on a field while the older player rolls the ball. The elderly player "throws" the ball by simulating it with a tangible substitute. This information is sent to the younger player digitally, who has set up a obstacle field for the older player to surpass. The obstacles are also tangible items that are being tracked by a computer [11, pp. 2–3]. An example of the game can be seen in fig. 3.2. The prototype forced a lot of communication and cooperation between the players and a lot of the engagement was originating from the older party [11, p. 6].

The spanish *University of Castilla-La Mancha* has attempted a prototype game that uses tangible objects to interact [5, p. 1]. In there paper *Increasing Engagement in Elderly People through Tangible and Distributed User Interfaces* [5] they describe the game as an "[. . . ] interactive and collaborative game designed to stimulate cognitive abilities" [5, p. 2] for elderly or people with Alzheimer's disease.

The game uses a mobile device capable of NFC[3] reading, tangible objects implanted with a NFC tag and a monitor that displays the feedback. The player is presented with a word on the screen that disappears after a few seconds. They are then prompted to

[3] Near-field communication.

select a tangible object that corresponds to the former word and are rewarded with points [5, p. 3]. In order to take visual handicaps into account the developers have used large-print displays, alternative colours and voice outputs to compensate [5, p. 2].

The results of the their attempt indicate tangible interfaces increase the understanding of the player towards the game. Further the physical action helps the think by emphasizing the connection between body and cognition [5, p. 4].

## 3.3 Outcome of the Research

My research has lead me to accumulate the information into set of guidelines specifically targeted at elderly people. The following points were established keeping the prototype game *Co-Smonauts* particularly in mind. At first will describe aspects that hold universally true to input and output interfaces. I will then proceed to establish more detailed information for both in separate sections.

The first and probably one of the most important aspects to remember in interface design is that *gameplay comes first*, as mentioned in 2.3. Having difficult playing the game because the button and slider do not make sense can result in frustration which as a consequence discourages play. In order to find a fitting interface for the game it is often advisable to establish the genre of the game and look at existing examples that have proven useful. When speaking about elderly interfaces it can be beneficial to look at strategy or simulation games as these often do not require expert motor skills.

Another important aspect is *consistency*. The ALTAC-project [16, p. 170] explained how this is fundamental to the player in order to understand the how the game works. Each input of the player must have the same out corresponding output. If an interface does not respond predictably it becomes cumbersome to use. It is also possible to apply this rule across multiple games. Consistency in the same type of gameplay helps the player recognize a certain function. As an example tapping at objects in a game often results in a selection or similar main function. Applying another less meaningful operation onto this action is not intuitive to the user.

In order for an interface to be intuitive it has to have a *clear structure*. This means similar tasks or information bars are grouped together, while function that a clearly different from each other are visually separated from the other. If the use of one element always follows the other the feedback should also display this accordingly.

As mentioned before, it is often hard to engage elderly players to game due to certain inhibition threshold. Unknown user interfaces can often seem daunting and changing someone's mind can often prove difficult. Therefore it is advisable to use a relatable or *familiar* interface. The Nostalgia prototype [15, p. 964] demonstrated that nostalgic or skeuomorph designs are easy to use and often do not require any explanation (see section 3.1.3). This can be as simple as making a button look 3 dimensional, in order to imply that it can be pushed, or very decorative as many simulation games often use exact interface replicas to navigate their machines (see fig. 3.3).

### 3.3.1 Output

As we have established in the last chapter 2 section 2.1, feedback is one of two main groups in which interfaces can be categorized. A critical aspect of feedback is the speed

**Figure 3.3:** Screenshot of *Euro Truck Simulator 2*. The game accurately depicts the interior of every truck [31].

at which it is received. Rudinger [16] mentions that every input of the player should have an *instant reaction* (see section 3.1.1). If the reactions are dragging the could confuse the player. In the worst case a player could operate multiple elements and would receive the output afterwards. This would make the functions of the input unclear.

One input does not automatically mean one output, quite the opposite! Having *multiple feedback elements* for one action enhances the understanding and clarifies the effect of input elements. A practical method of accomplishing this is by giving every action not only a visual but also an audible cue. This come very handy with an elderly audience due to the fact that many of them suffer from some form of cognitive deterioration. It allows the developer to cover all their bases.

In order to *simplify* the interface it can be advisable to remove any meaningless information from the output. An other solution to clear the clutter is by only showing the important information when the game requires it. Many role-playing games practice this such as CD Projekt's *The Witcher 3: Wild Hunt* [34] as you can see in fig. 3.4. The game removes its health bar, stamina and control aids while the character is not in combat and only keeps the necessary minimap interface. As soon as the player enters combat the interface reappears. As aesthetically pleasing this method is, it is important to notice that many elderly players require constant feedback and information about the game because of the memory difficulties mentioned in chapter 1 section 1.1, so one has to be careful not to remove essential elements.

Using *colour* to its fullest potential can aid the readability of your interface enormously. This does not mean one should use every colour in they have in their repertoire. If anything, similar to most rules of design, less is more [18, p. 233]. Using the same colour can help the player determine the use of many elements by grouping them toget-

**Figure 3.4:** Two screenshots of *The Witcher 3: Wild Hunt*. The left picture shows less interface elements than the right because the main character is not in combat [34].

her. Different contrasts can accentuate the importance of elements and make the game easier.

### 3.3.2 Input

The studies above all suggest that *touchscreen* inputs have considerably improved the engagement of elderly gamers in the past years (see section 3.1.2). Many older adults possess a smart phone and are capable of handling it. This clearly indicates that touchscreens are a preferable input method to more traditional control units such as keyboards or mice. The study of Murata [14] et al. have shown that when using a touchscreens it is preferable to have a sloped angle to ease the access and view. The target size for each interactive element should at least be 16.5mm x 16.5mm in order to ease selection with the finger. The distance between to items should not be more than 33mm, otherwise it affects the reaction time of the player.

Another valuable input method are *tangible objects* as mentioned in section 3.1.3. They mostly encourage engagement to the game because of the simple usage. It important the the individual objects are easy to handle and have simple shapes. This strengthens the ease-of-use of the tangible object.

Since most older adults are relatively new to video games it is preferable to give every element only one purpose. This avoids confusion of and elements function and improves the usability of the interface. Additionally it is also desirable to limit the total amount of elements to 5–7. Many older adults suffer from memory loss or weaker short term memory and increasing the elements they have to remember might prove challenging (see chapter 1 section 1.1).

# Chapter 4

# Interface design for Co-smonauts

Social bonding between elderly people and the newest generation has often proven to be challenging, especially in regard to technology. *Interplayces* [42] is a project of the research group PIE[1] from the University of Applied Sciences Upper Austria. The project aims to build a intergenerational game in collaboration with science centre *Welios*, the Johannes Kepler University and the interaction design studio *Netural*.

The project aims to create a prototype exploring the design possibilities for an intergenerational game and giving insight into design practices, especially concerning elderly players. The intergenerational game tries to connect young children and older adults by letting them interact via gameplay mechanics. As an active member of the project I had the opportunity to test and evaluate various interfaces for the game in an experiment with 26 participants between the ages of 60-70. The game we developed for this experiment is called *Co-smonauts*.

## 4.1 Co-smonauts: The Game

In 1961 Yuri Alekseyevich Gagari, a Russian astronaut, was the first man to ever journey to outer space. 1969 Neil Armstrong landed on the moon as the first man to stand on an extraterrestrial body. In 2012 the rover *Curiosity* landed on Mars, exploring the red planet ever since. Space exploration has been a part of most generations ever since it was deemed possible, connecting the elderly with the young [53].

This prototype game is specifically designed to test different interface designs that could help intergenerational communication, especially for elder citizens. Two players have to explore our wide solar system in a space ship while avoiding obstacles such as asteroids and an ever so depleting energy source. The players are able to fly to various planets and moons that prompts a description of that specific body, encouraging the players to explore more and find new information. Since the energy of the spaceship depletes while they are exploring, there are multiple energy pick-ups scattered around the solar system enabling the players to sustain their run for a longer time.

The ship is controlled by the *Captain*, who is in charge of steering the spaceship in the desired direction and avoiding the asteroids in the process. This role is intended for the younger player as it involves a more action based gameplay. The captain can control

[1] Playful Interactive Environment.

**Figure 4.1:** Symbols used for the game *Co-Smonauts*. Functions from left tor right: thrust, shield, scanners, health and energy.

his ship by using a joystick to input the direction and two buttons for acceleration and deceleration. The second role, and the one I will be focusing on, involves the *Navigator* and is filled in by the elderly player. There task is to help the captain, as the name suggests, navigate the solar system, while also micro managing the energy output of the ship. To do this the navigator is provided with a personal touchscreen and can individually control the thrust, shield and scanner capabilities of their ship. Increased thrust allows for a faster travel speed. Shield can protect from external threats and the scanner widens the map view of the navigator. However all of these capabilities increase energy consumption, requiring the player to manage there assets according to the current situation. Further to ease the navigation of the ship the navigator can place markers anywhere on the map, which activates an arrow on the screen of the captain.

Each mission can only be successfully completed by collaborating and the game as whole is unplayable without correct communication between the captain and the navigator. The elderly player was purposefully given a higher cognitive load as I wanted to test three different interface designs that helped lower the technological barrier of the hardware.

## 4.2 Interface Designs for the Study

During the creation of Co-smonauts I started to develop three different types of Interfaces in order to evaluate which of these would be most intelligible for elderly users. The difficulty in this task was trying to simplify the design without losing any essential information that might be necessary for the game. I hereby leaned on the various guidelines that I collected from [13, 14, 16, 18] in chapter 2 and 3 section 3.1.2 regarding interface use for elderly. I attempted to use my own paradigm as the major guideline for this task.

I was already aware of the required information the feedback had to deliver. In order to help the user recognize the use of each item throughout the three version, I started out by giving every item a representative colour. The thrust was red, shield was blue and scanners were yellow. Further the health bar was purple and the energy bar green. The elements also had symbols that represented their function. These simple and commonly understandable pictograms also remained the same between each version of the interface. This would help the user create and association with each colour, making ever item recognizable regardless of the interface that is being viewed [10]. The symbols with their representative colour can be seen in fig. 4.1.

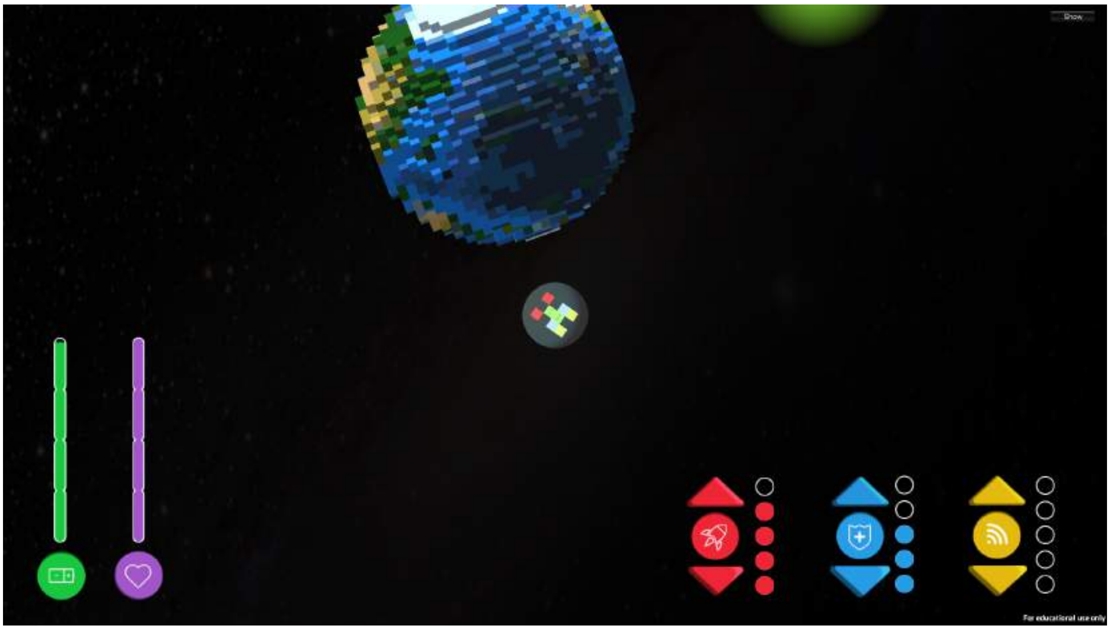

**Figure 4.2:** Variant 1: The button interface.

The second task on the agenda was to determine the genre of the game. Since the goal of the game was resource to explore space with a rocket and manage its resources, I categorized as a simulation game with slight strategy and action elements. We wanted the navigator to feel like they were in a futuristic space ship. A green submarine style radar was the first idea that stepped into my mind, since the gameplay required that the navigator communicate and guide the captain through space. This would have evoked a certain amount of familiarity and eased the understanding, however the game play required a more detailed point of view and the aesthetics did not seem very futuristic. Instead I used a larger map view that showed the real space objects. The player is now capable of describing the landmarks in space, “the blue planet” or “Mars” to communicate directions.

### 4.2.1 Version 1: The Button Interface

The first interface uses two buttons for each, for thrust-, shield- and scanning power. The buttons are placed next five dot bars that represent the level of power that is being used for each function. The reason for five time incremented bar was to ease the use of the buttons. In order for the navigator and captain to communicate precisely, the former had to be able to control exactly how much power was being used. However a button interface proved sub-par for an undivided bar. One could have tried to solve this by using a holdable button, but the need for precise timing would have added a further challenge to the user. The buttons and bars were placed on the bottom right part of the touchscreen. Two additional bars, representing energy and health, were placed vertically on the bottom left. All items were colour coded to there respective function. A screenshot of the interface can be seen in fig. 4.2.

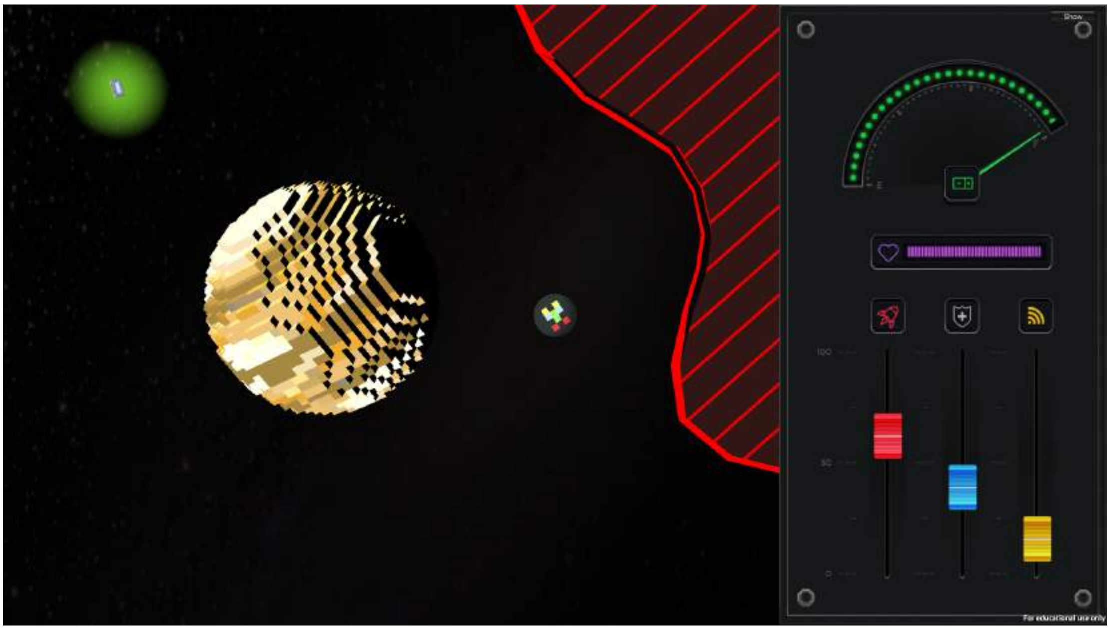

**Figure 4.3:** Variant 2: The slider interface.

### 4.2.2 Version 2: The Slider Interface

This GUI, unlike the former, occupied a quarter of the touchscreen on the right side. It provided a energy meter on the top, which resembled the fuel meter of a car. This design attempted to provide a familiar setting to the interface to make the modern theme of the game more engaging. Underneath one can find a horizontal health bar providing information on the ship status. Below the bar are three sliders for the same functions as the first one. However these sliders are not incremented and do not require an additional bar, because the position of the slider already provides that information. Further the sliders are designed to resemble an audio console, which made the understanding and use of each button clearer[2] as represented in fig. 4.3. A side note worth mentioning in regards to the 3 dimensional appearance of the elements is that I tried to light them from above. This is rather important because light coming from below can seem unnatural and off-putting as mentioned in [43].

### 4.2.3 Version 3: The tangible Interface

This version took a very different approach to the former two. The input of the user was not bound to the touchscreen anymore which opened up a lot of space for the navigational map. A “Pro Flight Throttle Quadrant” from Saitek3 was used to simulate real flight controls for the player. This approach was chosen due to the simulation nature of the game. Many vehicular simulation games shine with custom hardware interfaces and the unique nature of them is often a great selling point. Another reason was the familiarity of the device. While not all participants had experience with a touchscreen

[2]GUI that resembles real life hardware is called *skeuomorph*.

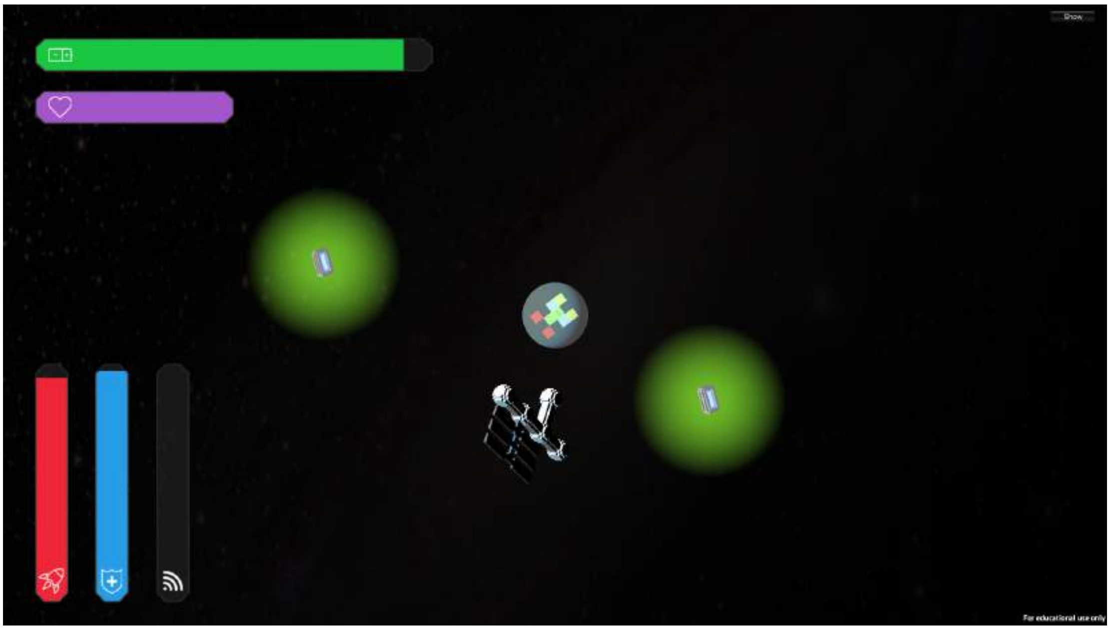

**Figure 4.4:** Variant 3: The interface for the physical controller.

device it was fair to assume that most of them had used a lever at least once in their lifetime. These levers also provided instant feedback because of their position in the slit. I added three bars that corresponded to the levers of the controller to repeat and strengthen the feedback. These were placed on the bottom left of the screen, while the energy and health bar were on the top left. The interface and controller were displayed as in fig. 4.4 and fig. 4.5.

## 4.3 The Experiment

I was able to test the interfaces during a study we conducted in our Interplayces project. We had invited 26 participants, from the age of 60-70, over the course of three days to test the game with every interface variant. From all participants 14 were female and 12 male. Most of the them had little to no prior experience with with video games and smart phone games in particular.

### 4.3.1 The Setup

In our room wie had a long wide table in the middle facing to 55 inch flat screen visible to both players. The captain, who was played by one of the research staff, sat on the right side of the table with an arcade controller to steer the spaceship. The navigator was on the left side of the table with a 24-inch touchscreen and an Saitek Pro Flight Throttle Quadrant controller, which was covered up by a piece of cloth whenever not in use. Each screen was linked to a separate computer, which were connected by local network for real time synchronization of the game variables. See fig. 4.6.

**Figure 4.5:** Variant 3: The physical controller.

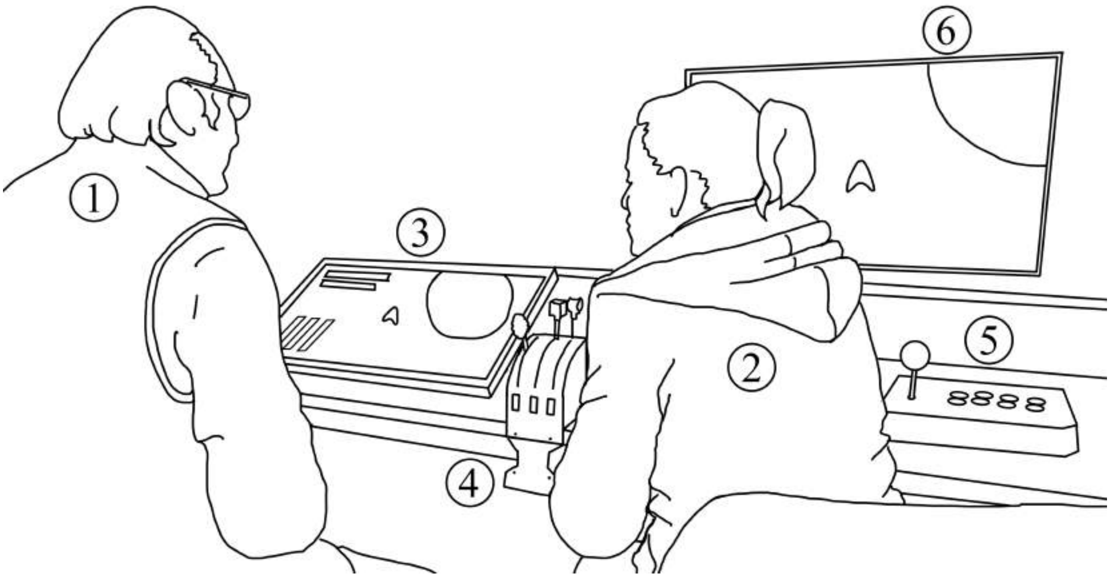


**Figure 4.6:** A diagram of the technical setup. 1: the navigator (elderly people); 2: the captain (research staff); 3: 24 inch touchscreen of the navigator; 4: Pro Flight Throttle Quadrant for variant C; 5: arcade game controller for the captain; 6: 55 inch screen for both players.

### 4.3.2 The Procedure

Each session was accompanied by two research staff members that monitored the experience. Starting of with a short presentation that explained the Interplayces project, its purpose and intents, we proceeded with the game itself. Players had to accomplish five small tasks in order to get them accustomed to the controls. After that they would advance to three bigger missions that for a greater challenge. After each major mission the players were required to fill out a short questionnaire regarding the mission and interface they had played on. The interfaces where placed in a random order for each participant, however the order of the missions would stay the same.

#### Tutorial Tasks

The five smaller tasks were as follows:

1. Identify the shield controls and increase its energy to the maximum.
2. Identify the thruster controls and increase them to half the power.
3. Identify the scanner controls and increase the energy as much as you like.
4. Since all these operations drain the energy of the spaceship reduce them back to zero.
5. Touch any point on the screen to create a navigational marker.

Afterward came the three major missions that required a reiteration of the learned tasks.

#### Mission 1

The objective of this mission is to find Saturn and fly close to it. In order to successfully manage this, the navigator had to increase thrust speed and had ideally increased there scanner energy in order to search for Saturn. The navigator would then, verbally or by using the navigational marker, tell their partner to drive to the desired location.

#### Mission 2

This time the players were trapped surrounded by asteroids and had to navigate a narrow path out. This mission had two different solutions. The navigator could increase their thrust and scanner energy and navigate carefully between the asteroids leading a safe path or they could have increased their shield energy and accelerated through the asteroid field itself to bypass the lengthy path navigation.

#### Mission 3

The last mission requires the players to collect five energy drops because the energy in their spaceship is low. This mission demands an active energy management of the navigator, depending on the situation. Certain drops on the map are surrounded by asteroids while others are far in the distance. The navigator has to change their energy consumption depending on the drop that they are intending to collect.

Finally the participant had an additional questionnaire specific to the interface variants regarding their preference. We then presented the future prospects of the study and ended the session afterward. Each participant to about 30-45 minutes to complete the procedure.

### 4.3.3 The Hypotheses

Experience and mental association play a huge role in how we understand objects and communicate with our peers. Needless to say my assumptions where based on our understanding of the elderly and their experiences with probable past hardware. It made sense that a tangible interface would increase the interest of elderly players reducing the barrier of understanding a new technology and encouraging a more cooperative gameplay experience.

This can be broken down to two hypotheses:

**Hypothesis 1** Elderly players will enjoyment will rise significantly when using the third, tangible variant interface to play the game. This will also increase perceived usability when compared to the other two interfaces.

I assumed that elderly players might prefer the physical controls as these might remind them of common hardware found in various devices. Unlike the digital interfaces these levers have an established functionality that is easily understood.

**Hypothesis 2** A tangible interface will remove most impediments to the elderly, encouraging them to engage in cooperative gameplay, reducing the cognitive load in contrast to the touch interfaces.

Having familiar controls will animate the elderly users to engage in an cooperative game with their intergenerational parter. On the other hand it is to presume that the anxiety elderly players feel toward the hardware discourages them from engaging in video games with others.

## 4.4 Result

Thanks to the help of the Johannes Kepler University I was able to receive correctly processed results of the data we acquired. While all three interfaces scored high regarding the enjoyment participants felt during the game, with only minimal differences (See fig. 4.7), there was a significant outcome concerning the preferred interface of the players. Surprisingly, more than half of the users favoured variant 2, the interface with touch sliders. See fig. 4.8. This directly opposes my first hypothesis. Even though touchscreen buttons where indeed the least favoured variant, the tangible interface did not raise the level of enjoyment as I would have assumed.

Regarding the cooperative engagement of the players, the subjects noted that the first, button interface increased there interest in collaboration. However the tangible variant did prove to require the least amount of cognitive load, partially affirming the assumptions of my second hypothesis. Nonetheless the difference of usability of the second and third variant are statistically insignificant, while showing that the button interface was more difficult to use. See fig. 4.9.

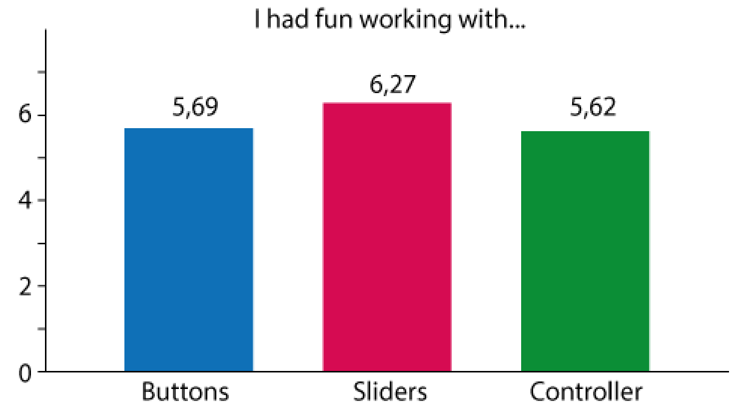


**Figure 4.7:** While Variant 2 has the highest enjoyment rate, all interfaces are highly rated.

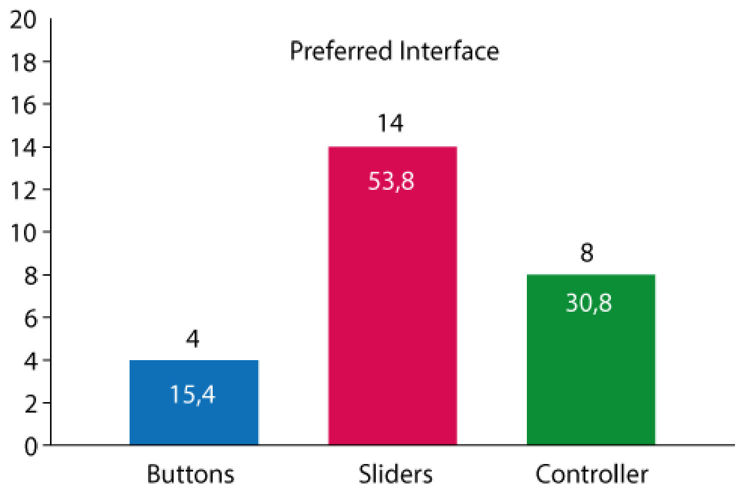


**Figure 4.8:** Variant 2 exceeds the other two interface by far. Variant 1 is exceptionally low.

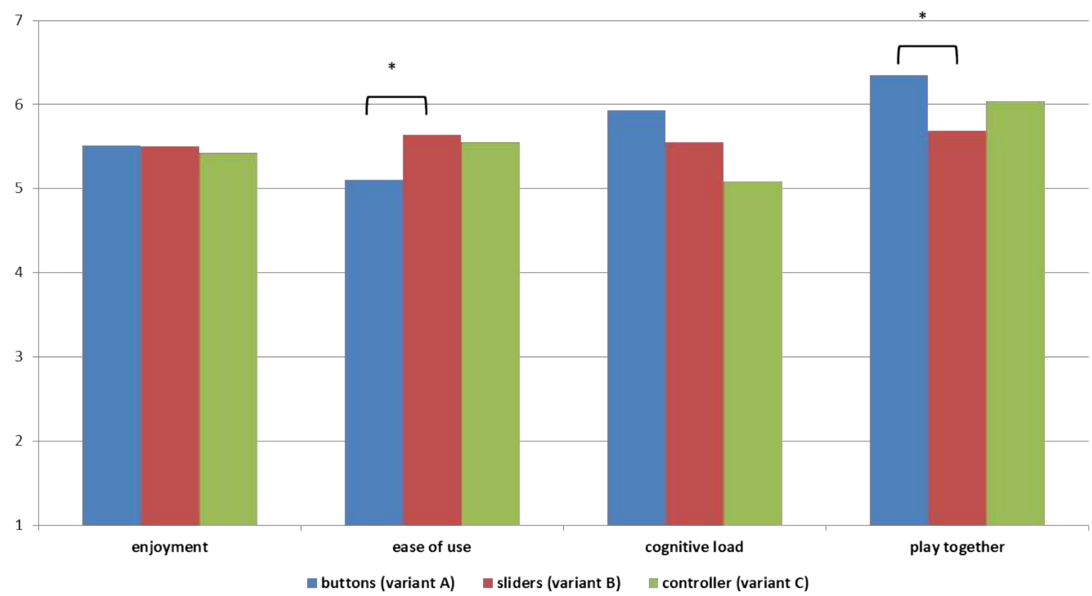


**Figure 4.9:** The data regarding enjoyment, perceived usability, cognitive load and collaborative preference.

# Chapter 5

# Outcome and Discussion

This thesis has created a paradigm that would not only be tested by the prototype game but on that could hold beyond it in order to guide future game development for elderly. The game Co-Smonauts was the perfect testing ground as it was meant to be an intergenerational game that encouraged communication between grandparents and their grandchildren. Creating 3 different interface version allowed me to test the engagement between a touch and tangible controls as well as between a skeuomorph and minimal button interface.

As much as I assumed that the tangible controls would be preferred by most participants due to its familiarity and simplicity, the results showed that the slider touch interface was much more preferred. This could have multiple reasons, for one the sliders were directly integrated into the screen so players did not have to divide their attention between the input and output. The participants also seemed surprisingly eager to use the touchscreen slider interface. The familiar aesthetics and the fact that the interface was integrated to the screen had a big impact. Since the players did not need to spend a lot of time understanding the interface they could focus better on the game itself. Further the proximity of the interface allowed them to play without having to move their eyes away from the screen. Observations during the workshop showed that while nearly all players enjoyed playing the game that most of them were anxious when the were told they had to use the digital devices due to some form of fear of humiliation. Nonetheless as soon as they understood the mechanics of the game satisfaction and joy rose.

The button interface was particularly less desirable to the other two versions. Some participants seemed to be confused about the tapping motion and tried to slide the arrows around. Others thought that the symbol was a button itself and kept tapping on that. Additionally, instead of having full control over the resources the players were limited to the incremented bar. All these aspects may have impaired the rating of this version compared to the others.

## 5.1 Limitations

### 5.1.1 Limited variety of Gameplay

This paper has a few limitations regarding the workshop. First, the guideline established in chapter 3 could not be tested to its fullest extent seeing as every game is limited to its gameplay. It would be interesting to know if the results hold up in an action or RPG type game that, in theory, do not favour the older players.

### 5.1.2 Apparent Embarrassment

As I mentioned before many of the participants felt as if they might humiliate themselves due to their lack of knowledge regarding video games and devices. This might have lead some players to answer their questionnaire incorrectly by feeling the need to give the interfaces top scores even if they saw flaws in them.

### 5.1.3 Cultural Differences

The third limitation that I observed was cultural. Being the son of Indian immigrants I noticed the players, while sceptical, still enjoyed and welcomed the idea that elderly should play video games alone or with their children. However, when speaking of video games in India, the general mentality of the older population is to avoid them or that they are time consuming juvenile endeavours. This different attitudes towards games might prove as an additional challenge to creating an engaging interface for elderly.

## 5.2 Future Research

The release of the Co-Smonauts game in the Welios Science Centre will be the main deciding factor to the success of the interfaces. Having elderly people engage in the game without being prompted to do so would be the best case scenario. It may reveal new information about the interfaces as well as overturn current findings.

Another aspect that might find a footing in the current gaming world are VR games that were briefly mention in chapter 2. Including VR interfaces in this group of guides might still be some steps away as it has yet to be fully established in the mainstream gaming world. It will be interesting to see future technology change the way we view and value communication and might bring generations closer together.

# Appendix A

# CD-ROM/DVD Contents

Format: CD-ROM, Single Layer, ISO9660-Format

## A.1 PDF-Dateien

Path: /

Cherukad_Jens_2018.pdf Complete master thesis

## A.2 Additional Files

Path: /images

*.jpg, *.png . . . . . . . Original images

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