Universidade de Aveiro Departamento de Comunicação e Arte
2018

JOAQUIM NUNO SALGUEIRO DOS SANTOS

DESENVOLVIMENTO DE UM PROTÓTIPO DE ARTEFACTO TANGÍVEL PARA TRATAR CRIANÇAS COM PERTURBAÇÕES DOS SONS DA FALA

DEVELOPMENT OF A TANGIBLE ARTEFACT PROTOTYPE FOR TREATING CHILDREN WITH SPEECH SOUND DISORDERS

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Comunicação Multimédia, realizada sob a orientação científica do Doutor Mário Jorge Rodrigues Martins Vairinhos, Professor Auxiliar do Departamento de Comunicação e Arte da Universidade de Aveiro e do Doutor Luis Miguel Teixeira de Jesus, Professor Coordenador, da Escola Superior de Saúde da Universidade de Aveiro.

Dedico este trabalho à minha esposa Ana, pelo seu constante apoio e auxílio. Por estar presente e me trazer de volta à realidade. Pelas incontáveis horas de que abdicou para que eu pudesse estar sossegado a produzir. E dedico também ao meu filho Gonçalo, que com a sua ajuda constante desarrumando tudo e sendo o que é, uma criança, tantas vezes sem o saber ajudou a quebrar a sensação de pressão e *sturm und drang* sentido. Ana e Gonçalo, vocês são mais que as palavras aqui vertidas. Esta dissertação é tanto vossa quanto minha.

o júri

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A todos os que de alguma forma me ajudaram ao longo deste período!

palavras-chave

Crianças; Perturbações dos Sons da Fala; Artefacto Tangível; Interação; Pais/Educadores de Infância e Assistentes;

resumo

Na primeira parte desta Dissertação são apresentadas diferentes abordagens – paradigmas de interação considerados relevantes – que poderão ser usadas para enriquecer um material de intervenção tradicionalmente físico e como tornar tudo num todo coerente, num artefacto tangível. As vantagens que um artefacto tangível poderá deter sobre um objeto tradicional, bem como o seu enquadramento na forma como as crianças aprendem, são analisados. São ainda descritos três casos considerados de sucesso e deles é produzida uma breve reflexão sobre a criação de artefactos tangíveis..

Na segunda parte da Dissertação é apresentado o jogo escolhido concebido para ser transformado num artefacto tangível – o "Jogo da Pesca". São abordados aspetos da mecânica de jogo - na versão tradicional e também na versão tangível/digital - e o porquê e as vantagens percecionadas aquando da sua transformação. As tecnologias usadas e os vários momentos e iterações que, tanto o protótipo quanto o software sofreram, são descritos e explicados os motivos e o fio condutor por trás das várias decisões tomadas.

A fim de obter sugestões e verificar se o protótipo estava a ser desenvolvido de acordo com as necessidades dos públicos-alvo identificados, realizou-se um teste exploratório, com uma amostra de 10 elementos. Durante esse teste foi utilizado o método de observação direta e os seguintes mecanismos de recolha de dados: grelha de observação e questionário/entrevista semi-estruturada. Isto permitiu a recolha de dados quantitativos e qualitativos, que nos ajudaram a concluir que o protótipo respondia às necessidades existentes, tem uma elevada capacidade de motivar o voltar a jogar e favorece a imersão. Por fim são apresentadas as conclusões e os resultados obtidos, bem como uma lista exaustiva de sugestões, comentários e alterações a realizar para criar um artefacto tangível, com características de produto final.

O artefacto produzido pode ser extremamente modular e versátil e existe uma clara necessidade e interesse em objetos similares por parte de terapeutas da fala, educadoras e auxiliares. Há no entanto aspetos a melhorar. O processo deveria ser ainda mais iterativo, com uma equipa multidisciplinar e com todos os utilizadores finais a participar no design/criação.

keywords

Children; Speech Sound Disorders; Tangible Artefact; Interaction; Parents/Caregivers;

abstract

In the first part of this Dissertation different approaches - interaction paradigms considered relevant - that can be used to enrich a traditionally physical intervention material and how to turn everything into a coherent whole, a tangible artefact. The advantages that a tangible artefact may hold over a traditional object, as well as its role in children's learning, are analysed. Three best practices cases are described and from them lessons are drawn for the creation of tangible artefacts.

In the second part of the Dissertation the game selected to be transformed into a tangible artefact - the game of Fishing - is presented and described. Aspects of game mechanics, both in the traditional version and in the tangible/digital version, are discussed. The reasons and advantages perceived in the transformation into a tangible artefact are reviewed. The technologies used and the various stages and iterations that both the prototype and the software suffered are described. The reasons and the motivation behind the various decisions made are explained.

In order to obtain suggestions and to verify if the prototype was being developed according to the needs of the identified target users, an exploratory test was prepared and carried out, with 10 participants. During this test we used the direct observation method and the following data gathering mechanisms: observation grid and semi-structured questionnaire / interview. This enabled the collection of quantitative and qualitative data, which allowed us to conclude that the prototype addresses the existing needs, has a high replay value and favours immersion. Finally, we present the conclusions and results obtained, as well as an exhaustive list of suggestions, comments and changes to be made to create a tangible artefact with final product characteristics.

The artifact produced can be extremely modular and versatile and there is a clear need and interest in similar objects from speech therapists, educators and auxiliaries. However, there are aspects to improve. The process should be even more iterative, with a multidisciplinary team and all end-users able to participate as co-designers.

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List of Acronyms

AR – Augmented Reality

CSS – Cascading Style Sheets

DBR – Design Based Research

EP – European Portuguese

FCP – Family-Centred Practice

GUI – Graphical User Interface

HCI – Human-computer Interaction

HTML – Hyper Text Markup Language

IoT – Internet of Things

JSON – JavaScript Object Notation

KTA – Kindergarten Teachers and Assistants

LDR – Light Dependent Resistor

LED – Light-Emitting Diode

MR – Mixed Reality

NPM – Node Package Manager

Rev – Revision

RFID – Radio Frequency Identifier

SLT – Speech and Language Therapist

SSD – Speech Sound Disorders

T2T – Table to Tablet

TC – Treasure Chest

TUI – Tangible User Interface

UbiComp – Ubiquitous Computing / Pervasive Computing

VR – Virtual Reality

Introduction

There are thousands of children that need speech therapy in Portugal (Schreck, 2009). According to data from 2009, between 20 to 30% of Portuguese children of pre-school age have, to some degree, Speech Sound Disorders (SSD) (Schreck, 2009). Schools have fewer professionals capable of treating these children and so the role of the parents and Kindergarten Teachers and Assistants (KTA) is more than ever very important.

At the same time, the proliferation of handheld devices has brought a myriad of applications to help children with SSD. However, their validity is, in a majority of them, scientifically unproven (Bowen, 2015). To address the lack of validated intervention material, from 2014 to September 2017 the School of Health Sciences of the University of Aveiro and the Institute of Electronics and Informatics Engineering of Aveiro developed a scientifically validated intervention program. The program, named Table to Tablet (T2), is comprised of a physical material, as well as the digital counterpart application. Both of these materials have already been developed and scientifically validated. They present a statistically significant efficacy.

This led to the idea behind this dissertation: 'A physical material has intrinsic qualities like weight, smell or texture, to name a few, and these can be used to stimulate speech production and thus help the speech and language therapists' (SLTs) intervention. A digital application, especially if tactile/mobile based, has the appeal of being a well-known device by many children and produce a sense of engagement through the use of sound, animation and colour. So, what if both could be combined into a tangible artefact capable of being used by children, parents and KTA, and also while being understood as a game and not a chore by the children?'

Problem

The two problems mentioned previously in the Introduction – the high percentage of Portuguese children with SSDs, that need specialized intervention and the lack of scientifically validated material in European Portuguese (EP) – open a new and underdeveloped field of research for which this Dissertation aims to contribute.

Nowadays SLTs use physical media (boardgames, teddy bears, other assorted toys and games) to stimulate speech and so help children to overcome SSD. As stated above there are some mobile or computer applications that can be used albeit with scientifically unproven efficacy (Bowen, 2015). However, both physical and digital approaches have their own limitations.

What is proposed in this Dissertation is the creation of a "hybrid" artefact, that is physical but also digital and that allows maximizing an Speech and Language Therapy intervention – a tangible artefact.

Relevance

Due to budget cuts (ASHA, 2015) schools and parents have fewer resources to try and help children with SSD. But the number of children with this pathology and the effect that it can cause later in life is well documented (ASHA, 2015; Lancaster, 2008; McCormack, McLeod, McAllister, & Harrison, 2009). A possible answer to this problem is presented in this Dissertation, with the creation and test of a tangible artefact, capable of being used by SLTs, KTAs and parents, in a one-on-one session or as a group activity, with children with SSD and typically developing children. The use of this artefact, the socialization that it implies and the opportunity to gain a reward, gamifies the experience and makes the children perceive the time as a moment of fun rather than therapy.

Research question

How can tangible user interfaces be used as a tool to help in the intervention in children with Speech Sound Disorders?

Objectives

The work described in this Dissertation aimed to: Design and develop a tangible artefact, to be used for intervention in children with SSD; design and develop an website/application for the Fishing Game prototype to be primarily used by the SLTs; gather data from the target/intended users, such as SLTs, KTAs, Parents and Children; analyse the available applications and the games on sale with wider use and acceptance from the SLTs; analyse low-cost solutions and electronic equipment to create tangible artefacts for children with SSD.

Dissertation structure

This Dissertation is divided into two main components: the theoretical and the empiric parts. In the theoretical part, the literature review is conducted and the problem presented. The following themes, divided into chapters, are approached:

(i) Chapter One – Method;

(ii) Chapter Two – Speech Sound Disorders: what they are; the most common in EP; the SLT approach and the role of parents and KTA;

(iii) Chapter Three – Tangible artefact: what it is; main paradigms of digital interaction with the physical world; the use of these artefacts in Health and Education; Interaction – how to design for children;

(iv) Chapter Four – How to develop a tangible artefact that addresses the problem: how children learn; the sense of community and rewards and how they influence the learning process;

(v) Chapter Five – Best practices use cases: the selection criteria; the Portuguese T2T; the LinguaBytes project from the Netherlands and the MIT Jabberstamp.

In the empiric part questions like the game origins, the technology behind the prototype, its iterations, testing and results were presented.

The following themes, divided into chapters, are approached:

(vi) Chapter Six – The Fishing Game: the methodology used to approach development of it; the history and rules of the game; why transform the original game into a tangible user interface game; the conceptual model; a default therapeutic intervention with the fishing game prototype;

(vii) Chapter Seven – The Technologies: The hardware used and why; the Software used and why; the activity explained; playing the activity; the website/application; building the prototype (iterations and final build);

(viii) Chapter Eight – Results: data gathered from the observation form and the grid;

The necessary evaluations/assessment and data gathering was conducted and from them sprung the final conclusions and future work.

(ix) Chapter Nine – Conclusions and Future Work;

Keywords

Children; Speech Sound Disorders; Tangible Artefact; Interaction; Parents; Kindergarten Teachers and Assistants; Invisible User Interface;

Part I – Theoretical Background

"To know the world, one must construct it."
Cesare Pavese

1. Speech Sound Disorders

This chapter aims to familiarize the reader with *Speech Sound Disorders*. A description of the most *Common SSD in EP in children* is included. On the third part, the *Assessment and Therapeutic Approach to SSD* will be analysed. On the fourth part the *Parents / KTA role: perceived and real* will be discussed.

1.1. Introduction

Children with SSD represent 40% to 90% of paediatric caseloads (Joffe & Pring, 2008; McLeod & Harrison, 2009; Oliveira, Lousada, & Jesus, 2015). Speech Sound Disorders take the form of gaps in their speech sound systems that can cause difficulties in producing or understanding phonemes (Bowen, 2015; Dodd, Holm, Hua, & Crosbie, 2003). They also have speech patterns and structures that should not be present in typically developing children of their age (Bowen, 2015). Children with phonologically-based SSD normally present difficulties in phonology, which can be observed by the number of phonological processes[1] in their speech (Orsolini et al., 2001). Phonological awareness, i.e. being able to discern and produce the correct phonemes, has an important role in reading acquisition (Felton & Brown, 1990), and the improvement of these skills prior to starting school diminishes the risk of future academic and socio-emotional difficulties (McCormack et al., 2009). So it is extremely important that these children's expressive phonological skills and phonological awareness are developed by the SLTs, parents and KTA, in order to support the underlying skills for literacy in children with phonologically based SSD (Gillon, 2004).

1.2. Common Phonological Processes in European Portuguese in children

According to (Jesus, Lousada, Domingues, Hall, & Tomé, 2015), there are nine phonological processes that can be considered more common in EP. In Table 01 below they will be summarised, using both phonetic alphabet and standard alphabet in the examples column for legibility purposes.

[1]Simplifications of the adult speech that a child uses during its language development. They can be seen as a systematic alteration or simplification that affects a class or sequence of sounds. (Bowen, 2015)

Table 1 - Common phonological processes in EP (Jesus, Lousada, Domingues, Hall, & Tomé, 2015)

Phonological Process	What it is	Example
Final consonant deletion	Children omit a consonant in the final position of the syllable or final position in the word.	The word "porco" is produced as ['poku] ("poco").
Weak syllable deletion	The weak syllable is omitted.	The word "chapéu" is produced as ['pɛw] (" ′péu").
Cluster reduction	An element of the cluster is omitted.	The word "zebra" is produced as ['zebɐ] ("zeba").
Gliding of liquids	The consonants /l/ (e.g., bola) and /r/ (e.g., maré) are substituted by a glide.	The word "bola" is produced as ['bɔwɐ] ("bowa").
Depalatalization	Replacement of a post-alveolar fricative consonant (e.g., ch or j) by an alveolar fricative (s or z).	The word "chapéu" is produced as [sɐ'pɛw] ("sapéu").
Palatalization	Replacement of an alveolar fricative consonant (s or z) by a post-alveolar fricative (e.g., ch or j).	The word "vassoura" is produced as [vɐ'ʃorɐ] ("vachora").
Devoicing	Replacement of a voiced consonant by a devoiced consonant.	The word "mesa" is produced as ['mesɐ] ("messa").
Stopping	Replacement of a fricative (e.g., s, z, ch, j, f, v) by a stop consonant (e.g., p, k, b, d, g).	The word "faca" is produced as ['pakɐ] ("paca").
Fronting	Replacement of a back consonant (e.g., g or k) by a dental/alveolar (t or d).	The word "cabelo" is produced as [te'belu] ("tabelu").

1.3. Parents and KTAs role

Speech and language therapists have a central role in SSD intervention but the current recommended practices point to the importance of a family-centred practice (FCP). This promotes not only the parents involvement in the sessions and in homework activities but also in planning a session (setting goals) (Pappas, Mcallister, & Mcleod, 2016).

Family-centred practice follows the following guidelines (but may include more components): (Pappas et al., 2016)

- » Whole family as client;
- » Positive family/professional relationships;
- » Empowerment and enablement of families;
- » Parental decision-making;

According to some studies (Mcleod & Baker, 2014; Pappas, McLeod, Mcallister, & McKinnon, 2008; Ruggero, McCabe, Ballard, & Munro, 2012), most of the SLTs already try and involve parents in some way and believe it to be fundamental for the success of the intervention. However, parents of children with SSD have a different way of perceiving their role and the SLTs' role.

Despite considering their involvement as a positive thing, parents tend to expect the session to be much more an interaction between SLT and child and see themselves more as spectators and less as decision-makers (Pappas et al., 2016).

Of similar importance to a child development due to the time spent with and nature of the relationship is the KTA. They are part of a child innermost circle (Sharynne McLeod, Daniel, & Barr, 2013). Kindergarten teachers and assistants can help in the detection and report the possible cases of SSD and in the implementation of specific activities with the child, as long as proper training, support and tools are provided by the SLT.

Kindergarten teachers and assistants are well aware of the cognitive and social impact of SSD in children and the negative attitudes people tend to have (McLeod et al., 2013). However, a caregiver has to attend the needs of several children and, at least in the Portuguese reality, cannot do one activity with just one child. Activities have to be able to be done in a group and benefit all.

1.4. Summary

In this chapter, SSDs were described as an inappropriate age level omission/replacement of sounds, perceived by the number of phonological processes in their speech (or, the simplification of adult speech by a child with SSD) for the EP children. The common approach to assess and intervene in children with SSD and also the parents and caregiver's role was discussed.

In the next chapter, the tangible artefacts will be discussed.

2. Tangible artefact

Beyond conventional typical interaction paradigms, such as Graphical User Interfaces (GUIs) and Command Line Interfaces, there are several interaction paradigms – like Natural Interaction, Ubiquitous Computing, Pervasive Computing, Mixed Realities or Wearable computing, etc. - and their value and importance in better understanding interaction cannot be underrated. However, for this dissertation and the proposed objectives, mainly the development of a tangible artefact, a chronological order of four related interaction paradigms was chosen. In this chapter the concepts of *Ubiquitous Computing/Pervasive Computing, Augmented Reality/Mixed Reality*, *Tangible User Interfaces* and *Internet of Things* and their importance to this dissertation will be discussed. The role that tangible artefacts can play in education and health is appraised. The concept of Interaction and how it differs from adults to children will be explained and some psychological aspects that affect how children learn are explored.

2.1. Main paradigms of digital interaction with the physical world

For the scope of this dissertation, in this section and subsequent sub-sections, the concepts and meaning of *Ubiquitous Computing/Pervasive Computing, Augmented Reality*, *Tangible User Interfaces* and *Internet of Things* are made aware.

2.1.1. Ubiquitous Computing/Pervasive Computing

The most profound technologies are those that disappear.
They weave themselves into the fabric of everyday life until they are indistinguishable from it.
Mark Weiser, The computer for the 21st Century, 1991

Ubiquitous Computing (UbiComp), also called Pervasive Computing or, as Weiser, the father of the term preferred, Calm Technology (Hiroshi Ishii, 2004; Weiser & Brown, 1996) goal is to increase the use of computers (Weiser, 1993). To make life both more comfortable and productive (Ebling & Baker, 2012), by making many computers available through the physical environment – hundreds of computers per room (Weiser, 1991). However, these hundreds of computers and the use of them are not really what Weiser meant (Hiroshi Ishii, 2004). Those were means to achieve the goal of "transparency" - a moment when people apprehend something so well they discontinue their awareness of it (Weiser, 1991). The necessary steps to achieve that vision will be discussed in the following paragraphs.

Weiser, in "The computer for the 21st Century" (1991), argued that personal computers, despite the large numbers of units sold, were still something obscure and demanding of a complex jargon to be able to be used (Weiser, 1991). However, for Weiser, the problem was not one of user interface but one born out of a misconception: a personal computer should be seen as an instrument used to achieve a goal, i.e. tapping into the real potential of information technology (Weiser, 1991), and not an end itself. In order to achieve its full potential, the computer should disappear into the background, no more being an object that attracts attention and needs special skills, but something so well learned that it would, akin to reading or writing, be used without the user even noticing or having to think about it (Weiser, 1991).

Weiser and its colleagues concluded that, despite the already common use of controllers or computers in some appliances that "activate the world" (Weiser, 1991), to be considered a UbiComp device it had to be capable of transmitting and displaying information more directly. Those devices had two major issues that needed addressing in order to achieve Weiser vision: location and scale (Weiser, 1991).

Location

Any UbiComp device needs to know its location in order to be useful and transmit relevant data. By knowing the correct location, a computer can adapt its actions, even without any sort of Artificial Intelligence programmed into it.

Scale

Scale is related to the main concept of having multiple machines in the same place but their area of actuation would be dictated by its size. Weiser envisioned three different sizes and called them Tabs, Pads and Boards. Tabs would be small, card size surfaces (for example driver's license card), Pads would be paper/magazine size and Boards would be equivalent, in size and use to a blackboard. They would be used as replacements for today's myriad of papers, cards, posters and publicity boards and they should be picked up or dropped as the user needed, like a "scrap computer" (as in scrap paper) (Weiser, 1991) and the real power behind the vision would be the devices interconnectedness.

The technology to support this concept should be, according to Weiser, inexpensive, with low power computers. The software should allow ubiquitous applications and the networks should be capable of connecting them all together (Weiser, 1991).

The main technical challenges and problems identified by Weiser were software and network related. Questions like being able to seamlessly migrate the contents of a Pad into several smaller Tabs that could be re-arranged by the user as a real "desktop" metaphor, or the content and user interface be able to follow the user into another division are still difficult due to several constraints, for example vendor related (Ebling & Baker, 2012). In terms of networks, Weiser identified the need for three different kinds of network connections in the devices: long range wireless (kilometres), tiny range wireless (centimetres) and very high speed wired, due to the need for faster data transfer rates (Weiser, 1991).

UbiComp is not virtual reality

Weiser was adamant in saying that UbiComp was not virtual reality (Weiser, 1993) and that the aims of both concepts were in fact opposite (Weiser, 1991), as we can see in figure 1. UbiComp aims to have the real world full of connected devices, cheap wireless networks, with carefree users, that do not need to carry around devices because they are everywhere, to be accessible by all. UbiComp wants to augment the World.

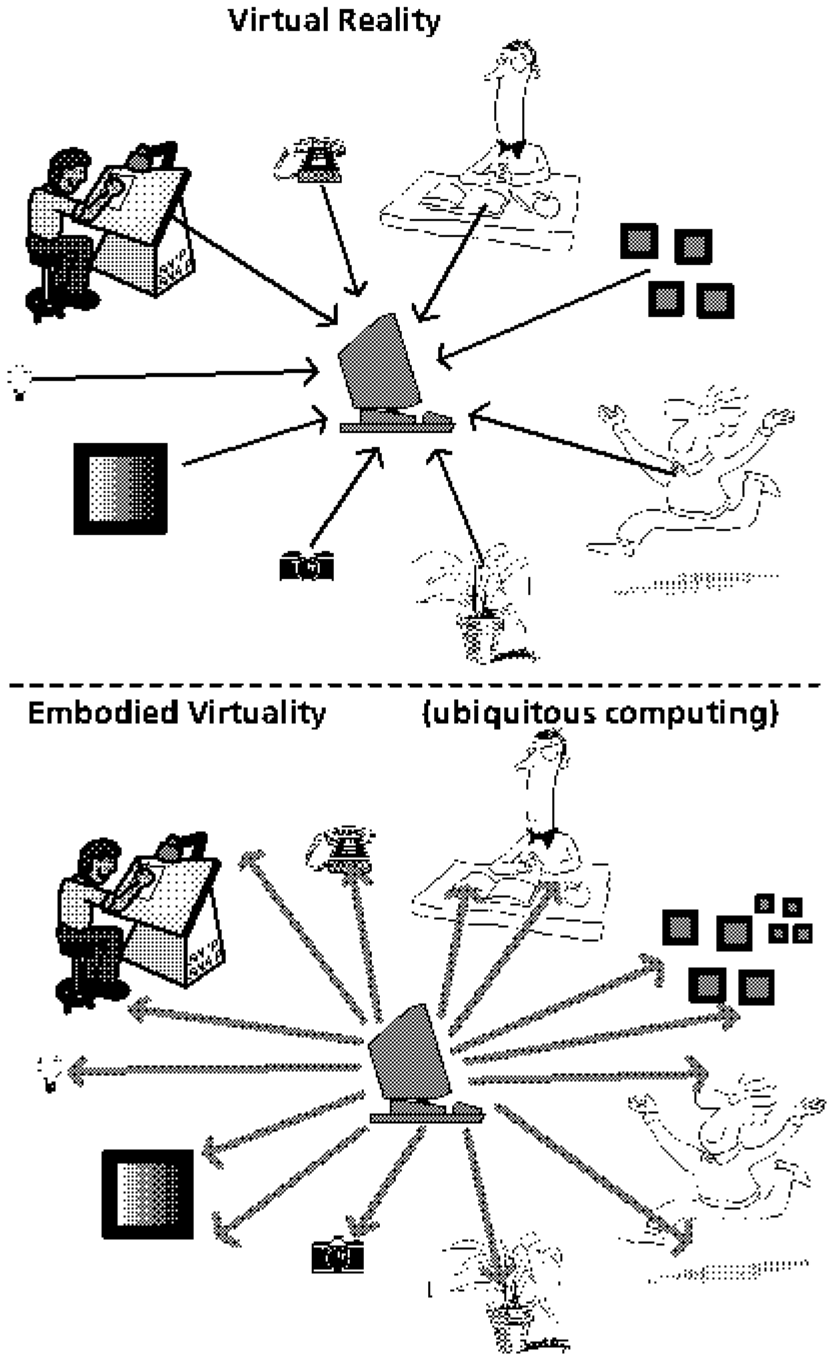


Figure 1 - Virtual reality versus Embodied (ubiquitous) virtuality (Milgram, Takemura, Utsumi, & Kishino, 1994)

Virtual reality, on the other hand, wants to create a virtual world inside the computer and bring into it all the elements of reality, by simulating it. It uses special equipment to allow the user to interact and immerse himself/herself in it. However, that causes more awareness towards the computer. It makes the user even more computer-centric, and, impacts on socialization that becomes mediated by the machine. Weiser argued that UbiComp would remove the unhealthy relationship that computers introduced in society and would eliminate the computer addict (Weiser, 1991).

UbiComp and ethics

Even in 1991, Weiser was aware that privacy would be a concern and a possible pitfall for his vision. The ability to be location-aware and transmit that information across a network, at high-speed, could potentiate a "Big Brother" society with unimaginable reach - "the potential to make totalitarianism up to now seem like sheerest anarchy" (Weiser, 1991).

The information could also be used in an abusive way by employers leading to the surveillance of employees and to the blurring of boundaries between private and professional life (Hilty, 2014). In fact recently (in the beginning of 2017) France approved a law to allow employees to turn off or not respond to digital enquiries/mails from their employers (DN, 2017) facilitated by the widespread use (Richter, 2013) (see figure 2) of the most ubiquitous of all devices (even if it hasn't really faded into the background) and the one that most closely adheres to Weiser idea of a Tab: the smartphone (Ebling & Baker, 2012; Ferreira, Orvalho, & Boavida, 2007).

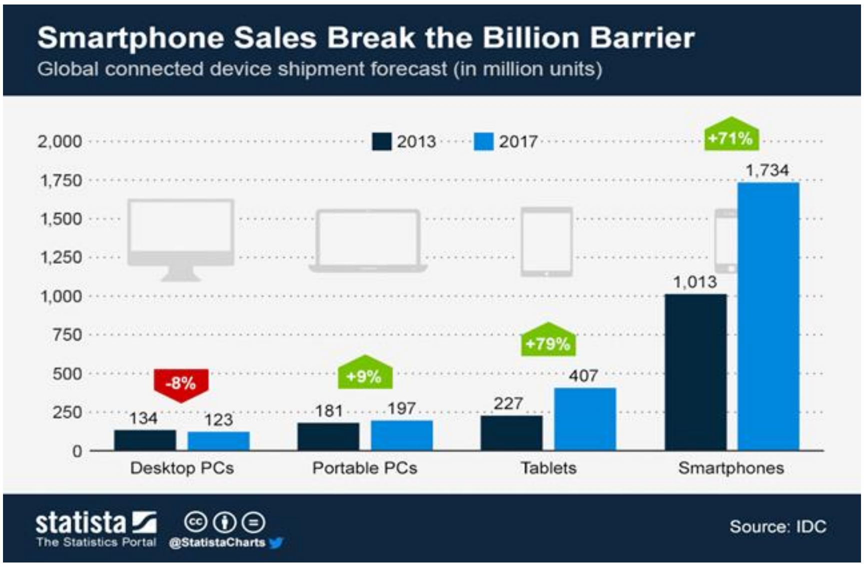


Figure 2 - Smartphone sales in 2013 and expected sales until 2017(Richter, 2013)

Weiser was also aware that the amount of information collected by the UbiComp devices on the users could be used by marketing firms in unpleasant ways (Weiser, 1991). This can be seen today with targeted ads or content and can have implications in terms of user autonomy and self-determination (Hilty, 2014).

UbiComp legacy and or conclusion

Weiser vision of a UbiComp "world" is yet to be fully implemented, with UbiComp devices being disconnected from one another and seldom interoperable (Ebling & Baker, 2012). The missing interconnectedness, key to Weiser vision and the fact that users tend to be possessive of their devices and use them more for social practices than for a productive life undermine key concepts in UbiComp. But Weiser's vision (still valid and followed today) laid the groundwork for other visions that aim incorporating reality and ways of augmenting it, always towards an invisible interface and technology that fades away.

2.1.2. Augmented Reality/Mixed Reality

Augmented Reality is about augmenting people's skills and senses…
in Augmented reality technologies, systems and applications (Carmigniani et al., 2011)

Augmented Reality (AR) can enrich our interaction with the real world by creating an extra layer – a virtual world of graphical images – that instead of replacing reality annotates and complements it with various kinds of information (Feiner, Macintyre, & Seligmann, 1993): digital objects, texts and information (Liberati, 2016), that appear to coexist in the same space as the real, physical world objects (Azuma et al., 2001). AR can be seen as a direct extension of Weiser's UbiComp vision that adds to the Tabs, Pads and Boards small, lightweight see-through devices with world enriching capabilities not restricted to the displays and the handheld interaction envisioned by Weiser (Feiner et al., 1993). AR is also not restricted to vision, it can potentially be applied to all senses and besides adding digital objects to the real world it can also remove real objects from the environment (Azuma et al., 2001).

Milgran, in "Augmented Reality: A class of displays on the reality-virtuality continuum" article, proposes that VR and AR are part, albeit opposites, of a Mixed Reality (MR) continuum as one can see in figure 3 below (Milgram, Takemura, Utsumi, & Kishino, 1994). In it, AR is just one step after the Real Environment and one step closer to a full immersion world where what is real and what is not would be nigh indiscernible – the exact middle point of the chart (Milgram, Takemura, Utsumi, & Kishino, 1994).

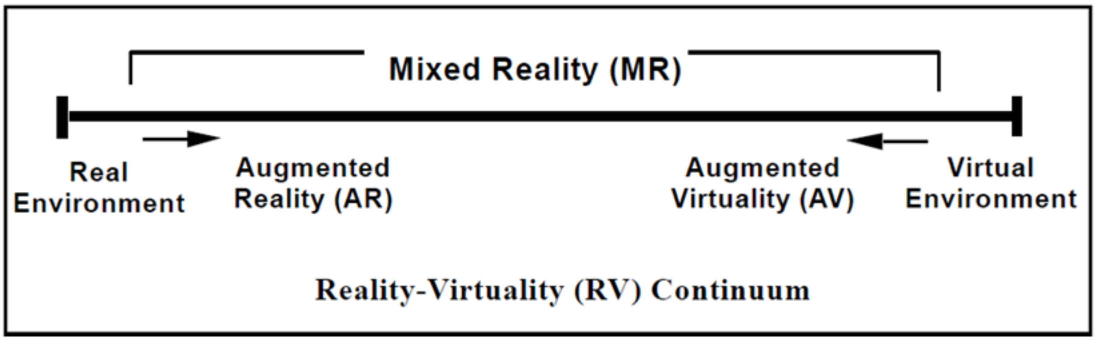


Figure 3 - The reality-virtuality continuum, according to Milgram ("Virtual Reality vs. Ubiquitous Computing, in cartoons.," n.d.)

There are three different AR displays: head-worn (Azuma et al., 2001) or head- mounted (Carmigniani et al., 2011) displays, handheld displays and projection displays (Azuma et al., 2001)/spatial(Carmigniani et al., 2011). The head-mounted displays can be further divided into optical see-through or video see-through, each with its own strengths and weaknesses, requirements and implementations. The handheld displays act as a window and use their camera and array of sensors to correctly produce and place the augmentations in the real world. The displays that rely on projections tend to be fixed into a location and used in teleconference systems (Carmigniani et al., 2011).

Also noteworthy is the research being done into a virtual retina display by MicroVision[2] that could address several issues on use and content privacy (Azuma et al., 2001).

Each allows for different immersion states and different advantages and disadvantages. They all give to the user the computer-generated graphical overlay layer while allowing for a real-world presence (Milgram et al., 1994).

[2] Available at http://www.microvision.com/

Two recent examples of two of the AR displays mentioned above, with varying degrees of success, are the Google Glass[3] project and the Pokémon Go[4] game. The first one is clearly a manifestation of the head-mounted see-through device. The second is a handheld monitor based AR display that uses the ubiquitous smartphone to juxtapose game elements to the reality surrounding us, while using the smartphone sensors to be location-aware, among other things.

Despite the above examples and reports that AR is on the rise and will be, by 2021 a 5.7 billion dollars industry (Anderton, 2016), this is a technology still in its infancy and as such with still fluid definitions and the idea of what AR really is (Liberati, 2016).

UbiComp and AR are seemingly the same since their goal is to enrich user's life through the merging of digital information with the real world. They both try to escape the virtuality of a simulated world and aim to bring computational power to the real world and environment. This poses difficulties in terms of defining exactly the focus of these technologies (Liberati, 2016).

In UbiComp, the computer is ubiquitous being perceived by the users as transparent, while still lending its computational power to the betterment of the user's life by displaying information and adapting to the user's actions (Liberati, 2016) and location. AR goal, on the other hand, is to enhance the user skills through a device (Liberati, 2016) without replacing them (Carmigniani et al., 2011).

However, simply displaying information about a real object is not enough to be considered a pure AR device. UbiComp goal is also to present information, through a device. The act of creating a new digital object is also debatable if the only objective is to use it as a form of label (Liberati, 2016) of something that exists in the real world.

AR should introduce new digital objects into our world, shaping and enhancing it with a different kind of digital materiality (Liberati, 2016). The digital object is autonomous, it does

[3] Available at https://www.google.com/glass/start/ and more information on https://www.technologyreview.com/s/532691/google-glass-is-dead-long-live-smart-glasses/

[4] Available at http://www.pokemongo.com/

not exist because or around the "real" object in the world simply to provide information about it (Liberati, 2016). It has a gravitas of its own.

AR is interactive and happens in real time, even if mediated through video and it registers (aligns) real and virtual elements with each other (Azuma et al., 2001).

One key aspect to AR is how the user can interact with it. There are tangible interfaces, collaborative interfaces, hybrid interfaces and multimodal interfaces. The AR interface needs to address social acceptance, by being subtle, discrete and unobtrusive (Carmigniani et al., 2011); it should allow natural interaction through the use of natural hand gestures so it would not be awkward to use in public and it needs to be fashionable (Carmigniani et al., 2011).

AR conclusions

Independently of the device used, the infusing of digital autonomous objects, throughout the real world augments the user's experiences and interactions, while possessing unique affordances and unexpected interaction outcomes or overheads (Dunleavy, Dede, & Mitchell, 2009; Raj, Karlin, & Backstrom, 2016).

AR actual and potential uses range from medical visualization to the gaming industry. It allows to maintain or repair complex equipment however problems such as registration errors, system lag (Azuma et al., 2001) or, more prosaically, social acceptance over fashion issues (Carmigniani et al., 2011) need to be fully understood and solved beforehand, if AR is to become part of everyday life.

AR has greater fidelity to the real world environments than VR, at least for now. But as technology evolves AR will get closer to the centre of Milgram's Reality-Virtuality Continuum and this will fade into a seamless real-virtual world. AR allows multi-dimension contact between its user's and promotes engaging sensory experiences (Dunleavy et al., 2009) that mix the physical sense of touch coupled with visual and auditory generated contexts.

From this augmenting of reality and transparency achieved through symbiosis between subject and device (Liberati, 2016) this dissertation will move into the use of a minimal interface. This interface is so natural to the user since it is based on understood physical objects (Hiroshi Ishii, 2004), inherently simple, that "fits the task so well that learning the task is to learn the appliance" (Norman, 1998, p.86).

2.1.3. Tangible User Interfaces (TUI)

Graphical User Interfaces fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the real world.
In (Hiroshi Ishii & Ullmer, 1997)

Form (ever) follows function
by Louis Sullivan

In 1997 Hiroshi Ishii and Brygg Ulmer presented a paper titled "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms". In it, they argued that to fully achieve Weiser's UbiComp goal of transparency and invisible computing, the interaction had to move away from GUIs and establish a new Human-Computer Interaction paradigm, the TUI (Hiroshi Ishii & Ullmer, 1997). As figure 4 illustrates, TUI would move away from the typical and generic combination of screen, mouse and keyboard interaction and would transform the world itself into an interface (Ishii & Ullmer, 1997). This would be achieved through augmentation of real-world objects and environments with digital information (Ishii & Ullmer, 1997).

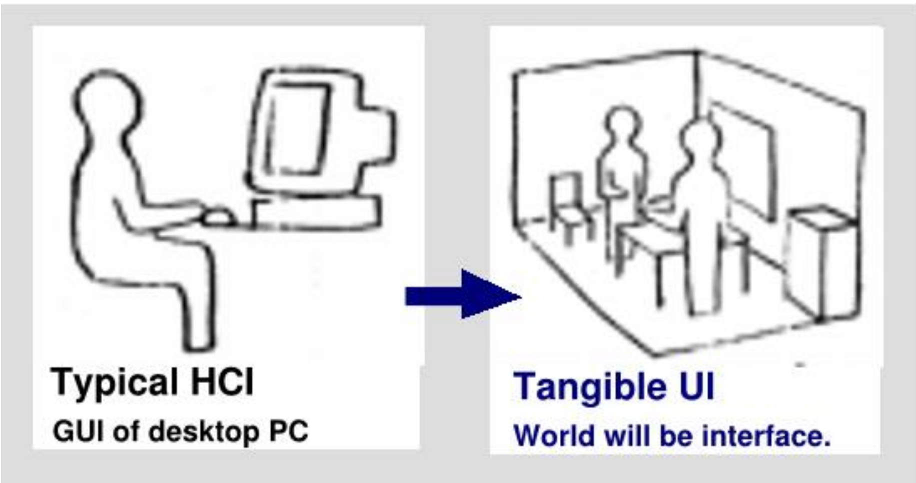


Figure 4 - How interaction is with GUI and how it could be with TUI (Ishii & Ullmer, 1997)

TUI conceptual model

Tangible Interfaces can be defined as those that support the user direct interaction with the digital world or digital device by use of real-world objects or tools (Azuma et al., 2001). They use physical forms designed and improved over the millennia to fit the specific task (H. Ishii, 2008) thus facilitating the user legibility and direct manipulation of the interface through the user's peripheral senses (e.g. touch or vision) due to its physical embodiment (H. Ishii, 2008; Hiroshi Ishii, 2008; Hiroshi Ishii & Ullmer, 1997).

As TUI employs the user’s experience of interaction with real objects to use with its digital representations, this alleviates the keyboard bottleneck (Stanton et al., 2001), and the user can focus its attention and consciousness on the task at hand and not on the interface (Hiroshi Ishii, 2004). In figure 5 below this method can be seen in a comparison of a TUI and a GUI for a desktop metaphor. This was used in the metaDESK project (Ishii & Ullmer, 1997).

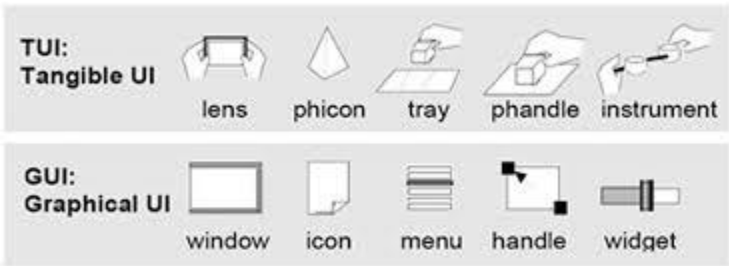


Figure 5 - metaDESK Tangible UI versus classic GUI (Hiroshi Ishii & Ullmer, 1997)

TUI started by using certain objects or shapes with which the user would interact and that had an actual perceived meaning, for example, a clock object would serve to control time – and time dictates sun position, like in the Urban Planning Workbench project (Underkoffler & Ishii, 1999). This can be understood as a rigid discrete interface (H. Ishii, 2008). However, one shortcoming of this approach is the specificity of objects and projects, making this interaction “tailor-made”. This greatly contrasts with the generic mouse and keyboard controllers (H. Ishii, 2008) that simply “work” for all kinds of different projects. The generic manipulation costs are a certain learning curve and a gap in immediate understanding of what is the manipulation of an object and the manipulation of a graphical representation of it (Hiroshi Ishii, 2004). When creating a TUI all physical objects have to be pre-determined and there are a finite set of objects and possible interactions (H. Ishii, 2008).

This limitation originated the next evolutionary step, a more "organic" and material malleable TUI (H. Ishii, 2008). This approach takes advantage of new digital and physical materials that can seamlessly pair sensing and displaying capabilities (H. Ishii, 2008). The use of continuous tangible materials like clay or sand allows for quick sculpting and display and together with emerging new materials that integrate fully flexible sensors and displays, TUI shows great potential to break the boundaries of pre-determined interactions (H. Ishii, 2008).

However, there are claims that this definition of TUI and its evolution is very limited (Hornecker & Buur, 2006). They argue that more than classic computer science TUI definition it should be discussed a broader space and interdisciplinary field within what they call Tangible Interaction (Hornecker & Buur, 2006). This broader field encompasses embodied interaction, tangible manipulation, a physical representation of data and embeddedness in real space and it can be approached from a Human-computer Interaction (HCI) perspective,computer science, product design and interactive arts point of view (Hornecker & Buur, 2006). This approach gives rise to a framework of Tangible Interaction, as shown in figure 6.

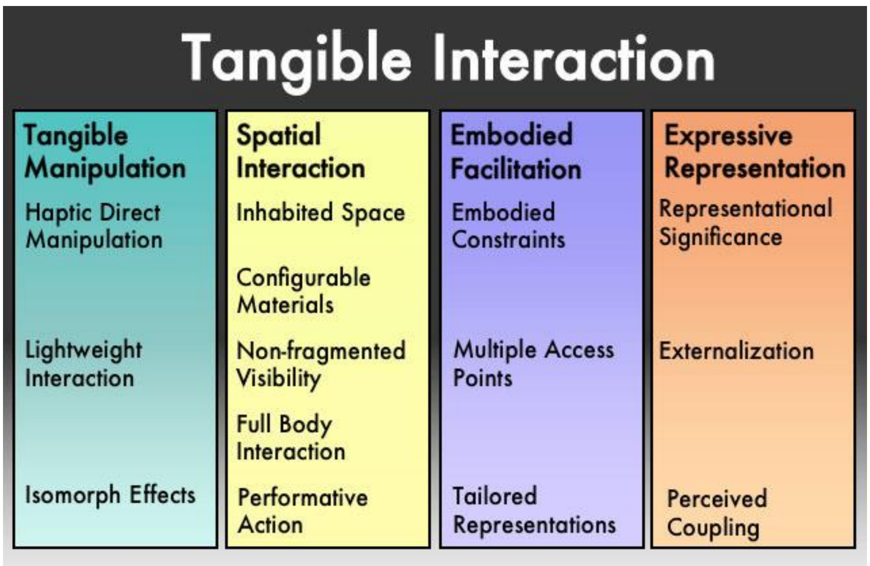


Figure 6 - Tangible Interaction framework (Hornecker, n.d.)

In this framework, the Tangible Manipulation refers to the use of material objects with distinct tactile (haptic) qualities. It is best applied to systems usually named TUI and tangible appliances (Hornecker & Buur, 2006). Spatial Interaction and Embodied Facilitation are related to the movement in space and the physical configuration of the computing resources are key to them. They affect and direct emergent group behaviour. Since tangible interaction is embedded in real space, interaction stems from a movement in space and the body itself is an input device (Hornecker & Buur, 2006). The Expressive Representation focus is on the material and digital representations used by Tangible Interaction systems, how they are understood (legibility) and how well they represent reality (expressiveness) (Hornecker & Buur, 2006).

Other authors (Alissa Antle, 2007; Hengeveld, Hummels, et al., 2008; Hengeveld, 2011; Hayes Raffle, Vaucelle, Wang, & Ishii, 2007b; Spermon, Schouten, & Hoven, 2014; Suárez, Marco, Baldassarri, & Cerezo, 2011; Xie, Antle, & Motamedi, 2008; Xu, Read, & Mazzone, 2007; Zaman & Abeele, 2007; Zaman, Abeele, Markopoulos, & Marshall, 2009) give relevance to the role of TUI involving children and the benefits they can offer, related to the ease of use while supporting learning and development processes (Almukadi & Stephane, 2017; Zaman et al., 2009). Young children (and even more if they have some form of disability) do not grasp menu structures, layered interfaces or icons. This is especially true when learning a language due to its increasing symbolisation (the word dog has the same meaning/relation to an image or drawing or actual dog). Children natural interaction style is exploratory and multi-sensory (Hengeveld, Hummels, et al., 2008). Furthermore, TUI require less interpretation, allow for a more flexible interaction and collaborative use, permit sensory experiences and are persistent (even powered off a clock is still a clock and allows interpretations while a mouse, despite being physical, when off holds little representation) (Hengeveld, Hummels, et al., 2008; Hiroshi Ishii, 2008).

Some authors suggest that TUI should be reactive, in order to solve inconsistencies and provide additional feedback (Pangaro, Maynes-Aminzade, & Ishii, 2003; Poupyrev, Nashida, & Okabe, 2007) or in order to be easier to use by children with disabilities (Hengeveld, Hummels, et al., 2008).

For that TUI should use actuators, electromagnets, microprocessors, smart materials and others to help children achieve a goal while being able to reduce or completely turn off this behaviour as the child progresses or is used by children without disabilities (Hengeveld et al., 2008). This actuated TUI would overcome the static and rigid nature of a physical object and give to it the malleability of a digital object: easy to create, change in shape, colour, position or speed (Poupyrev et al., 2007). This allows for an interface that communicates to the user changes in the system by re-arranging the user interface or even adjust the display to reflect changing information or user interaction (Pangaro et al., 2003; Poupyrev et al., 2007).

TUI is not AR or UbiComp

Despite being stimulated by the UbiComp concept TUI does not assume itself as being UbiComp due to a different vision in how to make technology invisible. TUI is interested in looking into the richly-afforded physical devices created by Human technological evolution from the last millennia prior to the computer era (Hiroshi Ishii & Ullmer, 1997) and borrow from them the interaction they afford, constrain and convene and make them into a or part of a TUI.

The challenge is in being able to map a physical object and its manipulation to digital computation and feedback in a meaningful way, maintaining its physical affordances and bringing them into the digital realm (Hiroshi Ishii, 2008).

TUI diverges from AR because unlike it, TUI places a strong emphasis on graspable physical objects as input and in a combination of ambient media and said objects, rather than relying on pure visual augmentations (Hiroshi Ishii & Ullmer, 1997).

TUI conclusions

TUI is a natural next step or should be said a return to the roots of Human (natural) Interaction, away from the static screens that permeate our lives, be it in a desk, in one's hand or embed in our everyday environment (Ullmer & Ishii, 2001). TUI assumes itself as an extension of Weiser's vision of UbiComp and one that can really implement the idea of transparent technology, so well learned that it fades into the background.

2.1.4. Internet of Things (IoT)

If we had computers that knew everything there is to know about things – using data they gathered without any help from us – we would be able to track and count everything, and greatly reduce waste, loss and cost.
Kevin Ashton in RFID Journal (22 June 2009)

In Weiser's UbiComp concept the interconnectedness and interoperability between devices were key to bring to fruition his vision. However, those concepts are far from solved and it is IoT that aims to solve that (Ebling & Baker, 2012).

The term Internet of Things was first coined by Kevin Ashton in 1999 regarding a specific context: supply chain management with items with tags (things) that would allow for a more efficient, less costly and less wasteful business (Caceres & Friday, 2012; Gubbi, Buyya, Marusic, & Palaniswami, 2013). Since than the definition evolved to cover more areas and today IoT can be understood as the possibility of sensing and actuating objects to communicate between themselves (machine to machine, also known as M2M), utilizing secure network connections and cloud services (unified framework) to transform the information that they obtain from that communication into useful information for people and enterprises to use (Gubbi et al., 2013; Verizon, 2015).

To be able to achieve a seamless UbiComp vision, IoT needs three main components (Gubbi et al., 2013):

1 – Hardware: the sensors, actuators and embedded communication hardware;

2 – Middleware: on-demand storage and computing tools for data analytics;

3 – Presentation: new tools to visually present and design data in order for it to be visualized, understood and accessed on different platforms and different applications.

IoT main goal is to make a computer sense information without human intervention and is on the brink of evolving Internet from static into a fully integrated and pervasive Future Internet (Gubbi et al., 2013).

Broadly speaking IoT is gaining momentum, with business, governments and academia investing in it (Gubbi et al., 2013; Verizon, 2015). Due to government policies, industry practices and even homemade "hacks" the world we live in is becoming electronic populated: more and more sensors gather data, control appliances and even send emails to the owners or engineering support (Caceres & Friday, 2012). This can be used to IoT advantage as long as the infrastructures are open to being used and the necessary coupling or interconnectedness by the things with the embedded infrastructures and between themselves is made possible (Caceres & Friday, 2012). The drop in hardware and cloud space costs (with the price per GB lowering) is also an important factor in making IoT accessible to the general public or small business (Verizon, 2015).

What are "Things"?

The Things in IoT are smart objects. For a device to be a Thing/smart object, it needs to: Physically exist and possess physical features, such as size, weight and so on; It needs to be able to communicate, even if in a basic level: it needs to be discoverable and needs to accept and respond to incoming messages; It needs to have a unique identifier; It needs one name (human readable) and an address (machine readable); It needs (at least) basic computing capabilities; it needs to be able to sense physical phenomena or actuate (causing effects) on the physical world (Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012).

The characteristics of the Things presented above support the three main pillars in IoT: anything identifies itself; anything communicates; anything interacts (Miorandi et al., 2012).

IoT in the near future: needs and challenges

Internet transformed the world into a small village, where everyone knows everyone and all are connected. The next similar event has already started, with smart environments thanks to 9 billion interconnected devices (Gubbi et al., 2013)– 24 billion plus expected by 2020 (SBI, 2016). With this growth, it is possible to predict that within a decade, the Internet will be a seamless union of classic networks and networked devices (Miorandi et al., 2012). In figure. 7 the technologies that are already contributing to that scenario and the expected key developments and applications to bring IoT into its full potential are laid out. IoT also has some specific challenges to solve, such as privacy, participatory sensing, data analytics, geographic information services based visualization and Cloud Computing besides the more standard Wireless Sensors Networks challenges: architecture, energy efficiency, security protocols and Quality of service (Gubbi et al., 2013).

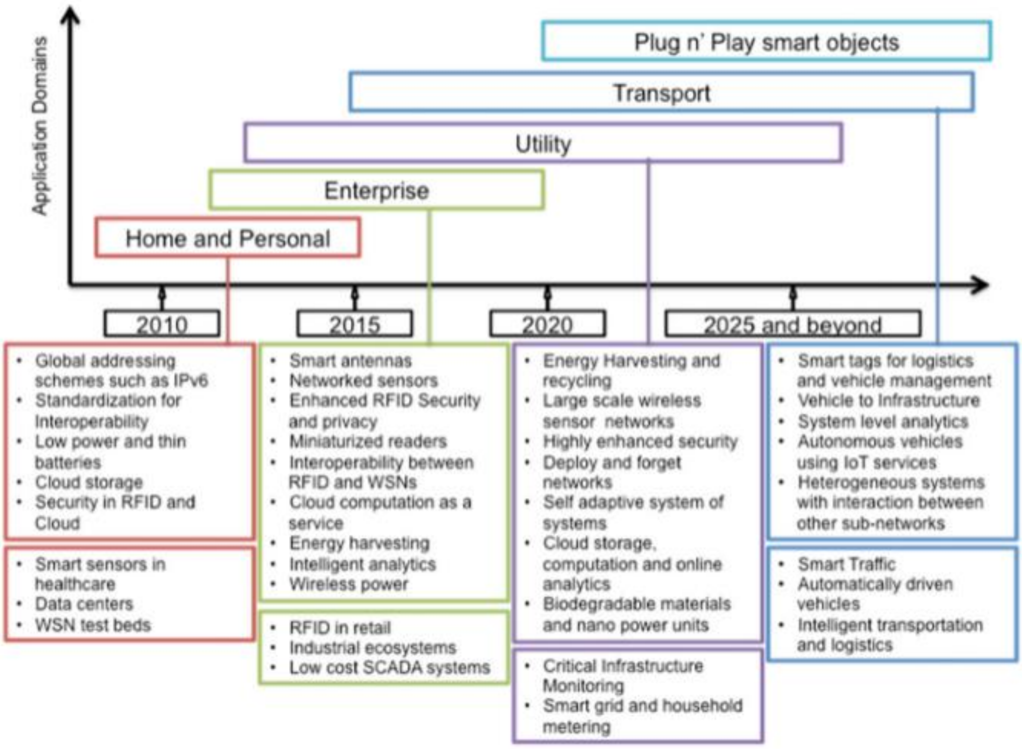


Figure 7 - IoT key technological developments roadmap (Gubbi et al., 2013)

Another challenge faced by IoT is its fragmented research community, most of the times focused around a single application domain (i.e. transportation or Health, for example) or a single technology (Radio Frequency Identifier (RFID) being one example) (Miorandi et al., 2012). While the fragmented research can be understood due to the fact that different countries, institutions or industries have different goals, the single application domain mindset is obtuse.

IoT objects will need to be able to support a wide range of very different devices with different capabilities and accommodate for all of them by being scalable, energy efficient, with self-organizing capabilities and able to analyse massive amounts of data, all the while with embedded security and privacy-preserving mechanisms (Miorandi et al., 2012).

IoT and ethics

IoT faces similar ethical issues when compared to UbiComp. The amount and type of data gathered from users raise alerts to the potential loss of privacy, user autonomy and self-determination (Hilty, 2014). Not all data gathered should be open due to the potential it has for cyberterrorism and abusive surveillance (Caceres & Friday, 2012).

Security is a cornerstone that can hinder IoT adoption commercially and give rise to ethical questions. How confidential is the data gathered and who has access (and how) to it? How private is the data? And if it is a domain such as health, can the patient access its own data? Or, by denying access to it, are the medical staff incurring in a case of technology paternalism in a classic dependency relationship (Hilty, 2014)?

IoT conclusions

A fully functional IoT will represent a kick-off for innovative services that will improve the user's experience and quality of life, due to the responsive nature and ability to anticipate user needs according to the situation and or location the user is in (Miorandi et al., 2012). It will also be a truly UbiComp world, with computing and information flowing (and available) anywhere.

However, there are several interdisciplinary challenges and infrastructure needs, as well as security and ethical issues to solve before being able to deploy a network of things.

2.2. Tangible artefacts in education and health

Despite the copious amounts of educational applications available in mobile applications stores, physically manipulating an object requires a different set of skills (Barredo & Garaizar, 2015). A physical, tangible artefact, enables or rather facilitates self-learning, requires autonomy while stimulating social interactions (i.e. working in groups) (Almukadi & Boy, 2016; Xie et al., 2008) while providing the necessary enjoyment and engagement (Xie et al., 2008), important in learning.

Tangible artefacts used in interactive games for a therapeutic context is nothing new, especially in fields of physical therapy or post-stroke recovery (Li, Fontijn, & Markopoulos, 2008; Vonach, Ternek, Gerstweiler, & Kaufmann, 2016). They also allow assessing several physiological parameters, without any stress associated with a visit to a doctor's office, relieving an anxiety felt by many children and some adults alike (Vonach et al., 2016).

In education both the needs of the teachers as well as the needs and curricula of the students have to be fully understood and satisfied (Bruckman, Bandlow, & Forte, 2007). And serious games and tangible interaction for learning and problem-solving satisfy both teachers and children alike (Almukadi & Boy, 2016). Children like to play and through a playful approach, learning is facilitated (Almukadi & Boy, 2016). Tangible artefacts by nature invite collaboration, allowing several users to interact with the artefact and themselves (Almukadi & Boy, 2016), thus increasing productivity levels (Fails et al., 2005).

In both cases, the artefacts should be cheap and robust to allow to be handled without care (Barredo & Garaizar, 2015). It is important to know that it is not enough to produce an object with an array of sensors in a seemingly playful way. The way in which the user interacts has to be driven through affordances, mappings and game logic to ensure reliability and to take full advantage of the potential of the artefact (A. Antle, 2007; Vonach et al., 2016).

2.3. Designing Interaction for and with children

Designing for interaction is all about how to design for people, their needs, emotions and intellect (Verplank, 2009). This makes it imperative to be extremely aware of what to expect from those who will interact with the final interactive product (Verplank, 2009).

When designing for children, children are presumed to be creative, intelligent and, if given the correct tools, capable of anything (Bruckman et al., 2007). With the shift towards participatory and ethnographic methods, those designing interactive applications or objects have to try and fully understand the how's and why's of people using the new creations (Bruckman et al., 2007; Verplank, 2009). However, when designing for children, one cannot expect to "know" or "remember" what a child wants or likes. As people grow and age both physical and cognitive abilities – motor skills, the speed of processing, amount of data processed - increase over time (Kail, 1991; Miller & Vernon, 1997; Thomas, 1980).

Only interactive experiences that include pertinent aspects of easy control and social experiences can be meaningful and playful for children (Marco, Cerezo, & Baldassarri, 2009). The children (ages 3 to 6 or seven) intended as a target for the artefact created alongside this dissertation are still –mostly – preliterate, with short attention spans, difficulty with abstractions and their fine motor skills are not yet fully developed (Bruckman et al., 2007; Thomas, 1980). Nonetheless, designing too childish can be perceived as boring or rude (Bruckman et al., 2007), since children are acutely aware of their capabilities (Nielsen, 2006, 2010).

A workaround is to embrace designing with children, as co-designers or evaluators/subjects, or a mixture of these (Bruckman et al., 2007). This has its own possible pitfalls and both adults and children need to learn to work together, but in the end assures that the design is made according to the needs and specificities of children (Bruckman et al., 2007).

2.4. Summary

In this chapter the interaction paradigms considered as more relevant to this dissertation - Ubiquitous Computing/Pervasive Computing, Augmented Reality/Mixed Reality, Tangible User Interfaces and Internet of Things - were summarised and discussed. The role that tangible artefacts can play in education and health was evaluated. The concept of Interaction and more importantly how it differs from adults to children was addressed.

3. Seamlessly combining TUI and Interaction for children

The choice between digital, physical or a TUI development of a solution to SSD can only be taken after reasoning how useful, what advantages and how can it improve learning/practice. In this chapter *How children learn, The Sense of community and its influence in learning, Points, Levels, Badges and Leaderboards* and *Towards Tangible Interaction* will be discussed. The evolution of the understanding of how children learn, the role that a playful approach can take and how the social interactions/sense of community influences learning and speaking, is appraised. The gamification approach, with point systems, levels, badges and leaderboards is explored.

3.1. How children learn

"Kids cognition is changing – Education will have to change with it."
Elon University and the Pew Internet and American Life Project

Historically children were seen as a *tabula rasa*, a blank slate in which knowledge could be imprinted (Madej, 2016). One of the most relevant contributions to the field of children's behavioural psychology was made by Jean Piaget – father of Constructivism. He employed observation techniques and interviews to study children, concluding that younger children respond differently from older children:

- » Children search for physical stimulation that in turn encourages their physical and cognitive development,
- » Children are naturally motivated to explore what is around them,
- » Children engage with their environment – and through the dynamics of play, they reinforce their learning.

3.1.1. Social and cultural contexts in learning – The sense of community and how it can influence learning

Jerome Bruner, a former student under Piaget and Vygotsky, a key figure in the evolution of theory about children's development, took Piaget's views further and added the cultural and social contexts to how children construct the world and their knowledge – social constructivism (Madej, 2016). Social constructivism argued that cognitive development emerges through practice in a social environment (Almukadi & Stephane, 2017). According to Vygotsky, culture frames how children interact with the world. Social experience is a critical factor in mental development – interpersonal connections and social interaction provide the means to a child access experience that they can then integrate into their view of how things work (Madej, 2016).

3.1.2. Role of Play in development

Vygotsky further delves into the importance of Play and adds that it helps a child to separate the meaning of an object from the actual object. For KTAs Vygotsky emphasises that play, from a child point-of-view, is not just a game, it is a serious thing, that they consider as work (Madej, 2016). One fundamental observation from Bruner regarding play was how children employed scenarios or stories to construct and experience the world (Madej, 2016).

3.2. Gamification approach

It is common practice for an SLT to use children's games (among other specialized tools) while intervening with a child, by modifying the game to fit its needs. It is also quite common to create cards with images that correspond to sounds and make a story tell or a game of it (Bowen, 2015). This is a gamified approach.

Gamification can be defined as making use of elements typically found in a game in a non-gaming context (Deterding & Dixon, 2011). As such the use of game elements and their perceived aptitude to motivate and engage users for long periods of time has been seen as capable of making other, non-game products, gratifying (Flatla, Gutwin, Nacke, Bateman, & Mandryk, 2011; Zichermann & Cunningham, 2011).

3.2.1. Points, Levels, Badges and Leaderboards

Typical game elements with an extensive use in gamification and with interest to the physical/digital counterpart of this dissertation are the use of points (and point systems), the existence of levels, attribution of (digital) badges and the use of leaderboards.

According to Zichermann and Cunningham in *Gamification by Design*, points are a vital element and should always be present at any gamified activity, if not in a visible way, at least visible to the activity designer only, so he/she can assess how the users interact with the activity and design the appropriate outcomes (Zichermann & Cunningham, 2011). When visible, points allow the user to know how close he/she is of their goal, and this can be highly motivational (Zichermann & Cunningham, 2011).

Levels, as the name implies, mark something, in this case, in-game progress and allow the player to take stock of where they are, over time, in relation to the game experience. They should be logic, in terms of level progression and easy to add to (Zichermann & Cunningham, 2011).

Badges appeal differently, as a symbol of status, a source for a collecting drive or the surprise and pleasure of being awarded a badge. For activity designers', badges serve as progress markers/achievement of goals and can be used in social promotion campaigns (Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015; Zichermann & Cunningham, 2011). In education, badges can be used as a motivational factor, a symbol of recognition, as credentials as opposed to exam marks and as evidence of having achieved a certain goal/expertise (Gibson et al., 2015).

However, despite their perceived value and importance (Gibson et al., 2015; Hamari, 2015; Zichermann & Cunningham, 2011), badges are not without critics, especially if considered as badly designed and pointless (Bogost, 2011; Zichermann & Cunningham, 2011).

Leaderboards can be seen as a simple list of names and ranks, that allows users to make simple comparisons. However, if a person is at a low rank, a classic leaderboard as explained above can be a disincentive so different approaches to rank listing are encouraged

(Zichermann & Cunningham, 2011). Two possible approaches are (Zichermann & Cunningham, 2011):

- » the non-disincentive leaderboard, that places the user always in the middle of the list, showing those below him/her and how close he/she is the next one above;
- » the infinite leaderboard from which a user never falls over/is replaced. To avoid having millions of names on-screen at the same time strategies like showing just the user's friends, or a regional view or a national view can be used.

3.3. Towards Tangible Interaction

From this, guidelines can be extracted to produce a TUI that can be effective in helping a child surpass its SSDs. It should allow some degree of simulation/storytelling, allowing the construction of mental models of knowledge. It should provide some form of social interaction with the artefact and the other players, all in a playful atmosphere (Almukadi & Stephane, 2017). TUI can provide natural interaction without emphasising any cognitive effort – a child does not need to learn or understand a set of rules or settings. The perceived focus is on the action executed and what it can represent. TUI can also have different feedbacks and interactions, being able to cope with different learner styles and levels (Almukadi & Stephane, 2017).

3.4. Summary

In this chapter the evolution of the understanding of how children learn, the role that a playful approach can take and how the social interactions/sense of community influences learning and speaking was appraised. The gamification approach, with point systems, levels, badges and leaderboards was addressed.

In the next chapter examples of what are considered best practices/best examples for this dissertation will be presented.

4. Technological mediated best practices

4.1. Selection criteria

The state of the art of SSDs, UbiComp, AR, TUI, IoT and Interaction that shares similar focus to this dissertation on TUI has several interesting and relevant literature.

However, for this dissertation, the following examples were chosen and considered to be best practices or success cases. Despite the fact that none is an exact fit in terms of technological requirements, target population or intervention area, they all have lessons to be heeded.

The first case is the *Table to Tablet (T2T) therapy software*, designed to be a full and comprehensive intervention program, a reliable and valid solution (Jesus, Santos, Martinez, Lousada, & Pape, 2015), to be used with children with SSD. It has a physical and a digital version. The SLT can use them interchangeably, but one doesn't communicate with the other. As a disclaimer, this Dissertation author has been an active participant in this project, being the software developer. While this may skew his opinion, it also brings a more detailed knowledge about the project, the SLTs and children's needs, results and reactions to it.

The second case is the *LinguaBytes* project, from the Netherlands. This project was the result of Bart Hengeveld PhD Thesis and consists of a full set of exercises and different activities that are mediated and occur thanks to tangible artefacts. The aim of LinguaBytes was to be a tangible language learning system for non-or hardly speaking toddlers, that could suffer from some form of motor disability (Hengeveld, 2011).

The third case is the *Jabberstamp*, developed by a team at the MIT Media Lab – Tangible Media Group that counted, among others, with Hiroshi Ishii. The Jabberstamp is a tool that allows children to add sound to their drawings, collages or paintings, enabling them to communicate more effectively prior to developing or mastering writing skills (Hayes Raffle et al., 2007b).

4.2. Portugal – T2T

The T2T therapy software was a project (PGIS ID73 P-136171, Portugal, 2014-2017) that started in October 2014. It was funded by the Fundação Calouste Gulbenkian under the Gulbenkian initiative "Innovation in Health".

It was based at the Institute of Electronics and Informatics Engineering of Aveiro, in the Campus Universitário de Santiago, at the University of Aveiro. The clinical part took place at School of Health Sciences, University of Aveiro (ESSUA) and in several kindergartens and schools of Aveiro (L. Jesus, Martinez, Valente, & Costa, 2017).

Table to Tablet main goal was to design, produce and scientifically validate a complete intervention programme in SSD with physical (tabletop) and digital (tablet) materials, for SLTs. In doing such the effectiveness of two intervention methods (tablet and traditional tabletop) using intervention approaches that have been shown previously to be effective could be explored (Jesus, Martinez, Santos, & Joffe, 2016). In figure 8 below an example of an activity in both versions can be seen.

Figure 8 - An example of an Hearing and Discriminating activity: on the left the digital and on the right the physical counterpart (T2T, 2017)

4.2.1. *Table to Tablet* development

The final version has 19 activities and is able to intervene in 19 phonological processes. *Table to Tablet* was validated as a 12 weeks' intervention programme (45 minutes each session) and both materials (physical and digital) can be interchangeable. Most of the activities have two levels of difficulty. It was designed using a Design Based Research (DBR) approach, with a multidisciplinary team and in constant contact with the end users: SLTs and children with SSD. During the design an earlier, a physical version was tested with a group of 7 children to gather feedback on the activities. This approach was similar to the one followed by (Hengeveld, Hummels, van Balkom, Voort, & de Moor, 2013; Hengeveld, 2011; Hayes Raffle et al., 2007b). Studies that include children's point-of-view are rare, and those that exist rely on their ability to verbally express opinions. This is a particular challenge for children with SSD, due to their difficulty to understand and express themselves (Bowen, 2015; Read, 2008).

We therefore collected their opinions the team used direct, non-participant observation and a "Smileyometer" (Likert scale with smiles) questionnaire (Read, 2008; Zaman & Abeele, 2007). In figure 9 below one of the Smileyometers used is presented.

Figure 9 - "Smileyometer" scale used to assess T2T during design and development phases

In the final version, T2T was comprised of 350 illustrations done by the T2T team illustrator and over 950 sounds for the digital version.

4.2.2. *Table to Tablet* results

The results obtained through a variety of tests show that the effectiveness of the tablet intervention methodology is comparable to the tabletop one. *Table to Tablet* adds evidence for the effectiveness of tablet-based interventions for children with SSD (Jesus, Martinez, et al., 2016).

A high level of satisfaction across the activities with children liking the activities and finding them fun was achieved. In terms of replay value, the results were also very positive (Jesus, Martinez, Santos, & Joffe, 2016).

Although a physical project with a digital counterpart, without any kind of interaction between them, this project, for the results it achieved, the end users it serves and the problems it addresses are to be examined and some parts replicated. With the DBR approach, the testing is done in a moment prior to fully allocating resources. This and the close proximity with the intended users are lessons to heed and follow.

4.3. Netherlands – LinguaBytes

LinguaBytes was developed during the PhD Thesis of Bart Hengeveld. It is a research prototype of a TUI, aimed at children to stimulate language learning of non-or hardly non speaking toddlers between 1 and 4 years old (Hengeveld et al., 2013; Hengeveld, 2011). A Research Through Design approach was used with five incremental prototypes being designed, built and tested in real-life settings (Hengeveld et al., 2013).

LinguaBytes identified and aimed at following several guidelines, such as (Hengeveld et al., 2013):

- Playfulness: Because young children learn mostly through play and play allows mistakes and re-tries;
- Social Interaction: Children work and play in groups. Interpersonal interaction should be stimulated;
- Tangibility: Young children explore the world by playing with it, so interaction should be tangible;
- Challenge: In order to have motivation interactions must be appealing, rewarding, engaging and fun;
- Adaptivity: Being able to adapt and optimize learning settings for each individual within a group;
- Technology: To be able to support adaptivity and the required learning behaviours, advanced technology not usually found on off-the-shelf materials must be used;
- Design: The products designed must be appealing to both challenged and able-bodied children, by being non-stigmatizing.

In figure 10 the TUI that resulted from these guidelines and Research Through Design approach can be observed.

Figure 10 - LinguaBytes' interface consists of output and input modules (top left). Input modules are especially designed for language exercises (top right) or interactive story reading (middle right) through the use of RFID tags. (B. Hengeveld, n.d.)

Despite the scarcity of empirical evidence on TUI benefits over existing technologies (Zaman et al., 2009) specially for children within this age group range, LinguaBytes author was confident that this TUI would increase the time available for children to learn and would enhance the children's participation (Hengeveld et al., 2013).

This would happen due to the fact that LinguaBytes was designed in a way that from the first moment when the materials are being placed in the work area, speech and movement are being stimulated. The time-consuming operations of menu/game configuration are done in an invisible way to the user. For them, they are only choosing what game to play or background to use but the system, through RFID tags and other means is assuming their choices and setting up the game and interaction. This also promotes social interaction and communication.

LinguaBytes was designed as a modular system with five different modules for input, output and control, plus several tangible input materials that allow the creation of 16 stories and 220 games and exercises and it took great care in being ergonomically accurate to the public it addressed (Hengeveld, Voort, et al., 2008; Hengeveld et al., 2013).

4.3.1. LinguaBytes results

The therapists that used LinguaBytes were very favourable to it and considered that it maintained children's attention better than traditional materials while allowing them more control and opportunities for initiative taking (Hengeveld et al., 2013). LinguaBytes was considered suitable for any children aged 1 to 4 years old except for those with very severe motor disabilities and there was a perceived positive effect on children perceptual-motor development due to the frequent manipulation of materials and the motor activity LinguaBytes stimulates (Hengeveld et al., 2013).

4.3.2. LinguaBytes shortcomings

The modules were critiqued as being more vulnerable/structurally weaker than off-the-shelf commercial materials. The manoeuvrability of the modules was limited due to the cables (Hengeveld et al., 2013). This shows that the use of cables is to be kept to a minimum, favouring technologies like Wireless, Bluetooth or Radio Frequency.

4.4. USA (MIT Media Group) – Jabberstamp

Jabberstamp can be understood as a tool that allows its users to evolve from media consumers (TV, for example) to (multi)media authors (Hayes Raffle, Vaucelle, Wang, & Ishii, 2007a). To achieve this, it allows the users (children aged 4-8 in the study conducted by Raffle et al) to add their voices to their drawings, creating a layered media in a cooperative or single person approach, guided or unguided. The sound can be added after the drawing, allowing more time to the children plan what to say or the sound effects.

The tool has a TUI approach, with a stamp to mark the page and record the sound and a trumpet to playback the sound, as can be seen in figure 11. Despite the tangibility and simple approach, the interface had to be explained to the children and some examples and time to explore had to be given. However, after knowing what the tools could do, children found them to be natural representations of their functions, sometimes approaching the trumpet to their ears to improve listening (H Raffle, Vaucelle, Wang, & Ishii, 2007).

Figure 11 - Jabberstamp in use, with the recorder stamp and playback trumpet tangible interface (Hayes Raffle, 2006)

Jabberstamp allows them to contextualize their drawings by combining graphics with sound, thus creating richer narratives prior to gaining reading and writing skills. This permits them to share not only drawings but also the mind-set and stories created around them, that otherwise would probably disappear in time (Hayes Raffle et al., 2007a).

Jabberstamp was designed to support single page and book mode, for more complex animations. It was tested in a school environment and at home, receiving praise from professional educators that remarked on the potential Jabberstamp has as a communication tool in the classroom (Hayes Raffle et al., 2007a). In figure 12 it is apparent the complexity a drawing supplemented with sound can attain and the visual cues on the number of times the listener should press the sound action.

For this dissertation goal, Jabberstamp adds important guidelines or things to be wary of.

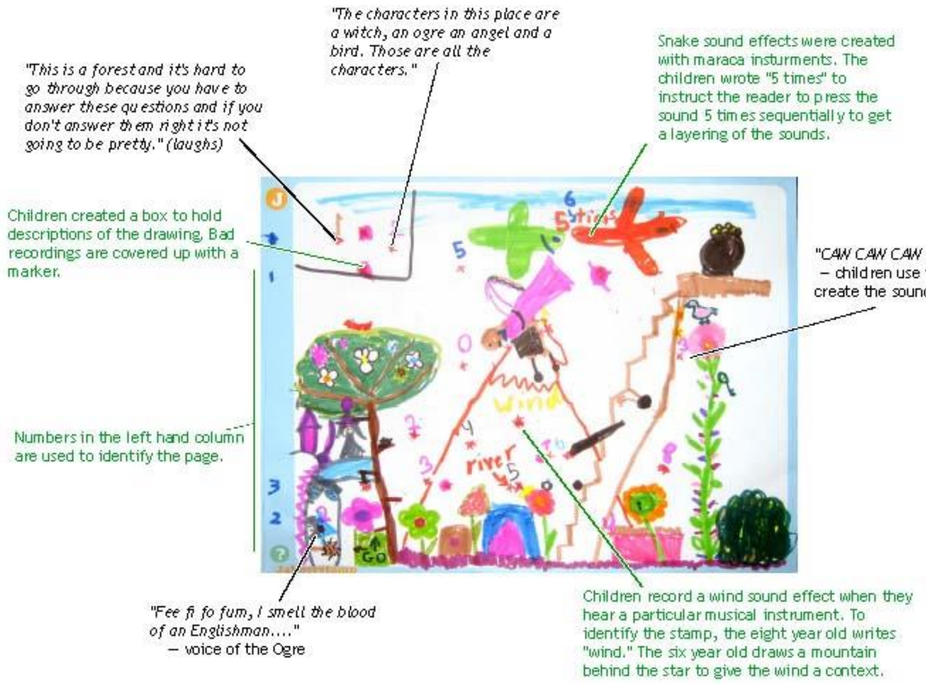


Figure 12 - An annotated and sound rich drawing made with Jabberstamp (Hayes Raffle, 2006)

4.4.1. Jabberstamp lessons to heed

While Jabberstamp works with plain paper and aims to seamlessly incorporate the user interface in the children day to day practices, by use of traditional elements children know and use (the paper, the pens, the rubber...) (Hayes Raffle et al., 2007b), in the end there was a need for an initial explanation. This isn't necessarily a flaw because after the explanation children were able to use all naturally and create rather complex stories, cooperate in mixed-age groups and assume roles of coach/direction (older children in regard to younger children). This just reinforces the idea that a user can and will interact with TUI, AR or any interface in unexpected ways (Dunleavy et al., 2009; Hiroshi Ishii, 2004; Raj et al., 2016). Depending on how Jabberstamp was introduced to the users, their perception and use of it would change. If it was introduced as a sound recording device compositions could be only sound or the sound would not be related to the drawings resulting in compositions without any immediate message (Hayes Raffle et al., 2007b). If it was introduced as a drawing tool, users would record sound only after considerable planning, resulting in final compositions more accessible for others to quickly understand (Hayes Raffle et al., 2007b).

4.4.2. Jabberstamp guidelines and development strong points

Jabberstamp has had several iterations with design changing according to user input, in an early prototype test (Hayes Raffle et al., 2007b). Jabberstamp allows to use a playful approach to capture children attention and allow for an emerging literacy (Hayes Raffle et al., 2007b). They are effectively learning without noticing it.

4.5. Summary

In this chapter, three examples of technological mediated best practices were reviewed. These best practices ranged from TUI for children with disabilities to a combination of a physical and digital interchangeable intervention programme for children with SSD. Their strong points and weaknesses were described as a set of important lessons to heed during this Dissertation next part: the empirical part and actual development of a Tangible artefact.

In the next part, the empirical approach will be explained.

Part II – Empirical work

"In theory, there is no difference between theory and practice. But, in practice, there is"
Jan L. A. van de Snepscheut

5. Method

In this chapter is addressed the *methodology used* to develop the prototype and how the data was gathered (*Exploratory test*). In the end, there is a *Summary* of this chapter.

5.1. Methodology used

The Fishing Game prototype aims to be innovative and solve a real problem in the real world (Pedro & Antunes, 2016), and as such, it involves several different and diverse participants, as can be seen in figure 13. This richness in feedback, different uses and perspectives produce several design iterations.

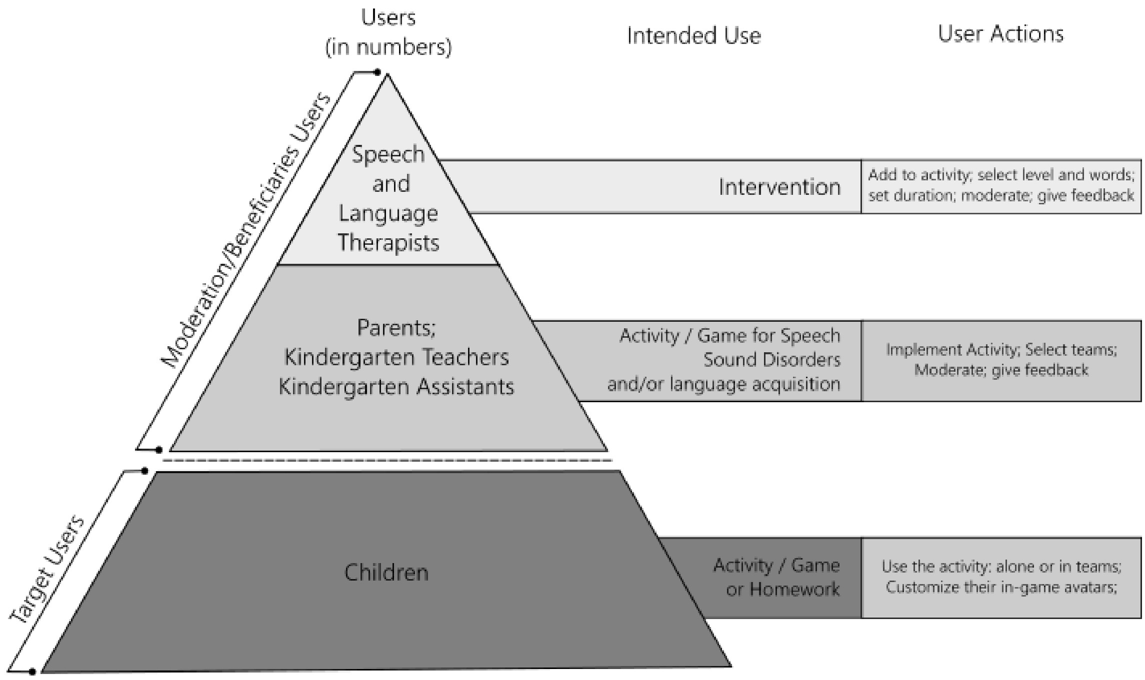


Figure 13 - The expected users of the Fishing Game TUI, their intended use and possible actions.

This constant iteration and evaluation (De Villiers & Harpur, 2013) is a trademark of Design Based Research (DBR). DBR is capable of producing two different and non-exclusive outcomes: the theoretical (this dissertation and papers) and the practical (the artefact itself) (Barab & Squire, 2004). Figure 14 below shows a generic DBR workflow that was closely mimicked during this dissertation, with the exception of the two final moments in the iterative process: Implementation and evaluation. These were merged in the exploratory test.

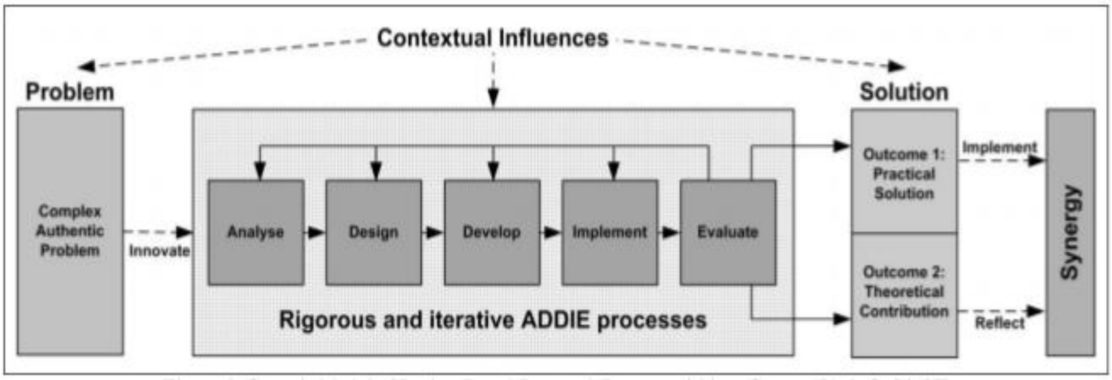


Figure 14 - Generic DBR model (De Villiers & Harpur, 2013)

DBR allows the researcher to be involved in a way that he/she may glimpse unexpected uses or interactions with the prototype, causing a need to alter said prototype or re-assess the target-users and what they do and their needs.

5.2. Exploratory test

Due to time constraints, an exploratory test was conducted to gather data (qualitative and quantitative) regarding the use of the Fishing Game prototype. This test was deemed necessary due to the relevance and innovator value of this Dissertation and prototype. Contrary to the predominant examples (Barredo & Garaizar, 2015; Hengeveld, Voort, et al., 2008; H Raffle et al., 2007; Vonach et al., 2016) found through SCOPUS regarding tangible artefacts, this one is about the transformation of a common and “traditional” game, for children, already in use by SLTs (Gillon, 2008), into a Tangible artefact.

5.2.1. Sample definition

The sample group for the exploratory test consisted of 10 people – end/expert users – with ages ranging from 4 years old (the youngest) to 55 years old (the oldest). It was a convenience sample. The parents’ informed consent, in agreement with the “Declaration of Helsinki” regarding human experimentation by the World Medical Association, was procured (Attachments – A1). In order to be a *de facto* informed consent, the parents received a document (Attachments - A2), briefly explaining the test. All images were taken with permission and, in case of the children, always when they were with their backs to the camera, to preserve their identity.

The sample can be further clustered into 3 sub-groups:

» Children: Six children, with ages ranging from four to six years old. This group had two boys and four girls, all speakers with normal development – no SSDs;

» Speech and Language Therapists: two SLTs, with ages ranging from 42 to 54 years old. Both are also lecturers at the School of Health Sciences, University of Aveiro;

» Kindergarten teacher and Assistants: one kindergarten teacher, aged 55 and one kindergarten teaching assistant, aged 51.

This sample allowed to test a variety of situations, namely one on one Speech and Language Therapy intervention, children's use of the activity as a game (group activity) and KTAs with children. The only missing element(s) from the expected users were parents.

5.2.2. Data gathering

The technique used to gather data was direct observation, while the instruments for data gathering were a form (qualitative data) and a semi-structured questionnaire (with both qualitative and quantitative data).

5.2.3. Exploratory test – Observation form and open questions

In order to carry an effective direct and non-intervening observation, especially of an activity involving children and a certain amount of play, a simple and fast to fill form was created.

A set of open and closed questions, using a Smileyometer(J. C. Read, 2008) was also prepared to be used at the end of the test, with the target users (children).

Due to the variety of the sample and constraints the observer could face, a form was prepared to address all scenarios in a single two-sided A4 page. It was up to the observer to know what he was observing and where to annotate it. Both the form and questionnaire used a unique ID for the person observed interacting with the prototype, the type of user he/she was, age, duration of the session and date.

The form was divided into dimensions/broad areas with clearly defined parameters to mark as observed (yes or no), non-observed and an area reserved to take some quick notes. Those dimensions were:

- Game/Prototype Usability;
    - Parameters regarding the ability to identify the game, its objectives and components.
- Game/Prototype (physical) Characteristics;
    - Parameters revolved around the materials, colours (or lack of), robustness and feedback from the game;
- Gamification.
    - Parameters regarding the desire to play more, if the player knows if/when is his/her turn to play and his/her score;

The questionnaire was also set on an A4 page, and the observer would choose what to ask and to whom.

It was divided into two parts, one aimed at the children, with two Smileyometer scales (one with five smiles representing values 1 to 5 and the other with 3 smiles, representing values 1 to 3) and one aimed at the SLTs and KTAs. The last one had a set of open questions that were used to conduct an informal but directed talk.

Both documents, written in Portuguese, are reproduced in Attachments (A3 and A4).

5.2.4. Exploratory test – Location and setting up

Due to convenience purposes, the test was scheduled and took place in a Kindergarten near the University of Aveiro, the "Jardim de Infância de Santiago". This allowed having, in the same place, three of the five intended users: The children, the kindergarten teachers and the kindergarten teaching assistants. The fourth intended users, the SLTs, joined the group at the kindergarten.

The test was held in the kindergarten library for the following reasons: it is a quiet and spacious room with plenty of natural light and it is a room that does not have a strict occupation timetable. After selecting a table, the chest was opened, its contents were put in place and the fish basket (with the Arduino) was connected to the laptop. A set of printed game rules (in Attachments – A5) was available and the SLTs and KTAs were encouraged to read them. A brief explanation of how the prototype worked, what the components' role and what the buttons did was given. This explanation was thought as something similar to the instructions one would receive when buying such an equipment. The observer prepared the observation forms and the set of questions to ask the users.

5.2.5. Exploratory test – Four possible use cases tested

The Fishing prototype limitations, on hardware and software, limits its use to two participants at the same time, for now. Due to the number of participants on the exploratory test, more than one expected use scenario was tested.

- The first instance tested was the SLT treating a child, using the activity;
- The second instance tested was the Kindergarten Teaching Assistant and a child and their interaction with each other and the activity;
- The third instance tested was a group activity – two children playing the activity, talking with each other about what the other caught, points won and similar subjects;
- The fourth and final instance tested was a child and the kindergarten teacher playing and how both interacted.

NOTE: the only missing instance was the parent and child playing the activity.

5.3. Summary

In this chapter, the Method and all it is composed of are discussed. The Exploratory test, its sample definition and instruments to collect data through observation were addressed. The location and setting up the test including the four possible use cases tested was discussed.

6. The Fishing game

This chapter briefly describes *The Fishing game* and its origins, its transformation into a TUI object and the *Conceptual model* and its requirements. The *Default therapeutic intervention with the TUI Fishing game* is also described and finally a synopsis of the main ideas presented.

On the last chapter from Part I, **4. Technological mediated best practices**, three cases, considered best practices, were presented. Their objectives, approaches, strong points and perceived flaws were scrutinized. Whenever possible, the Fishing Game prototype used that knowledge to avoid the same pitfalls.

6.1. The Fishing Game

The New York-based game maker Clark & Sowdon are credited (MuseumOfPlay.org 2018) with the invention of the game of Fish Pond from which a version was patented in 1890 by McLoughlin Brothers. One Fish Pond from them can be seen in figure 15. The game would use wooden poles with small hooks and the fish would have metal circles to provide a hook-able place.

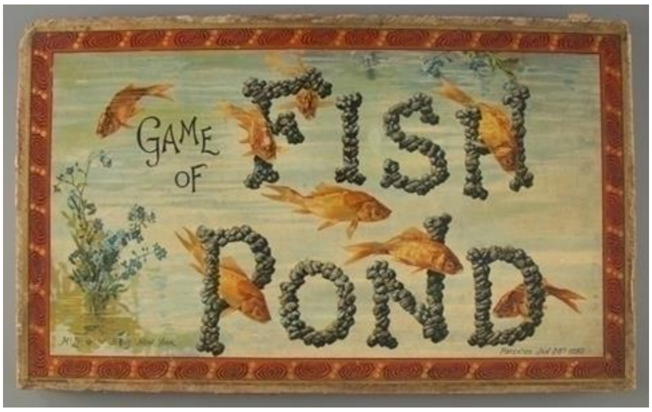


Figure 15 - Game of Fish Pond from the McLoughlin Brothers – image ©The Strong - Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Nowadays most games, like the one in figure 16 have plastic or wooden poles with small magnets and the fish have a metallic piece that will provide the hook-able place.

This is a dexterity game and the rules (that may vary from publisher to publisher or be determined by the players) are as follows: All figures go into the pond. The players will take turns in attempting to catch a fish with the (magnetic) fishing pole. Each player has a set number of attempts to try to catch a fish, without looking into the pond – to better emulate a real fishing activity at a lake/ocean. The number of attempts is agreed previously between players. Each figure has a number printed on the back. For older players, the value of the figures is added up to determine the winner. For younger children, the number of fished fish determines the winner.

The Fishing Game prototype, with all its components, the Activity software and the website/application were developed to be as close as possible to the traditional game and use the rules described above or, in the case of the web/app to act as a possible replacement to both the setting up of the game/activity and the clinical file of the child.

Figure 16 - Modern day Fish Pond game and its contents.

6.1.1. Tangible User Interface Fishing Game rules

The rules are broadly the same as described above with the following exceptions:

- All figures will go into the chest that serves as both a carrying space and the "board" game area;
- Fish and other figures will have a certain range of values. For example, a codfish value can go from 5 to 15 points, mimicking the fact that the fish can be a small or

a bigger codfish. How much each figure is worth will be calculated randomly within a range of values, during the game.

6.2. Why make it a TUI?

It can be argued that the default (traditional) Fishing Game is already engaging and in use in intervention by SLTs (Bowen, 2011; Gillon & McNeill, 2007).

However, the TUI artefact can present additional advantages:

» It allows the customisation of sprites (both the avatar representing the player and the fish). This allows the user to engage in a participatory culture – consumer/player active in co-production (Bruns & Jacobs, 2006) - and makes each game unique;

» Eases the process of preparing the session (the SLTs, parents or KTAs). This can be a process that requires using the website/app or not:

  o After filling in the online version with the name and age of the players, everything else will be set up by the system. For example, as the activity starts, the name tags are already filled in and, as a word piece is put in place, the systems assume the corresponding pair (in case of the minimal-pairs activity), fetches the corresponding sounds and starts the desired level of difficulty;

  o If the website/app is not used, the game can still be played and the system will set up almost everything since the RFID tags will be read and they carry the information about the difficulty level they belong to, the scenario (ocean), the activity to play (minimal-pairs, auditory bombardment or other SLT activity) and so on.

» Eases the burden of certain game related tasks such as keeping and updating a score or show who is winning on a leaderboard. All these tasks can now be taken care of by the software. Additionally, the software can introduce extra challenges, bonus and "power-ups";

» The TUI allows the introduction of extra gamification elements such as self-updating and tamperproof badges. These, without the need of any external assistance, will update to show the player progress in game. This may lead to a desire to perform better in order to be able to "show off" to others his/her badge;

» Eases the post-intervention process. The SLT does not need to record any data from the session because a "log" file will be created for her/him with all the relevant information needed (player's names, age, intervention time, how many misses and so on). This file can (ideally) be accessed through the online software or be emailed to the SLT;

» Extra motivation by playing a game in a new format that is flexible and allows for uniqueness in each play, potentiating children's preferences towards digital games (Furió, González-Gancedo, Juan, Seguí, & Rando, 2013) while still retaining the physical traits.

Tangible user interfaces are also appealing to children and make them effortlessly engage in playful learning by bridging the gap between a physical action and a digital representation (Almukadi & Stephane, 2017).

6.3. Conceptual model

The Fishing Game prototype is, at its core, the traditional Fishing Game described above. So, conceptually speaking, the users can expect to find the same organization, functionalities and set of rules.

As such, their previous experiences with a traditional fishing game will allow them to seamlessly use the prototype with just a very quick explanation of some components and their functionalities, like the Fishing Basket.

In table 2 below we can compare side by side the traditional version and the TUI version.

Table 2 - The traditional and the new side by side - a fishing game comparison

Traditional (physical game) typical components and uses	**TUI artefact – Fishing Game prototype**
Used for: Stimulating dexterity;	Stimulates dexterity and will serve as an intervention approach for the SSDs or an activity for parents, KTAs and children;
Ages: 3-5 years old;	Depends on the SLT appraisal;
Materials: Wood, Cardboard, …;	Wood, assorted foam boards, ironmongery, electronic components;
Contents: 2 or more fishing poles; lake to fish on, certain number of fish.	2 fishing poles; 10 figures (6 fish and 4 assorted figures), chest mimicking the lake; fishing Basket, rocks acting as speakers, laptop.

The relationships, game mechanics and mapping of functionalities remain the same. However, certain parts are extended to aid in greater immersion or alleviate the users from certain tasks, like keeping the scores – now kept by the software and always on display.

6.4. Standard intervention with the TUI Fishing Game

Due to different typologies of target users intended to use the TUI fishing game, and variations of them, more than one use case scenario could be described. For brevity, a complete scenario – the fishing game being used by an SLT - was chosen. Notes will appear as below, inside grey boxes, whenever a use case scenario deviates from the one described below.

> Notes will be presented inside grey boxes.

Since it is outside the scope of this Dissertation, the TUI intervention below assumes that the SLT as already performed all the necessary assessments and trials to determine the child needs. The Fishing Game would be used in the intervention activities, with a set of pre-determined phonological processes. A one to one approach is also being assumed.

6.4.1. Game concept and mechanics

The SLT can, preferably before a session, via a device (mobile or computer with internet connection) access and fill in certain settings such as the name of players, gender, age, type of intervention area and process, to name a few.

> Parents and KTAs can access similar options. Their settings and results will be recorded on a database to be used in the child assessment, if they choose to do so, or they can just use the Fishing Game without any information regarding the users.

Having determined the type of intervention to perform with the Fishing Game prototype (for example a minimal-pairs discrimination), the words to be used and the level of difficulty, the SLT can place the corresponding image inside a black bag. The child can then be asked to choose one image "blindly" and then try to pronounce the correct word. All of this promotes communication and speech production and will help disguise the work activity as a game.

> Parents and KTAs will have to receive from an SLT information regarding the minimal-pairs words to use with the child, so they can then place them in the bag.

The child can then place the minimal-pairs image in one of the two available slots in the fishing basket (as seen in figure 17), take the last image from the bag and place in the empty slot. The fishing basket Light-Emitting Diode (LED) lights will be off at this time. The software will handle all the settings in the background.

Figure 17 - Set of minimal-pairs and their physical placement in the Fishing Basket

The SLT and the child decide who will play first and the number of attempts each one has. The first player will press the white button to turn on the first player LED. Each one will pick its fishing pole and the first player proceeds to, without looking inside the (chest) board, try to catch a fish.

The fishing basket blue LED lights will blink. If any player presses a blue button at this time, a sound with the name of the image corresponding to the button will be heard. This will help the players by reproducing a word in which they may have some difficulty or do not remember.

If the player fails, he/she, according to the rules defined beforehand, can try again a certain number of times. If he/she succeeds, he/she will have to release the catch (fish or another object) from the fishing pole's magnet and place it in the fishing basket slit.

As soon as the catch goes through the slit, the RFID tag will be read. If the catch is a fish, the software will read the word minimal-pairs associated with it. The player will then have to press the corresponding blue button to choose if the fish is associated with minimal-pair word A or minimal-pair word B. If the player fails, an error message and sound will be displayed/heard. This should not be discouraging, rather a cheerful form of "Try again!"

(positive reinforcement). If the player chooses correctly a congratulatory message and sound will be played and the child's high score (displayed on screen) will be increased in a certain (random in a range) number of points, depending on the fish value.

If the catch is a Treasure Chest (TC), the player's high score will be increased by a certain (random in a range) amount: 10 points. An image will be displayed and a cheerful sound will be heard.

If the catch is an octopus or a crab, the player still has to put it in the fish basket and one of two possibilities will occur:

- The player's high score will be increased by a certain random (in a range) value and a message saying that the octopus/crab market bought the catch by x points;
- The player's high score will be decreased by a certain value (depending on how many points the player has a percentage will be taken) or remain zero if it is the first catch of the player. A message saying that the octopus/crab ate some of the player's fish will be displayed;

It will then be the other player's turn to try to catch a fish.

The game will progress until there is no more fish available. It is not mandatory to catch the TC or any of the crabs or the octopus.

In the end, the player's name with the highest score will be displayed on the screen and a congratulatory sound will be heard. The child's significant actions during the game (for example the number of correct and incorrect guesses, minimal-pairs words used and so on) will be recorded in a log that the SLT can access remotely and check the child's evolution.

Parents and KTAs, if they set the game via a device (mobile or computer with internet access) will have their game statistics logged in as well, in a different area – homework. The SLT can access and check this area to see if the homework was completed or not, how much time it was doing it or the number of correct guesses.

6.5. Summary

This chapter dove into the (board game) Fishing Game origins. Its rules and objectives were explained, as well as the reasoning behind transforming such an established game into a TUI. Lastly, a possible standard intervention by an SLT using the TUI prototype was presented.

In the next chapter the technologies used and why will be explained. A discussion of the software used and developed for the prototype, as well as the hardware choices and the prototype build iterations, will be presented.

7. The Technologies

In this chapter, *the Hardware* used to build the game will be described and the reasoning behind its choice will be presented. *The Software* that was developed, the design and build iterations and challenges will also be presented The chapter will conclude with a synopsis of the reasoning that led to the finished "Fishing Game" prototype.

7.1. The hardware

The Fishing Game was designed to be self-contained, low-cost and easy to replicate, with embedded physical computing capabilities. Figure 18 shows not only the physical components of the prototype but also the hardware needs and the software, as well as the communications between them and the users. As such this figure should be seen as a reference to the entire chapter.

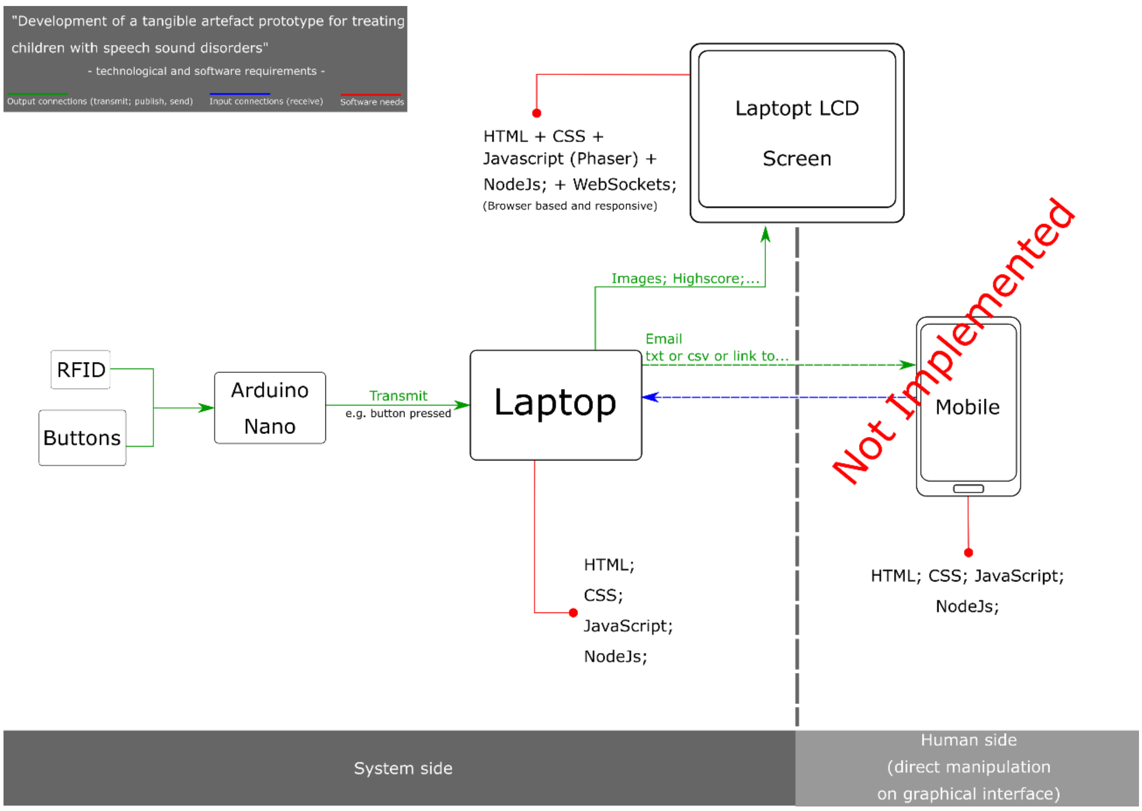


Figure 18 - Technological (hardware and software) requirements for the Fishing Game artefact

Inside the treasure chest are all the necessary parts to play the activity. It was planned to be easy to transport, install and use "as is", requiring just an electrical outlet. However, due to time and budget constraints, the LCD screen was not placed in the Chest lid, so a laptop's screen was used. Also a Raspberry Pi approach was discarded due to the same reasons and a laptop (as the prototype "control centre") and its screen were used instead.

The main electronic hardware parts and their functions and capabilities are the following:

» Arduino Nano - Arduino is an "open source physical computing platform for creating interactive objects that stand alone or collaborate with software on your computer. The Arduino board is inexpensive…" (Banzi & Shiloh, 2014, p.1). The Arduino was created to be used extensively in Interaction Design and Physical Computing, both of which resonate with this dissertation and project.

<u>Why use the Arduino (Nano) on this project?</u>

Arduino is easy to use for beginners, with a large and thriving community and is:

- Inexpensive – The "official" Arduino Nano can be bought for 20€[5], with "clone" boards being sold for 2€[6];
- Simple IDE or possibility to integrate it in other IDE's like Atom (with the Platformio[7] – for development of Internet of Things applications - extension);
- Open source Software and Hardware, which allows third-party creation of modules, shields and other parts that can easily be integrated and speed up the prototyping;

The main characteristics that are of significance to this project are as follows:

- Dimensions are 18 x 45 mm;
- 14 Digital Pins (Input or Output) and 8 Analog (input) Pins;

[5] https://store.arduino.cc/arduino-nano
[6] As seen in Aliexpress, for example
[7] Available at http://platformio.org/

- Can be powered via Mini-B USB, an unregulated external power supply (through Pin 30) or a 5V regulated external power supply. The power source will be automatically selected to the highest voltage source.
- Several communication capacities: UART TTL serial communications and I2C (TWI) and SPI communication (Arduino, 2017);

The Arduino main objective in this prototype is to "sense" data through sensors (the RFID reader RDM6300 and the buttons) and communicate received data through serial communication via node.js and socket.io with the laptop. Ideally, in a future revision, it will receive and execute an order from the laptop (or Raspberry Pi if already installed). These orders vary according to the type of data sensed and when it was sensed (in relation to activity time – sensing the ID from a fish is different and will get a different set of orders than sensing and communicating when a button is pressed).

» RDM6300 125Khz RFID Reader module is capable of reading the code stored into a 125KHz compatible read-only or read/write card or tag. Due to its small size and low cost it can be applied in a variety of places and functions, ranging from office/home security to interactive toys (Seeed, n.d.);

<u>Why use the RDM6300 Reader on this project?</u>

- Small size (dimensions are 38.5mm ×19mm×9mm);
- Low-cost (approximately 1.30€ per unit[8]);
- Capable of communicating with the Arduino via a Tx pin using UART TTL technologies/interface;
- Has a maximum effective (reading) distance of up to 50mm;
- Takes less than 100ms to decode the tag/card;
- Has an external antenna that can be placed near the fishing basket slit to read the fish/other figures (Seeed, n.d.).

In future revisions of the Fishing Game prototype, the RDM6300 RFID Reader may be replaced.

[8] Seen in Aliexpress;

The tangible artefact consists of the following parts:

- Treasure chest: a rectangle with 30 centimetres height, 31 centimetres depth and 41 centimetres width; The inside of the lid would contain an LCD monitor, the empty space allows to carry the entire parts of the game (fishing poles, a fishing basket, fish and speakers disguised as rocks). During the activity, the empty space inside the chest is the "sea" in which the fish are placed. The high sides of the box make it difficult to someone forget about the rules and try to glimpse the fish that it is about to catch. Underneath the "board game" area would be housed a Raspberry Pi 3b (not present at this time. The laptop simulates its functionality);
- The figures (fish, crabs, octopus and TC) - each has an RFID tag to allow the software to determine how many points to attribute, and what to do next;
- The fish basket - it has one RFID reader, one Arduino, three buttons, four LEDs (two blue and two white). The blue LEDs have different light sequences according to a simple premise – has a fish been caught? The white LEDs indicate which player turn it is;
- Fishing poles – a 48 centimetres wood rod, with a neodymium magnet encased in a cork (that mimics a buoy), at the end of a string. It has a handle to be easier to grab and use;
- The rocks – speakers encapsulated inside a foam structure to mimic sea bottom rocks.

7.2. The software

In the creation of this prototype, several programming languages and libraries were used and different pieces of software (or scripts) were created. Below, this development, the different parts of it and how they all connect will be described.

7.2.1. The Activity

The activity was the first software to start being developed, due to its importance, the number of graphic elements it uses and special specificities in terms of both gamification and SLT intervention approach. It was also very dependent on the other parts of software being developed so it was the last part to be finalised.

Software used to develop the activity

The activity was coded using a mixture of HyperText Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript, with the Phaser Framework [9]. Phaser is a JavaScript framework specialised in 2D game development for mobile and desktop environments, ideal for the prototype goals (Davey, n.d.). JavaScript Object Notation (JSON) was used to store several values and properties attributed to each fish or figure, for example name, value (range of), or the minimal-pair it represents.

The HTML and CSS provided a structure in which to embed and call the several JavaScript files (or rather states) created using Phaser. Each State represents a part or module of the activity that can be called and dismissed when needed. This allows for a faster, modular development and to re-use code without the need to rewrite anything. Phaser, in turn, would load and use when needed several assets, including the JSON file. To optimise resources, sprite sheets (a collection of images, arranged in a form pattern, bundled together) were created. Whenever a sprite sheet is created, two files are generated and need to be called: the image file per se (in png format) and a JSON file, that has all the details concerning the image (name of image(s), position in X and Y coordinates (in row), width and height). Figure 19 shows a sprite sheet used in the activity.

[9] Availabe at http://phaser.io/

Figure 19 - The seal Life sprite sheet. It has a companion json file.

Sprite sheets are especially important in online games or applications because they reduce the number of requests (calls) to the server each time an image is needed; there is only one request that brings just one file, and only the needed image from that file is rendered.

To make the activity more scalable and ready to deal with real-time use and requests Node.JS was also used. Node.JS can use and run a JavaScript server-side (traditionally an area for other languages, such as PHP). With Node.JS and its Node Package Manager (NPM) several packages were installed, to allow bi-directional communication between the activity and the Arduino with the server via WebSockets (socket.io[10] plus node-serialport[11]) or to render the HTML code in the browser through Node (express.js[12]).

This implied creating a simple server-side and client-side set of files to handle requests and responses.

[10] Available at https://socket.io/
[11] Available at https://github.com/node-serialport/node-serialport
[12] Available at https://expressjs.com/

The Activity explained

Figure 20 shows the main screens of the activity and will support the activity description.

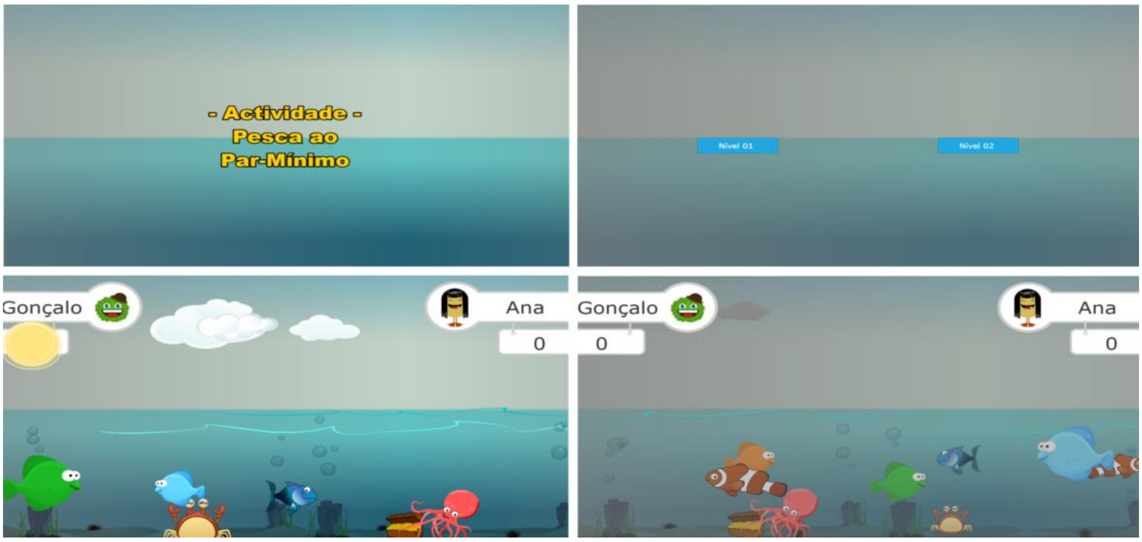


Figure 20 - The activity screens. From left to right, top to bottom: Main/welcome Screen, level choice, 1st level – sun, white clouds and seagulls squawking , 2nd level – dark clouds, rain, mist and wind sounds.

The first very basic screen (after a preload bar – not included in the image above – to tell the user something is happening) is just the name of the activity. It is time-based, so after 3 seconds it will go to the next screen (in the background the code is calling the next state). The next screen allows to choose between level 01 or level 02: The first level presents the written word that corresponds to the image. Level 02 does not. To add an extra game feel to it, the possibility of developing a "World Fish Tournament", in which the players could go around the World fishing and collecting points, was also discussed. Difficulty would be chosen by the SLTs and would be represented as a rough (more difficult level) or as a calm sea.

In figure 21 a diagram of the Fishing Game activity and prototype use is shown to facilitate understanding the flow of the activity. Since the diagram image is quite large it is advisable to read it on attachments (A6).

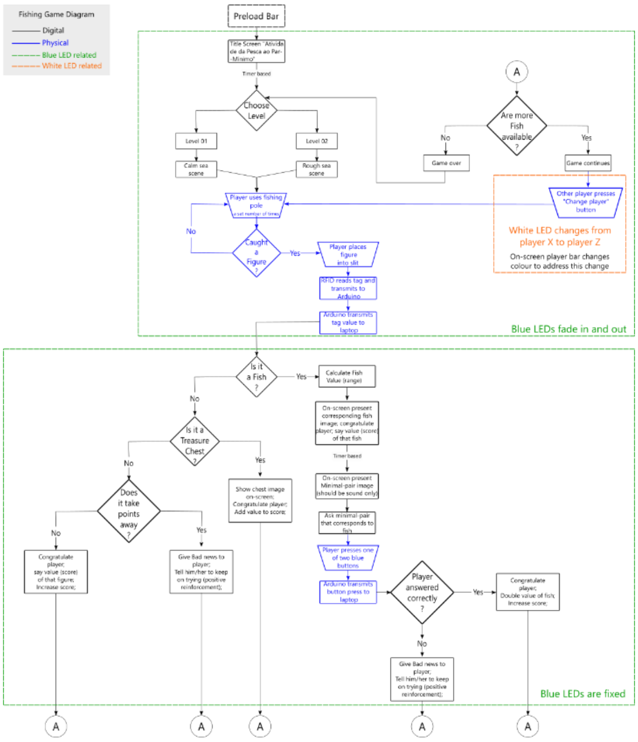


Figure 21 - Small scale image of the Activity diagram complete with physical actions from the player(s).

Due to time constraints, only some parts of this idea were implemented, namely the calm (level 01) versus rough (level 02) seas – as shown in the final two images.

Level 01 was designated during development as the Mediterranean Sea while level 02 was called the Atlantic Ocean.

Level 01 has a sunny day and calm sea. The Sun image is randomly picked out of 4 possible images anytime the activity starts (or restarts) and calmly moves elliptically across the screen. The number of clouds as well as their shape, scale and speed are also randomly picked anytime the activity starts (or restarts). This makes the activity appear slightly different each time it is played.

Fish were initially randomly picked from the sprite sheet shown in figure 19, to ensure variety in shape and colour. However, since they had a physical counterpart (wooden fish), their on-screen creation and aspect had to be enforced. The colour is variable (randomly picked) but their shape is pre-determined to match a specific physical fish. Fish swim in a very smooth sine wave trajectory.

In all the sea life, as well as the clouds, a parallax effect was enforced to give extra realism and sense of depth. With it, closer objects appear to be bigger and swim/move faster than further away objects, which appear to be smaller and slower.

Sound wise level 01 has some seagulls squawking and the rolling of waves, in an attempt to evoke a summer day.

Level 02 is almost identical to level 01 except that it is a rougher sea, there is no Sun, the clouds are grey, there is some mist and rain is falling. No speed differences have been implemented yet.

The sound effects are those of a windy day and a rough sea.

Note: the player's names were initially thought to be inserted into the website or app, and stored in a database. It was designed to save other data that could later be accessed and with it create a" Top Scores" board, a player high score history or a log for the SLT to examine. However due to time constraints that was postponed for a coming revision.

Playing the Activity

Playing the activity involved some physical parts that are needed to trigger the software events.

Figure 22 synthesises the gameplay by highlighting key moments.

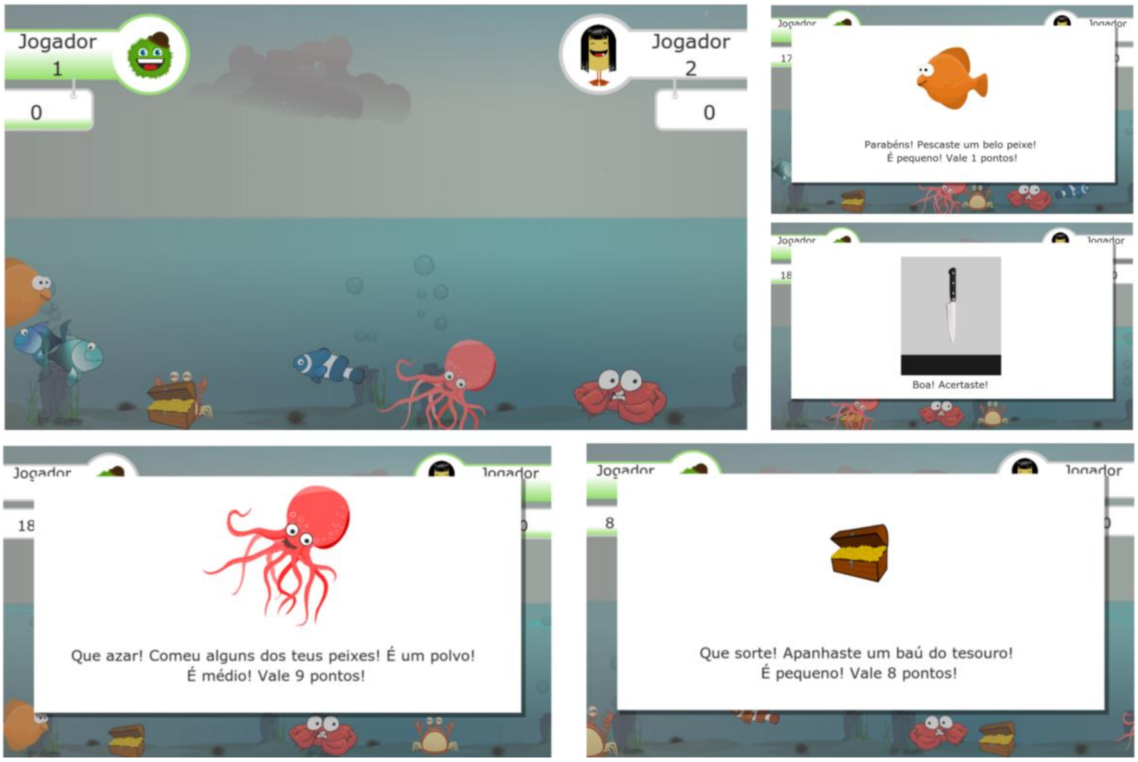


Figure 22 - Playing the activity. From left to right, top: fish swimming; fish caught; minimal-pair image discrimination. Bottom: example screens of other figures and messages associated with them.

After level selection, the player uses his/her fishing pole to try and catch a fish. Meanwhile, on-screen, fish are swimming idly from one place to another (as seen in the top left image). As soon as one fish or figure is captured and it is inserted into the slit, two things happen simultaneously: the fish or figure disappear from the screen and, as can be seen on the topmost right image, a close up image of the catch and a text appear, while an audio file plays saying the same thing as the text on-screen. The size of the image depends on the number of points the catch gives. Also, the text/audio may be congratulatory if it is, in fact, a fish or if, despite being an octopus or crab, they are giving points. However, if they take points from the player, the text still tries to give some positive reinforcement. This screen is time-based, so after the allotted time it will change into another screen. If it was a fish being caught, the player will be confronted with a screen with the minimal-pair image[13] (topmost right, second image with the "faca" minimal-pair).

[13] This is not how it should happen, as the SLTs pointed out in **Chapter 8.3.2 – SLTs and KTAs**

At this moment the player has to choose a button that he/she thinks is the one that correctly discriminates the minimal-pair and presses it. As soon as the choice is made, a text and audio give congratulations or say to try again next time. If the player chose correctly, the high score increases (doubles the amount of the fish value).

The images at the bottom are examples of the screen the player will get if he/she catches an octopus or a treasure chest.

7.2.2. The Website/app

The website and intended mobile hybrid application were coded but not implemented. It was shown to the SLTs during the Exploratory Testing to gather preliminary feedback as well as to better understand their needs. More about this can be read in chapter 9. Conclusions and Future Work -> ***Suggestions and Improvements based on feedback gathered during the Exploratory Test***

Almost all of the previously mentioned languages and technologies used in coding the activity were used on the website and app with some exceptions:

- » The Phaser framework was not used;
- » Node.JS was used but with different packages being installed;
- » HTML and CSS had a larger role;
- » Bootstrap was widely used.

Bootstrap is a front-end library that allows to quickly build or prototype responsive (i.e. that can adapt to any screen dimension) websites or apps (Otto & Thornton, 2011).

Figure 23 shows how the website/app looks like and will serve as a basis for a brief description of it.

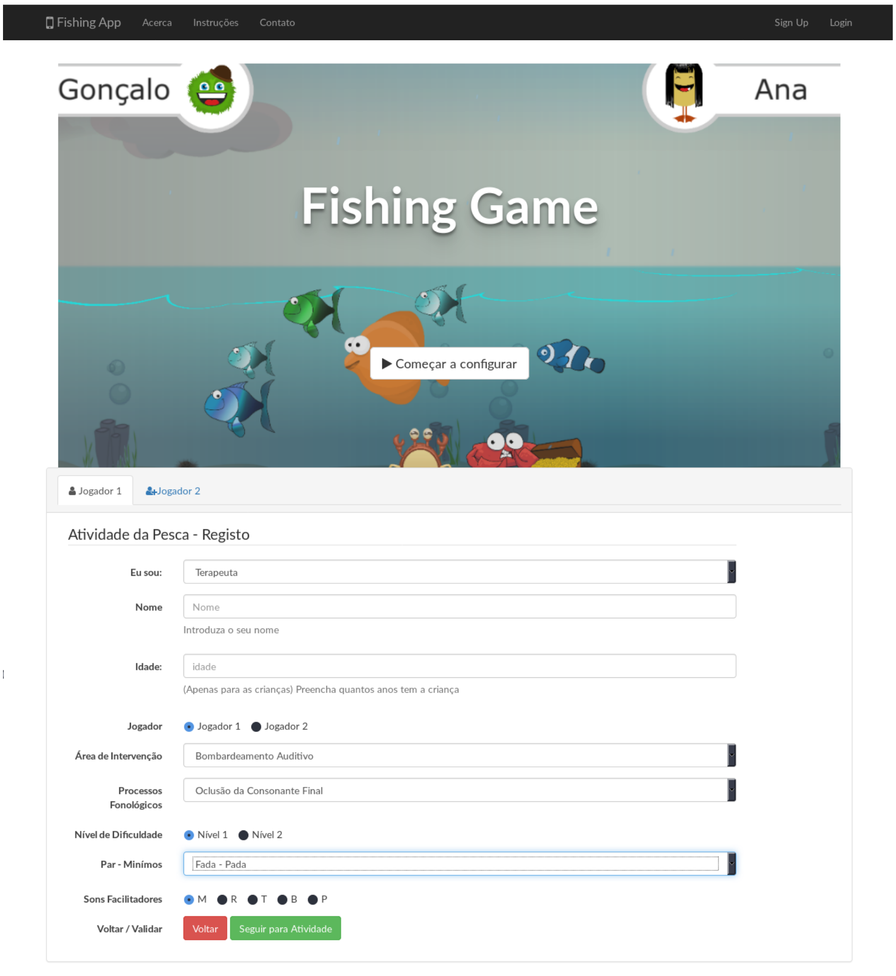


Figure 23 - The Fishing Game web/app.

As can be seen, the web/app was designed as a simple website. On the navigation bar (navbar) on top, an icon that brings the user to the default screen can be seen. There is also an **about** area that explains what this website/application is and what is intended to do, an **instructions** area and a **contact** area. On the right-hand side of the screen, there is a **sign-up/login** area that would be connected to a database and would retrieve data if the person logging in already possessed an account.

Below the image, on the main screen, there is an area to add users to the activity. This is the configuration area, that would collect data to be stored on the previously mentioned database and would be used by the activity to set up some fields (like the name and the" Top Scores" board) and settings (level of difficulty or minimal-pairs in use, to name a few).

All of this would have been transformed into a mobile application installer package by simply using a software like Apache Cordova[14]. Cordova wraps the code into a native container that can access the mobile device native functions (like the accelerometer, for example) and several different platforms, making our web-based software be able to be deployed in any device – platform agnostic ("Apache Cordova," 2012).

7.2.3. On the Arduino

The software on the Arduino was coded using the Arduino programming language.

A library to be able to use specific hardware - the RDM6300 RFID Reader – was also used.

This script performs a very simple set of orders. First, it listens to an RFID tag being inserted into the slot while fading in and out the blue LEDs. If a tag is inserted, the script will read it, convert the hexadecimal value to a decimal number and performs a check to see to which fish that value belongs to. That fish id is then sent through serial communication to the laptop. The blue LEDs are now fully bright. The slot and the reader have a flag variable, i.e., until something happens (player pressing a blue button), they will not be able to read any new tag.

As soon as the player presses a blue button (be it the correct answer or not), all flags used to prevent double-clicks, double readings or other sources of inconsistencies on the code are set to "open" again and the Arduino is again ready to listen to new tags. The blue LEDs return to fade in and out.

Independently of the above actions, the white button and the two white LEDs below it (see figure 24) is always "open" to a possible button press, to change the player. They have a small delay to avoid double-clicking issues.

[14] Available at https://cordova.apache.org/

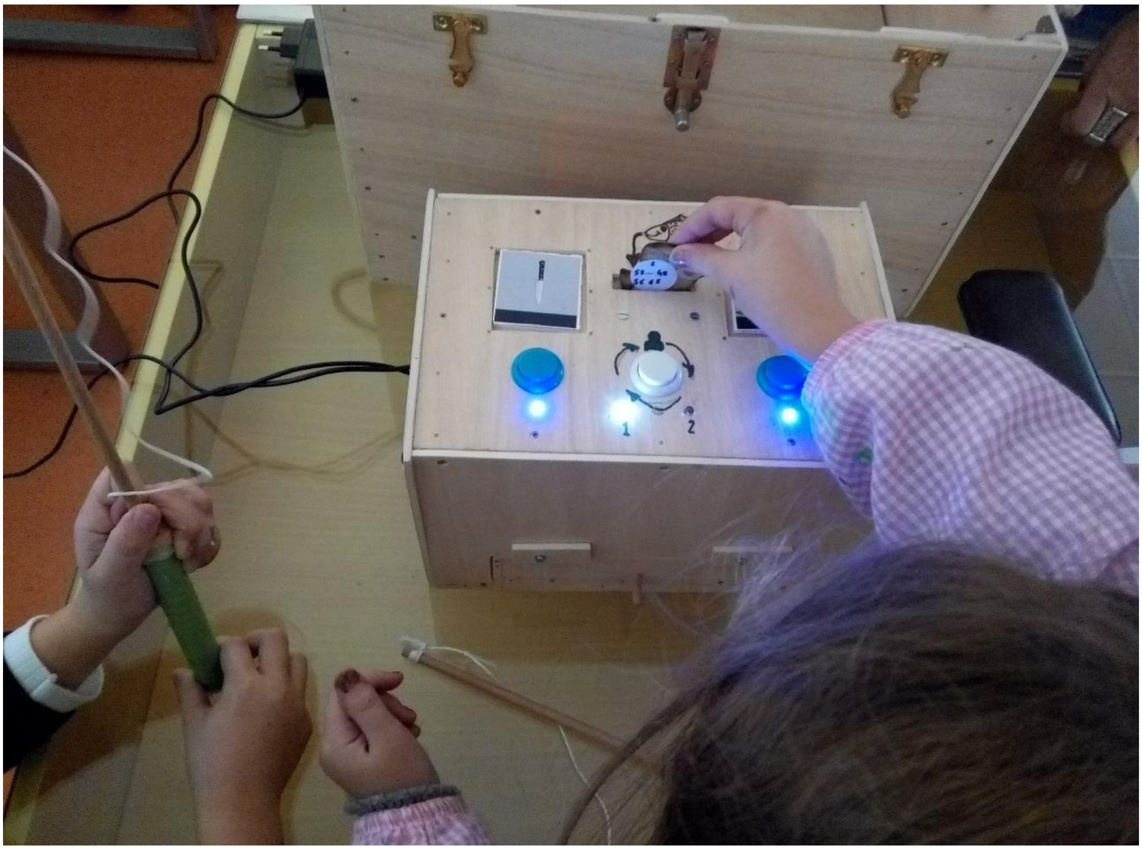


Figure 24 - The Fishing Basket in use.

7.3. Building the prototype – Iterations and final artefact

Some elements of this prototype, due to their importance, role or particular challenge evolved more than other elements and produced more than one revision (Rev). Figure 25 shows the prototype, just before it was tested with end users for the first time.

Figure 25 - The complete prototype prior to the Exploratory Testing. The Fish (figures) are already placed into the board area, inside the chest.

7.3.1. Treasure Chest

The prototype "Treasure Chest (TC)" is the outermost box. Like all the elements in the Fish Game, its design was based on a maritime theme, so the idea was that it should mimic an old TC. That was reflected not on the shape (no round top lid) but on the choice of ironmongery and straps. It contains inside all the components needed to use in the activity with the exception of a laptop/desktop pc. This laptop is needed to power the Arduino Nano and electronics and to display on its monitor the digital representation of the fishing activity[15].

Despite being "just" a carry box (for now), it went through 2 revisions – producing three prototypes- as can be seen in figure 26.

[15] Please see "Conclusions and Future work" to read about the Treasure Chest Rev. 03.

Figure 26 - The three Treasure Chests side by side.

Treasure Chest initial build

The first build of the TC was done entirely with white foam board (also known as K-line) and glued with a hot glue gun, as shown in figure 27.

Figure 27 - First build of the Treasure Chest. Larger and deeper than the final versions.

Some concepts are already present, like the LCD display inserted on the lid, the removable board area to access the Raspberry Pi and its capacity to carry all the remaining activity components inside.

In this first build, the speakers were embedded into the lid, next to the LCD display.

After the build was completed and loaded with the remaining components completed at the time, it was deemed too cumbersome to transport and taller than needed. Two SLTs, who were research assistants at the Speech, Language and Hearing Laboratory (SLHlab) at the University of Aveiro, were consulted; they clearly stated that there was a need for intervention materials with such characteristics, but considered the prototype too big, especially when SLTs also have to carry a considerable amount of other physical material into each therapy session.

Treasure Chest Rev.01

This build primarily addressed the size issue previously detected. To be fast and cheaper to prototype it was done in cardboard and glued with a hot glue gun. The reference scale used was the size of a 15" LCD display and all the other dimensions revolve around it. The idea of the LCD being inserted into the lid and the board area being removable and above the Raspberry Pi were kept. During the resizing, the inserted speakers were abandoned, and they were re-thought as disguised (pier) rocks, to go with the maritime theming.

To be able to proportionally rescale everything and have a sense of the end result, a simple 3D model (a basic box with the dimensions of the LCD display) was made. A 3D Open Source software, called Blender[16] was used. This allowed to add or subtract to the dimensions of the box until achievement of the final result.

Then the physical model was built to address and test certain areas unclear or unthought-of during the 3D modelling process, like the hinges or the inner reinforcements, for example.

This TC Rev. 01 was an in-house model only and after being built was kept as a source of measures and example of how to do certain parts of the build and allowed to start developing the next revision.

[16] Available at https://www.blender.org/

Treasure Chest Rev.02

This revision was built on top of the previous trials and used in tests with the real users, so a certain level of robustness and completeness was needed. The choice of materials and the time allocated to its build also reflected that.

As can be seen in figure 28, this revision was built using 5 mm thick plywood, balsa wood, wood glue, nails, screws, some ironmongery (hinges and bolt) and other assorted materials. All the parts were measured against TC Rev. 01, sawed and groomed by hand. To ensure that everything would fit perfectly, a triple approach was used when securing the wood parts: they were glued, kept in place with clamps until dry and then nailed and screwed together.

Figure 28 - A sturdier Treasure Chest, built of wood. Notice the LCD emplacement waiting for a next revision.

Rope straps and holes were added. The first ones assure an easier transport while the later was thought to be used to connect the Raspberry and LCD to a power outlet and the TC to one or more Fish Basket[17].

Wood hinges that can be locked in position were made to ensure that the chest lid would stay open at a 90° position. Since the TC and all the elements are to be handled by the users, and some are children, great care was put into eliminating (through grinding and sanding) all parts susceptible of causing injury or discomfort.

[17] See "Conclusions and Future Work – octopus's tentacles"

Notes on what should be improved were taken during the actual build, as well as during the meetings with this Dissertation supervisors and during the exploratory testing[18].

7.3.2. Fish (and other Figures)

Fish are the main element in a fishing game. In this prototype, they have an extra dimension (they are not just an object with a value assigned to it or being counted as one more fish caught by the player) due to their RFID tag. This tag gives access to as much information as needed, included in the JSON file read during the activity. Fish had one revision. Similar to the TC, during the build and actual use some notes were taken on possible improvements. Ten different figures created: Six fish, two crabs, one octopus and one treasure chest.

Initial build

The material used in the first build was white foam board, a Paper Mate black felt pen and an X-ACTO knife as can be seen in figure 29. They were initially freely drawn without any specific reasoning other than being representatives of their "categories": fish, crabs, octopus and chest. Their scale was calculated relative to the size of the (initial) TC.

Figure 29 - The initial build of the "Fish" and the materials used in it.

[18] See Chapter 8 – Results Analysis

When informally presented to two SLTs from the SLHlab, parents and this Dissertation supervisors, the unanimous opinion was that the figures needed to be more "kid-friendly" and should be more appealing.

Fish Rev. 01

This revision happened at the same time of the TC Rev. 02, using the same materials and rationale.

Free to use, vector-based images were searched, keeping in mind the concerns relative to being attractive and friendly. An informal document with 4 pages was assembled (Attachments – A7), with possible fish, crabs, chests and octopus to choose from. This document was shown to the previous group of experts (SLTs, Dissertation supervisors and parents) that had seen the first build and they were asked to choose a certain number of elements from it.

From this, the images with more votes were chosen and taken to Espaço IDIOT, the Physical Computing Laboratory of the Communication and Art Department from the University of Aveiro. In this lab, the technician Gabriel Lopes helped with image conversion to a file format understood by the laser cutter and with the handling of the laser cutter itself. In figure 30 the laser cutter in action can be seen, as well as the end result.

Figure 30 - Fish being laser cut from the plywood and the end result.

The RFID tags and a steel washer to allow the fish and other figures to be magnetically caught were hot glued.

Again, actual use led to rethinking the figures, so a new revision was deemed necessary.

7.3.3. Fishing Poles

Fishing Poles were built during the TC initial build and the TC Rev.02 and the materials and scale followed the same reasoning.

Despite several ideas during the initial brainstorming sessions, time-related constraints led to a pragmatic and simpler approach. The ideas for a more advanced Fishing Pole were collected and will be used in a future revision.

Fishing Pole initial build

The first build of the fishing poles was based entirely on white foam board and hot glue and was more of a test for scale and proportions than an actual usable item. Two of them were built and their position and how best to carry and fit them inside the TC was analysed. A revision or a complete rebuild was the objective since the beginning.

Fishing Pole Rev. 01

Revision 01 consisted of a wood rod with 40 centimetres, string, corks, green duct tape, neodymium magnets and hard cardboard rolls from a micro-ATM terminal. This was all glued with the hot glue gun, ground with a mini-grinder, hand cut with a saw and drilled. Hot glue was used to model the butt cap of the fishing pole. Parts of its creation can be seen in figure 31. The Fishing Poles performed as expected and the magnets were powerful enough to fulfil their assigned role. A future revision will make this object more interactive and allow it to be part of an extra layer of immersion to the player.

Figure 31 - The fishing poles and some build details.

7.3.4. Fishing Basket

The Fishing Basket was the prototype element that took the longest to build and develop, mainly because it is the most complete and the one that is closest to the initial idea of how it should be and behave. Due to its importance and to have assumed the "central stage" role it was the driver of several design, technical and material changes. One consideration was always taken as a decisive factor: the end-result had to be cheap and easy developed by any hobbyist.

<u>Fishing Basket initial build</u>

The basket was initially built using white foam board and hot glue. The original concept had one RFID reader per slot but this would increase the price and could make unusable a module being tested at the time (ESP-01)[19]. Two very similar solutions arose:

- » To create two slots that would coexist and allow the Fish to slide down one of the ramps and be read by a single RFID reader;
- » To upgrade the RFID reader to a more powerful version, capable of reading multiple tags at the same time and with a wider reading area. With this and the two slots, the RFID could in theory, when placed at the centre, read both slots.

[19] The ESP8266 ESP-01 – Wi-Fi capable up to 90 meters and programmable using the Arduino IDE (or other) and language.

The second option had, however, an increase in price and complexity (in hardware and/or software), and a problem still persisted: In which slot had the player placed the fish? This was important to determine if the player had chosen answer A or answer B.

As figure 32 shows, the first solution was used. To circumvent the problem of knowing which slot was chosen, a light sensing solution (using a Light Dependent Resistor (LDR)) was produced. If a fish would be inserted in a slot, it would occlude the light shining on the LDR thus causing changes in the resistance value being read.

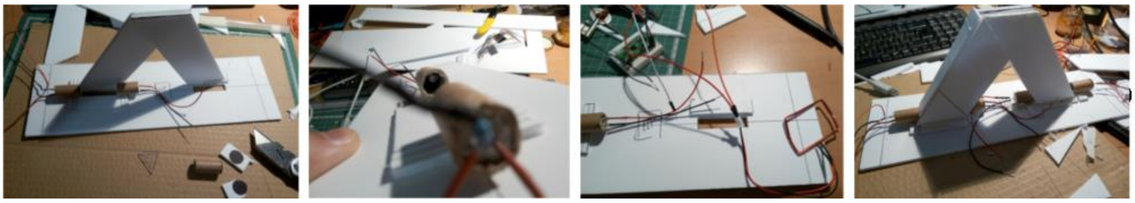


Figure 32 - Solution with 1 RFID and 2 slots (not visible). Note the hard cardboard with the wires where the LDR and LED are housed, opposite facing.

This is a common and cheap approach however not without issues. If the build would be dependent on the environment light, consistency could not be guaranteed. A test or actual use in a room in broad daylight would be completely different from a test or actual use at night or in a room in low light. A software solution that would self-calibrate could be implemented but again, not without possible issues. A solution tried was to focus on the LDR a blue LED positioned opposite the LDR. The casing for both LDR and LED was made out of a hard cardboard roll from a micro-ATM terminal. The casing on the LDR side was painted black inside and the back was shielded as best as possible to avoid any kind of light interference.

This approach, however, defeated the purpose of using the cheapest ESP and an upgraded module, the ESP-12F was tried out.

In spite of all these changes, in hardware and approach, the problems subsisted. The light intensity readings were not consistent or sensible enough, even if (in the software) a range of acceptable values was created. The ramps angle and the placement of both the LDR and the LED made the action of pushing an object through the slit very difficult. Finally, the ESP-

12F revealed to be very susceptible to power fluctuations making it a very difficult and unpredictable module to work with.

In light of the issues with the initial build, a redesign and rethink of the Fishing Basket was needed.

Fishing Basket Rev.01

This revision, still made using white foam board, changed several concepts. Its dimensions were smaller in length but larger in depth and used just one slot, 3 buttons and 3 LEDs. The larger buttons, as figure 33 shows, were supposed to have the same colour, however, at the time of this revision, those were the buttons available.

Figure 33 - Fish Basket Rev.01 - better dimensions, buttons and just one slot.

In terms of electronics, this revision abandoned the Wi-Fi and ESP modules approach and the Arduino Nano as a solution to the problems identified earlier was chosen. This, of course, made the use of cables a necessity. As figure 34 shows a circuit was designed and soldered and this Rev.01 was in fact tested by this Dissertation supervisor's.

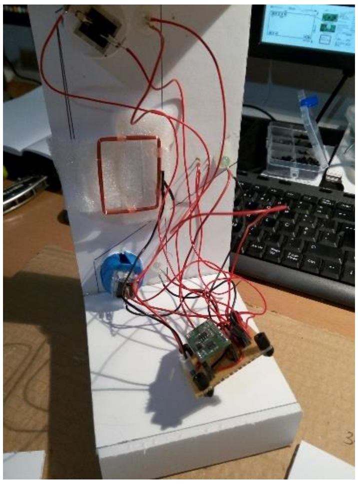


Figure 34 - Rev. 01 circuit detail.

Wrapping paper was used on the slit to cause some attrition to the object being inserted and allow more time for the RFID reader to react and read the tag.

It was decided that this Revision was ready to be built in a more durable fashion.

Fishing Basket Rev.02

The FB Rev.02 was built using plywood, wood glue, nails, nylon screws, screws, acrylic and other assorted materials. When cutting the top panel, the position of the buttons was aligned and space was arranged to accommodate the images for the activity. The slit was also placed in line with the buttons and all LEDs were aligned.

A drawer was built on the front panel so the players could retrieve the objects after a session. The back facing panel was fitted with a transparent acrylic panel to allow to visually debug the system.

The circuit board, shown in figure 35 with the RFID reader and the Arduino, among other components, was fitted to the interior of a side panel using nylon screws.

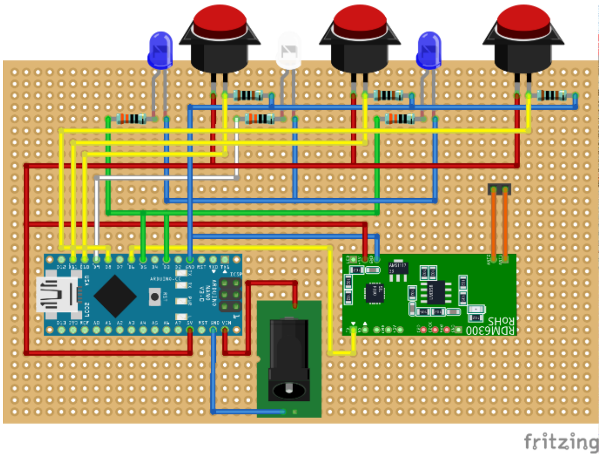


Figure 35 - Circuit board diagram before changes done in Rev.03 and still being powered by a USB charger with a 3.5mm jack.

This circuit board included an independent power supply in the form of a USB charger since the micro USB cable on the Arduino was used just for transmitting data to the Raspberry Pi on the TC. The same side panel was cut to allow the cables to be properly fit. When this version of the FB was again tested by this Dissertation supervisor's new questions arose: What is the player's order? Who starts? How do you know who is the first player?

Fishing Basket Rev.03

To solve this issue, a slight redesign was necessary, resulting in the version shown in figure 36. Physically it involved the addition of an extra LED to the centre/middle of the Fish Basket. The white (centre) button, which previously just acted as a way to repeat the audio file associated with the object caught, was now used to change players. Each player had to actively take his/her turn, akin to the watch used in the chess games, by hitting the button. Additionally, the slit to insert the objects and the white button received some graphic markings (cultural conventions), shown in figure 36, to better identify their purpose and reinforce the player's actions.

Figure 36 - The final revision, with a slight difference: another white LED to show which player turn is and the graphical markings to help associate the button and slot to their respective role.

On screen, that action changed the colour on the player tag while physically it turns on or off a white LED on the Fish Basket, as can be seen in figure 37.

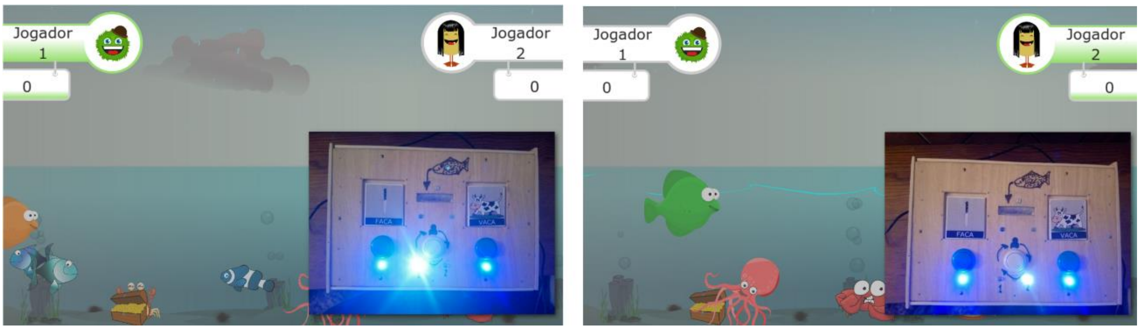


Figure 37 - On-screen player 01 is highlighted and the physical counterpart has the LED 01 lit up (left image). The right image is the same but for player 2.

The Raspberry Pi solution was postponed due to time constraints and the possible extra layer of complexity it would add. An approach in which the laptop would be used as screen and processing unit was preferred.

In figure 38 below, some examples of how the fish basket build process evolved can be seen.

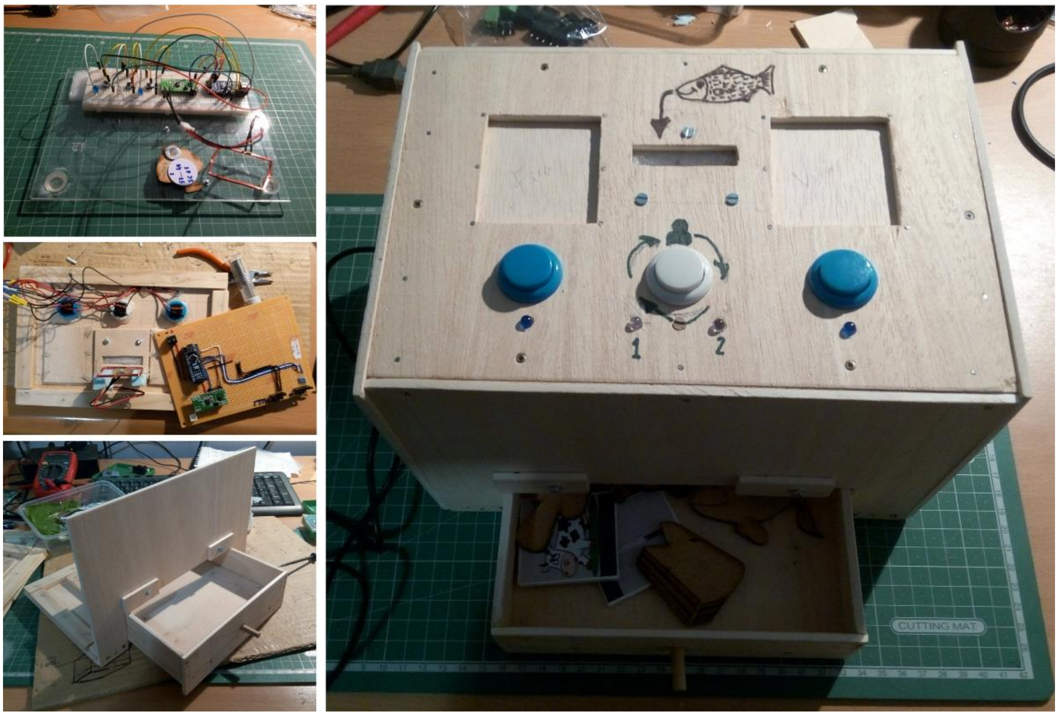


Figure 38 - The evolution/iteration of the prototype Fish Basket latest version: from breadboard to usable prototype.

7.3.5. Speakers – Rocks

The speakers were initially thought as being encased in the TC lid, close to the LCD. With the reduction in size, the speaker concept had to be rethought and an extra element came into consideration. This affected other elements' scale since one objective was that all elements could be housed together, inside the TC. To keep the maritime theme, the idea of turning the speakers into a rock like element, similar to those found in piers, was considered.

Speakers initial build

The speaker's main material was insulation blue foam. This type of foam can be easily carved into shapes, by using different knives and other assorted tools or techniques. The speakers were built by cutting and carving different size pieces of "rock", all glued together with hot glue. This added to the look of something real, from nature, with crevasses and gaps, instead of a single carved face. To finalize, they were spray painted with an earth/cement grey and some beach sand and pebbles were added. In figure 39 several stages of the build process can be seen.

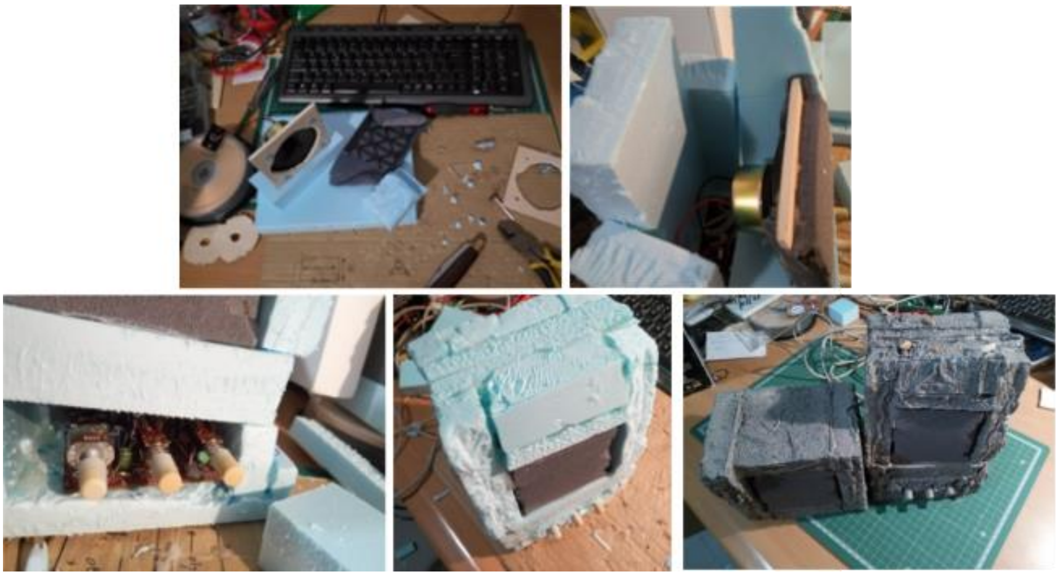


Figure 39 - Creating the rocks out of blue insulation foam.

7.4. Summary

In this chapter, the hardware and software choices and pitfalls were explored. The several iterations the prototype underwent, both in software as in hardware, were documented, and the final Fishing Game version was presented.

8. Results

In this chapter, the results of the Exploratory Test will be presented. The *Observation Grid* used to gather data through direct observation, as well as the *Open Questions Questionnaire* will detail the feedback received. Data will be quantified through the use of the Smileyometer scale (J. C. Read, 2008).

8.1. Observation Form

The observation form was divided into three dimensions or broad areas – prototype/activity usability, prototype/activity characteristics and gamification. Each of these had a set of parameters, as described earlier in **5.2.3 Exploratory test – Observation form and open questions**.

This was applied with a direct observation approach, without any intervention on the part of the observer during the activity. The observer strived to annotate all the interactions and relevant exchanges of commentaries.

In the subsections below, we will present the feedback collected from every area and parameter and summarise some ideas and areas for improvement.

8.1.1. Game/Prototype usability

The *first parameter* analysed reflected if the player was able to identify the game and its objectives.

Two out of the six children tested immediately identified the game. The others were not vocal enough to demonstrate if they knew what they were playing and the SLTs (that remained present for the whole duration of the test) or the KTAs identified the game for them.

They all knew the "classic" objectives and assumed that the unusual images (chest, octopus and crabs) had a similar value and role as the Fish. Only one player and one SLT said to have found out that the unusual elements had different score behaviours.

One player even said that she liked this game more than the classic that she had at home. Her speech was along these lines: *"The one I have at home is a blanket and we can stand on it and fish with our hands. But this one is more fun!" – CT, aged 6;*

When asked why she replied that this had a larger variety of figures and some stole points (this child caught an octopus and noticed that it had halved her score). She went on to say to the Kindergarten Teacher that she should buy this game for their classroom.

We then tested (*second parameter*) if the player was able to identify the game components (fish and other figures, fishing poles and treasure chest).

All stakeholders were able to correctly identify the game components and even discriminate the figures (saying that one was an octopus, another a crab, etc…).

The *third parameter* was if the player was able to identify the game elements and its function (buttons and slit).

Regarding the six children tested, this was an unobserved parameter. The SLTs and the KTAs role-played with the children and helped them when they first caught a fish or when they needed to change players or chose a minimal-pairs. From that moment on it was a learned behaviour.

The test that involved two children playing against each other was also mediated by an SLT so the same explanations/role-play were present.

The *fourth parameter* analysed if the game elements timings were correct.

Unfortunately, it was not possible to register this parameter. The children were having such evident fun while using the prototype and the SLTs and KTAs so involved with them that none seemed to notice (or care about) the timings needed for a fish to be recognised, or the word to appear.

Further testing is required to understand if the timings are correct. One cannot assume that the stakeholders will be so thrilled all the time and has to assume that the novelty of the situation and the fact that it was a "one-off" test made stakeholders unaware of the timings.

We finally observed if (*fifth parameter*) the player knew when it was his/her turn to play.

Regarding the entire sample, nine out of ten knew when was his/her turn to play. This does not mean, however, that they did or took the correct steps in order to play/pass their turn. They all knew that after player X would be their turn. But player X would most of the times forget to press the button to change player or the player in question would fail to realise it and correct the situation by pressing themselves the button. This would result in points being given to the wrong player.

8.1.2. Game/Prototype (physical) characteristics

Many of these parameters were only observable in the children. This was due to the brief explanation given to the SLTs and KTAs that made them aware of the uses and whys of many of the physical characteristics.

The *first parameter* was if the game and its elements dimensions were adequate. No comments from the users were registered.

The *second parameter* was if the colour of the game elements is adequate. Again, there were no comments about the (lack of) colour of the physical components of the activity and little attention was paid to the ones on-screen.

We then tried to observe if the materials used to build the prototype invited the handling of it (*third parameter*) and if the prototype was considered robust (*fourth parameter*). Again, no comments were observed. The observer marked them to ask in the questionnaire/talk with the SLTs and KTAs.

The *fifth parameter* was intended to understand if the feedback throughout the activity was efficient. Two out of the six children waited for the feedback (e.g., the audio feedback of the word after inserting the figure into the slot) or were aware of it.

The *sixth parameter* was if the physical constraints serve their purpose.

This was observable in three out of the six children. It was more apparent regarding the slit and its use.

The *seventh parameter* was if the mapping of the buttons and their actions are consistent and correctly perceived and used during the activity.

Four out of the six children correctly and consistently used the buttons when they were supposed to and to the desired end.

8.1.3. Gamification

The *first parameter* was if the stakeholder was able and willing to play or participate until the end.

All the stakeholders participated until the end, showing great interest and willingness. Some (children included) even wanted to know details about the prototype/study.

The *second parameter* was if the stakeholder was willing to play more.

Four out of six children asked if they could play more.

The *third parameter* was if the stakeholders were aware of their score, at any given time.

One alternative would be asking from time to time who was winning as a form to gauge how well they were aware of their score. This proved to be unnecessary since the SLTs and the KTAs started doing it without any prior talk about asking it.

Three children knew their score, one was not aware of it and two were not observable. Despite knowing the score and being quite attentive to the value of each figure fished, the children did not seem to maintain the idea of who was winning. They looked at their points on the screen and would say "I have x points!" but nothing more. When the activity ended, children would often ask who had won.

8.2. Open questions questionnaire

The open questions questionnaire was divided into two sections – children; SLTs and KTAs. Below we will discuss the results and answers obtained in both sections.

8.2.1. Children

Children were asked a set of four questions, two of which with a visual Likert like scale, the Smileyometer (J Read, 2008). Two scales (meaning two value ranges) were used. One had five smiles, so values would range from 1 to 5 while the other had three smiles, with values ranging from 1 to 3. Being our target users their feedback was very important and more than their answers the observer was very attentive to what they said to their KTAs or to each other about the activity.

The *first question* was if the stakeholder had enjoyed playing the activity.

This was a question made while showing the 5 values in the smileyometer, as depicted in figure 40. The scale was explained to the children in the following manner:

"You see, the first smile is sad. He has not enjoyed playing this game. The second smile is – well,... I really do not care about it. The third smile liked it a bit. He could play more... or not! The fourth smile is happy, he enjoyed playing the game. The fifth smile is really really happy because he enjoyed it a lot."

Figure 40 - Smileyometer scale with five values.

This was said while pointing to each smile in turn. The child was then asked to choose the smile that depicted his/her feeling towards the game they had just played.

Five (83%) out of six children picked the happiest smile, which has a value of 5, and just one (17%) chose the third smile, which has a value of 3. That is, more children enjoying playing the activity than not.

The *second question* was what feature had the stakeholder enjoyed the most. This was an open question.

Despite being an open question and so with a broad range of possible answers, most of the children mentioned similar or the same aspects as being the most enjoyable.

Four children mentioned that they really had enjoyed fishing/catching fish. At least one remarked it was like going fishing (actual fishing) with his/her father. Three enjoyed pressing the buttons and two placing the fish in the slit.

Some additional comments included: they enjoyed the fishing pole itself; the crab figure; the octopus figure; the chance to play the game and the variety of figures instead of being a game with "just" fish.

The *third question* was what feature had the stakeholder enjoyed the least. This was an open question.

Three children did not point out anything they disliked.

The remaining three pointed different aspects: one disliked catching the crab figure because it stole points; another disliked pressing the buttons because it was just that – "*…you press the button and that's it!"* - said ST and the last one disliked watching the game on the PC, he/she would rather just play it physically.

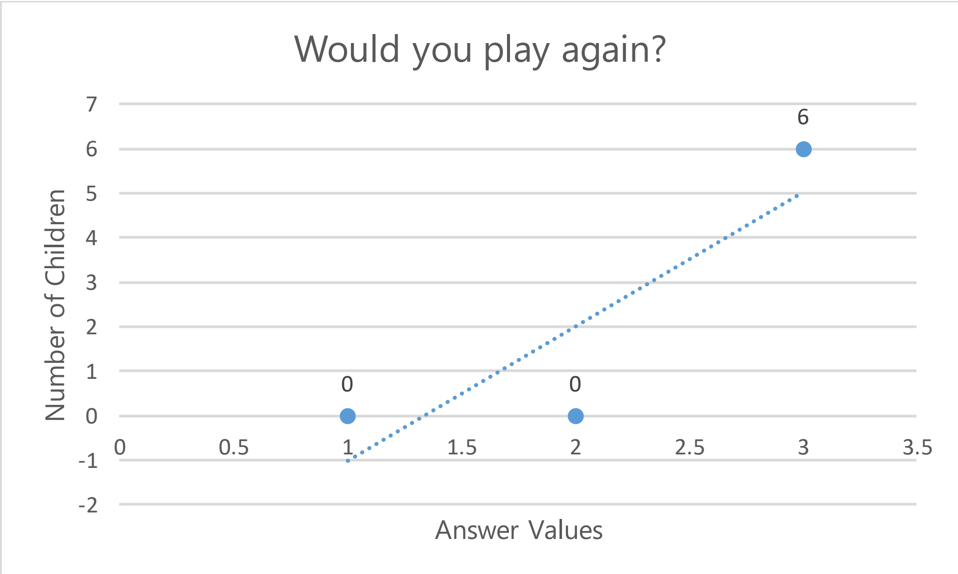
The gameplay was not fully understood by the stakeholders. Many were not aware that catching a crab or an octopus could take or give points. Similarly, many were not aware that answering correctly (pressing the buttons) would double their score. This as to be made more clear through more visual and auditory cues as well as physical cues to be implemented on the existing Fishing Game components or components yet to be developed.

The *fourth question* was if the stakeholder would play again.

This was a question made while showing the three values Smileyometer, shown in figure 41. The scale was explained to the children in the following manner:

"Ok were we have more smiles. You see, the first smile is sad. He does not want to play again. The second smile is again indifferent; he really does not care if he plays or not. The third smile is so happy he cannot wait to play more."

Figure 41 - Smileyometer scale with three values.



All children picked the happiest smile, which had a value of 3, i.e. all children wanted to play again.

Note: All these values and answers should be taken with the proverbial "grain of salt" due to some unreliability in children's answers due to a multitude of factors/effects (Janet Read, Macfarlane, & Casey, 2002; Zaman & Abeele, 2007).

8.2.2. Speech and Language Therapist and Kindergarten Teachers

In relation to the SLTs and KTAs, the open questions were introduced in a sort of informal talk that took place after testing all the children and after them having had the chance to try out the activity themselves. This resulted in a fluid conversation with moments that resembled a brainstorm session. The observer mainly listened, offering his comments occasionally.

The *first question* was if they would change anything in the concept or prototype.

While some said they would not change anything, that it was interesting to see this transformation of a classic game and that it was nice to have the auditory feedback when something was inserted into the slit others had more, sometimes divergent, opinions. An SLT said that had noticed the children (and their own) difficulty to remember and press the button to change players, would make that automatic. This had an immediate retort by the other SLT that said that some children had mentioned that they enjoyed pressing the buttons, so this change on button press should be maintained. What this action needed was more feedback/being made more visible, she also suggested.

The *second question* was if they would change anything in the game or activity.

The KTA said that she would not change anything in the game, as it is so comparable to the "original" game that no explanations are needed. However, she felt that the way the score was being handled lacked more and better feedback. This would, in her opinion, increase the competition and game aspect of the activity between the users. The SLTs both enjoyed the game. They would add more fish so you can have more auditory stimuli since at the moment there are only 3 per player: they suggested 6 to 8 per player. With the increase in fish, they immediately added that the distractors (the crab and octopus) numbers should also increase in order to maintain proportion and challenge. A sort of "superclass" figure capable of shifting the entire game for all players was suggested. This will be talked in chapter 9. Conclusions and Future Work -> ***Suggestions and Improvements based on feedback gathered during the Exploratory Test***. The way the auditory stimulus was working was also remarked as being at fault. Children should pick the figure, insert it and listen to the word (in the loop if needed) and only when this action was completed, should they see the image. What was happening was that the image would come up and allow the children to do have a visual, (not auditory), feedback. This will be revised.

The *third question* was if they could, how would they expand the prototype.

The KTA mentioned that she works with bilingual children, and furthermore, since nowadays, at a young age, a second language is taught, she then suggested the prototype be multilingual. The SLTs would like the prototype to have more uses and not be just the game of fishing. They suggested to give names to the fish to make children repeat those names and as such sound production could be stimulated. Another approach to extend the game functionality would be to use more game scenarios that the adult could choose from. Some fish or other figures with some word values associated with them could be tossed into the pond for children to fish. When fished and inserted into the slit the word would be unveiled and the children would be encouraged to use it to construct a story.

The *fourth question* was a preamble to the fifth question and sixth questions, depending on the answer. The SLTs and KTAs were asked if they would like to see more games made into TUI. If they answered yes, they would go on to question number five – *If yes, which games?* - if not they would go to question number 6 – *If not, why?*

They all answered yes.

The *fifth question* was which games would they like to see made into a TUI artefact.

The answers were as follows (written in Portuguese due to familiarity with the games and names): *Três em linha*; *Jogo da Glória/Ganso*, *Loto de imagens*; *Jogo de identificação indireta estilo Quem sou eu?*

These can all be possible stand-alone development avenues or add-ons to the existing TUI artefact, adding extra elements and adjusting others and, of course, the software binding them all.

Questions from the observation form that were asked during the conversation, since it was deemed more productive, were about the robustness of the prototype and the adequacy of materials and how appealing it was to be used.

Both KTAs and SLTs alike said the prototype was robust enough if the activity was used under (adult) supervision. Left unattended it was robust but accidents do happen. Regarding the kind of material and its appeal, they all agreed that wood is used quite often, that children are used to seeing in other toys and enjoy using them. They mentioned that some parts could use other materials to give an extra sensory input that may help in the immersion into the activity.

8.2.3. SLTs and the Web/App

As a conclusion, both SLTs were shown the unimplemented but partially developed Web/hybrid app[20].

This web/app will allow preparing sessions remotely and is the visible front of a back office area where an SLT can keep and generate logs or visual representations (i.e. graphics and other visual forms to represent information) from sessions and target users.

In it, the SLT can log in and get access to a roster of target users or add a new target user. It can choose an area of intervention, a set of exercises and what words or facilitator sounds to use and other functionalities This web-based application can even be used by KTAs or parents, which will be able to access and set different parts of the application.

Their feedback was collected and saved for a future implementation.

8.3. Summary

In this chapter, the observation form, as well as the open questions questionnaire used in direct observation during the Exploratory Test were discussed.

A brief description of the unimplemented web/app to the Fishing Game prototype was presented. Several ideas, feedback and suggestions were summarised. The next chapter will discuss the overall conclusions, how to take the Fishing Game into a bigger pond and future work.

[20] Hybrid apps are web (browser based) applications developed using HTML, CSS and JavaScript that are then wrapped in a layer that allows interaction with a smartphone/tablet hardware and software, independent of code/language.

9. Conclusions and Future Work

From the analysis of the data gathered and presented in the previous chapter, we can draw several conclusions. They are presented below.

9.1. Observation Form

9.1.1. Regarding Game/Prototype usability

The feedback and perceived recognition, as well as the ease with which the players started playing the game, are valid indicators that the transposition of the traditional game into the TUI artefact was successful. It should be noted the added interest on the extra figures (octopus, crab and treasure chest). However, the fact that the score was different for each object (as well as the on-screen object scale that changed according to the points earned) was not readily seen and only two out of ten participants noticed it. Better audio and visual feedback are needed in the next revision to assure that this is an understood behaviour and can transform the gameplay experience.

The game components seem to be well designed and help in identifying the game and the activity (fishing) which the game is based upon. Some figures can be further developed, since the stakeholders engaged specific conversations about fish variety, i.e. if a whitefish or a cod.

Further testing with all the stakeholders is required as it allows to understand if the affordances and design work and if within minutes the stakeholders are ready to use the activity to its fullest.

Furthermore, testing is required to understand if the timings are correct. One cannot assume that the stakeholders will be so thrilled all the time and has to assume that the novelty of the situation and the fact that it was a "one-off" test made stakeholders unaware of the timings.

Knowing one's place in a queue or in this case his/her turn to play doesn't seem dependent (especially in an activity with just two players) of any sort of visual or auditory feedback. It is something that the players do and know. However, interacting with a button to signal this change is not an expected behaviour and as such, despite knowing (the SLTs and the KTAs) or being told (the children) and despite the markings above the button, this was generally overlooked and a source of distress. To avoid this a different solution has to be implemented and the suggestion can be read in point ***Suggestions and Improvements based on feedback gathered during the Exploratory Test***

9.1.2. Regarding Game/Prototype (physical) characteristics;

Further testing is required to understand if the dimensions are correct.

Further testing is required to experiment and understand the importance (or lack of) of colour. Since the digital part was on the laptop screen, off-angle relative to the treasure chest and main activity area, it may have been perceived as a "secondary" thing to look at. The tighter integration desired (the LCD display on the chest lid) may lead to a better understanding and ability to test this parameter.

Further testing and modifications are needed to improve on feedback, as per suggestions and observation.

At least on two occasions, some figures were pushed into the slot so fast that the RFID reader was unable to read them. Several suggestions were given by the SLTs and KTAs to alter slightly the phrases and sounds, in order to give more feedback, regarding, for example, score. These suggestions are collected in point ***Suggestions and Improvements based on feedback gathered during the Exploratory Test***

A possible reason for half the children being aware of the physical constraints such as the slit and its use may be due to their turn in playing the activity. The first one to play used the constraint (and the SLTs/KTAs help, of course) to know what to do to the fish and the slit while the second did it because she/he watched the first one do it.

The mapping of the buttons and their actions are generally well understood and used. There is some "natural resistance" against using the button to change players, the users seem to expect it to be automatic. Despite two children not being observed has to be so active or capable of using the buttons, they did play the activity and enjoyed it. The other player or the SLTs/KTAs helped them with the buttons and they started using them after a short while.

9.1.3. Regarding Gamification

All stakeholders, for one reason or another, enjoyed taking part in the study and/or activity. While some of this (especially regarding children) can be dismissed or looked at considering the novelty factor, it is encouraging to get this feedback.

More than half stated their desire to play more. The remainder may not have done it by a number of reasons, such as, for example, the test being run just before the Christmas holidays and children being busy taking part in dance/singing rehearsals for the school Christmas show, so they wanted to go back to those activities.

The stakeholders were aware of their score or at least knew where to look at, on screen. However, at the end, they were mostly unable to say who had won and with how many points. This also lead to some suggestions, that can be read in section ***Suggestions and Improvements based on feedback gathered during the Exploratory Test***

9.2. Open questions questionnaire

9.2.1. Regarding Children

The majority of children enjoyed playing the activity. Even the child that answered differently did not choose a negative smile/value, so even he/she would play.

A clear pattern could be observed: Children enjoyed playing the game, even evoking memories of happy moments; the game is varied and rich enough to be attractive and fun; the digital part of it went unnoticed. This may be because of the previously mentioned off-angle screen. Further testing with a new Fishing Game revision (of all its components) is required.

All children wanted to play again. Even considering factors like “novelty” and possibly being away from some chore they disliked, the results are encouraging and very positive. What remains and is dependent on further and more exhaustive testing is if this willingness to play would be maintainable after a number of games played.

9.2.2. Speech and Language Therapist and Kindergarten Teachers

A need and desire for tools such as the Fishing Game prototype was clearly observed. The prototype was seen as almost ready to serious field and clinical testing after some small bugs and feedback issues were solved. Both SLTs and KTA said it was something that they could see themselves using with their children.

9.3. Suggestions and improvements based on feedback gathered during the Exploratory Test

During the entirety of the Exploratory Test, the observer was able to collect a large number of inputs/feedback, some direct as in the final talk with SLTs and KTAs as well as some indirect, overheard during the activity use. Those suggestions improvements and feedback are addressed in this subchapter.

Keeping with the maritime theme, a Pirate figure could be created. This figure would be able to steal away all points, from all players (in practice resetting the entire score and doing "tabula rasa" of all progress) and sail away (meaning, the Pirate would be thrown again into the chest). This would be used to counter-balance the treasure chest image and would increase the challenge factor.

Also, the score could be in starfish and could have some sort of adding animation to increase the visual feedback.

Two sets of scores could be used. One, to reward the better fisherman, would be based on a number of fish caught and how much they are worth. The other score would be to reward the player that answered correctly more times (in practice who did the most and better word discrimination, in the case of the minimum pairs). This would make being attentive and answer correctly worth more to a player.

The number of points each catch is worth should be more evident, through the use of auditory cues. At the moment a voice can be heard saying “You caught a Fish. It’s small”. The voice should say “You caught a fish. It’s small. It’s worth X points!”

Similarly, the voice should also say, after some interaction from the player (successful catching a fish and discriminating it; successful catching a fish but unable to discriminate it; unsuccessful catch- crab or octopus) the number of points the player has, at that moment.

Also what the voice says and what is written on screen has slight differences that should be addressed. For example, the voice says (in Portuguese) – “Tenta de novo!” and what appears written is “Tenta outra vez!”.

At least one SLT felt that it would be interesting and would help with the immersion to see a representation of the fishing pole on screen, to have an idea of its (relative) position.

9.4. General conclusions

The Fishing Game or rather what can be produced with the concept behind it can be extremely modular and versatile. A need and desire for similar devices clearly exist in the SLTs and KTAs alike.

However, certain aspects should be improved in order to have an even better product. There should be, from the “get go” more tests with users that would produce more iterations, of all aspects of the prototype (physical and software). A multidisciplinary team that included children, SLTs, KTAs and even parents as codesigners would allow the production of an end product suitable to respond to everyone’s needs and desires.

9.5. Future Work

From the reading of several papers and the processes involved in the creation and building of the Fishing Game prototype, ideas, wishes and needs arose. They could help in making a better and final product and are summarised below.

9.5.1. Taking the Fishing Game into a bigger pond

The Fishing Game, by its characteristics and value as a tool for SLTs, KTAs and children in general, deserves to keep on improving and expanding, to really help and have an impact in someone's life.

Because of that preliminary talks have already taken place to create a (national) brand by the University Technology Transfer Unit (UATEC) and the author.

9.5.2. Strategies to publicize/advertise the project

A website with the list of materials, costs, steps/how-to's, as well as a GitHub repository will be made available to everyone, as an open-source project, with an open-source license like MIT, for example.

A GitHub page will be created (as well as a dedicated domain), with a project summary, an issue tracker, a mailing list and the necessary documentation and readme files. Information on how to better proceed can be read in a blog post and the comments it got[21].

Promote the project internally, through the University of Aveiro newsletter as well as departments and investigation units own newsletters. Use and create social accounts for the project and feed them with news and updates in a regular fashion.

Advertise in the proper places for this kind of projects, like the website "Hacker News[22]", "Hacker Noon[23]", "The Changelog[24]" or "Sourceforge[25]".

This will allow not only the project to stay alive but to gain visibility while being constantly improved. The only request the original author has is that people share data (for example, country, type of SSD or why they are recreating the Fishing Game) to be used in future academia works, such as papers and a PhD.

[21] This post can be accessed at https://blog.smartbear.com/open-source/how-to-turn-your-pile-of-code-into-an-open-source-project/
[22] Available at https://news.ycombinator.com/
[23] Available at https://hackernoon.com/
[24] Available at https://changelog.com/
[25] Available at https://sourceforge.net/

9.5.3. Steps towards a final product

In terms of prototype building, future work should address some shortcomings of this dissertation, due to time constraints, bugs and other issues. It would be beneficial to:

- Have a professional designer/illustrator with some background in illustration for children creating all the graphical assets of the prototype (both physical and digital);
- Research on the use of colour. Fish and remaining parts could/should be coloured to be more attractive and easier to identify;
- Treasure Chest Rev.03 - Implement the LCD monitor – on the TC lid and the Raspberry Pi – beneath the "gaming area". This will allow the artefact to be truly a self-contained (minus the power needs) unit;
- Research and experiment with different materials and textures for different parts of the prototype. This would bring into play a broader range of tangible qualities that could further improve the intervention, through a richer immersion, playability and engagement;
- Have more inputs from the objects: the fishing pole reacting to a "fish" caught – use of vibration motors; the "sea" moving with waves according to the game level and difficulty, among others;
- Implement the self-updating and tamperproof reward badge as well as the avatar (both coexisting in the physical and digital world);
- Implement and allow the players to choose and customize their in-game avatar and the fish/images colours and numbers; This would allow for extra difficulty levels (a game with more than one octopus, for example). A certain minimum number of fish should always be present to allow the SLT a more prolonged intervention;
- Fish and remaining figures must be able to cope with the stress of repeated use – sturdier figures with fewer parts susceptible of breaking up are needed;

- Research and possibly implement the use of a newer and more capable RFID Reader, able to read multiple tags at the same time, at greater distances;
- Creation of an easy to check the "Top Scores" board and the chance to upload your badges/rewards to an online portfolio/social community of choice;
- Implement MongoDB and its connection to the activity, website and app;
- Implement the web/app reinforced with the creation of a suitable back office area for the SLTs with access to data from their sessions, in graph form, that can easily be transformed into an intervention report;
- Implementing different types of badges/rewards – not necessarily tied with SSDs – to further increase the game aspect of the activity. For example, a reward for "Fastest fisher" or "Most fishes caught";
- Keeping the maritime theme, the cables – from the TC into the Fishing Basket(s), power outlet and speaker - can be disguised as octopus's tentacles with some cloth and a wire to do some bends;
- Implement the "World Fish Tournament" idea: the players go around the World fishing and collecting points. Difficulty would show through use of rougher or calmer seas;
- Eventually, a skill-balanced challenge (different skill level players would face a different challenge in the same game) would be an interesting addition (Kraaijenbrink, Van Gils, Cheng, Van Herk, & Van Den Hoven, 2009) if the SLTs and KTAs/parents would consider it viable. This would allow the activity to cater to a larger public and have a longer "life expectancy";
- If a single Fish Basket design is to be maintained, implement a "can of worms" – small objects to hook into the tip of the fishing pole. These objects – "worms" – can have an associated RFID that identifies the player, thus

eliminating possible mistakes of to whom attribute points. The system as is is not capable of that. This would also allow to:

- Create a different rule or change the gameplay. If a player catches a certain figure he/she can play again or be out of play for a certain number of times;

» Adjust the rules to the eventuality of more than one image being caught at the same time, as well as different game scenarios or possibilities.

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Attachments

A1 – Informed consent declaration;

A2 – Parents text informing about the exploratory test goals;

A3 – Observation Grid;

A4 – Open questions questionnaire;

A5 – Rules of the Fishing Game;

A6 – Fishing Game diagram;

A7 – Fish and figures collection;

A1 – Informed consent declaration

DECLARAÇÃO DE CONSENTIMENTO

Considerando a "Declaração de Helsínquia" da Associação Médica Mundial

(Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996 e Edimburgo 2000)

Desenvolvimento de Materiais/Instrumentos de Intervenção em Terapia da Fala

Eu, abaixo-assinado, (nome completo) --

Responsável pela criança (nome completo) --
-- , compreendi a explicação que me foi fornecida acerca da investigação que se tenciona realizar, bem como do estudo em que será incluído. Foi-me dada oportunidade de fazer as perguntas que julguei necessárias, e de todas obtive resposta satisfatória.

Tomei conhecimento de que, de acordo com as recomendações da Declaração de Helsínquia, a informação ou explicação que me foi prestada versou os objectivos, os métodos, os benefícios previstos, os riscos potenciais e o eventual desconforto. Além disso, foi-me afirmado que tenho o direito de recusar a todo o tempo a sua participação no estudo.

Por isso, consinto que lhe seja aplicado o método, o tratamento ou o inquérito proposto pelo investigador.

Data: ____ / __________________ / ____

Assinatura do Responsável pela criança: ____

O Investigador responsável:

Nome:

Assinatura:

A2 – Parents text informing about the exploratory test goals

Muito obrigado desde já por se ter disponibilizado para tomar conhecimento deste estudo, a realizar no âmbito do Mestrado em Comunicação Multimédia da Universidade de Aveiro.

A fim de que possa tomar um decisão informada, mas não podendo dizer tudo para que não haja enviesamento dos resultados que se esperam obter, aqui fica uma breve descrição do que se irá passar:

- Será pedido à criança, por uma Terapeuta da Fala ou por uma das suas educadoras ou auxiliares, para jogar com ela o jogo da pesca (de tabuleiro, com cana de pesca magnética).
- A criança jogará e ser-lhe-ão perguntadas algumas palavras à medida que apanha os peixes. No final o observador irá perguntar à criança se gostou de jogar, o que gostou mais, o que gostou menos, o que não percebeu e porquê.
- Poderá ser pedido à criança que jogue com outra criança também.

No total não deverá tomar mais de meia hora do tempo da criança.

De novo, muito grato pelo tempo e atenção disponibilizados.

Cumprimentos,

Joaquim Santos

A3 – Observation Grid

GRELHA DE OBSERVAÇÃO

IDENTIFICAÇÃO DO INTERVENIENTE			**Duração**:
Tipo	**Nome**	**Idade**	**Data**

DIMENSÕES	PARÂMETROS	OBSERVADO		NÃO OBSERVADO	*Observações*
		Sim	**Não**		
Usabilidade do protótipo/jogo	Identificação do jogo e respetivo objetivo				
	Identificação dos componentes do jogo (baú, cesta, peixes, cana, etc.)				
	Identificação dos elementos de jogo e respetiva função (botões, aberturas, etc.)				
	O interveniente sabia quando era a sua vez de jogar/participar				
	Os tempos de resposta dos elementos de jogo estão adequados				
Características do protótipo/jogo	As dimensões do jogo, respetivos componentes e elementos, são adequadas				
	As cores dos elementos de jogo são adequadas				
	O material utilizado na construção do protótipo/jogo convida ao manuseio				
	O protótipo/jogo é robusto				
	O feedback ao longo do jogo é eficaz.				
	Os constrangimentos físicos existentes funcionam.				

DIMENSÕES	PARÂMETROS	OBSERVADO		NÃO OBSERVADO	*Observações*
		Sim	**Não**		
	O mapeamento das teclas e suas ações são consistentes e corretamente apreendidas e utilizadas.				
Gamificação	O interveniente conseguiu/quis jogar/participar até ao fim				
	O interveniente quis jogar mais				
	O interveniente esteve motivado e interessado				
	O interveniente sabia a sua pontuação, em qualquer momento				

NOTA: Os parâmetros de observação podem não ser aplicáveis (NA) a todos os intervenientes.

A4 – Open questions questionnaire

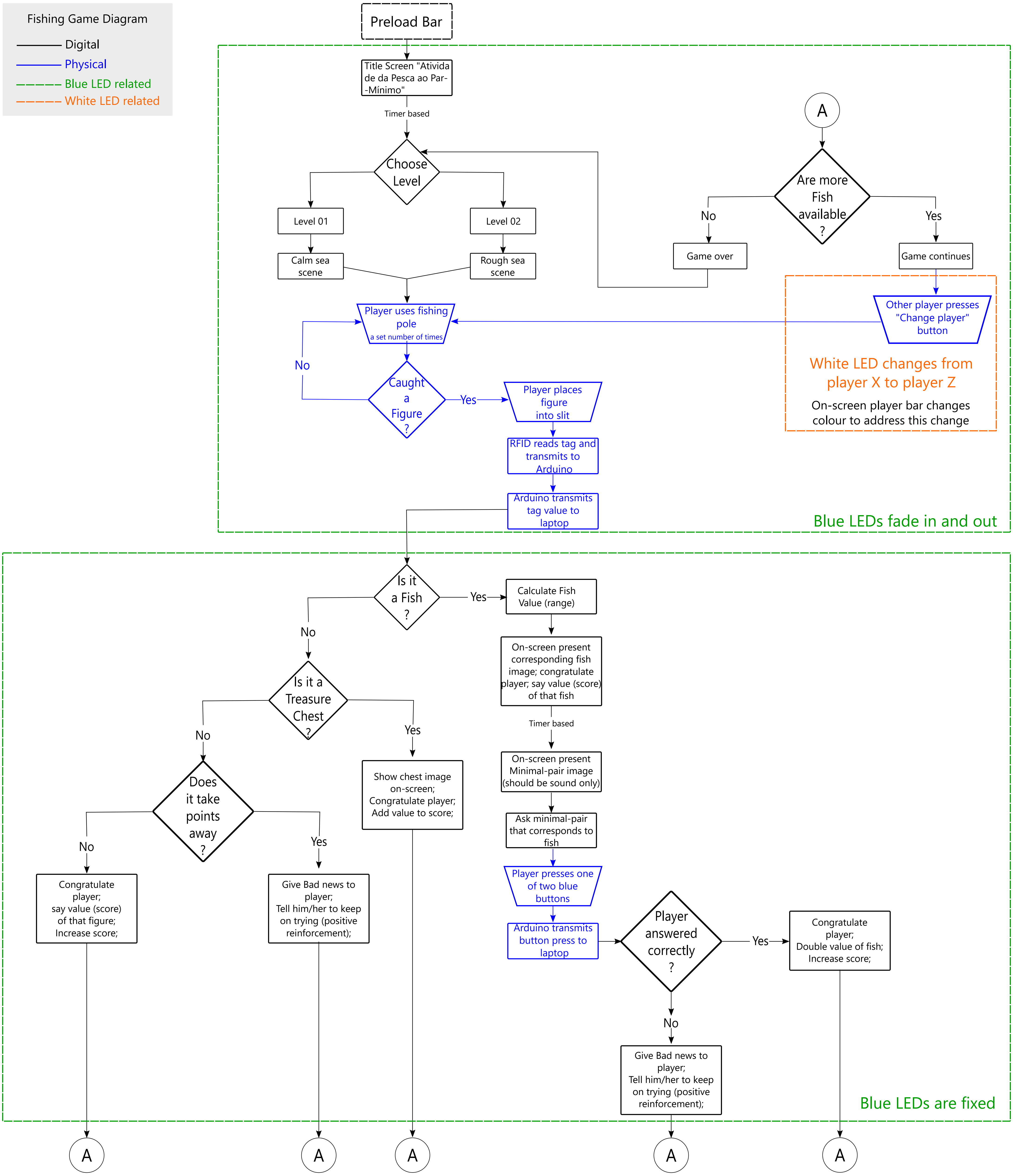
Questões adicionais (abertas e exploratórias): **Crianças**	
Gostaste de jogar este jogo?	
O que gostaste mais?	
O que gostaste menos?	
Voltavas a jogar?	
Terapeutas, Educadoras e Auxiliares	
O que alterava em relação ao protótipo/conceito?	
O que alterava em relação ao jogo/atividade?	
Se pudesse como adaptaria/expandiria o protótipo?	
Gostava de ver mais jogos como este?	
Se sim, quais?	
Se não, porquê?	
Gostaria de te uma área privada onde pudesse gerir as sessões e dados dos utilizadores?	
Gostaria de ter um registo das sessões e apresentação dos resultados?	
Que sugestões/melhorias gostaria de deixar?	

A5 – Rules of the Fishing Game

Regras do jogo

- Todas as figuras vão para dentro do "lago" (que é o baú).
- Os jogadores jogam vez à vez tentando pescar um peixe com a cana, sem olhar para dentro do baú.
- O número de tentativas/vezes que um jogador joga é a definir entre os jogadores, antes de iniciar a atividade.
- O jogador é responsável por mudar (usando o botão branco) para a sua vez.
- Os botões azuis permitem escutar a palavra identificada pela imagem ANTES de se introduzir um peixe. Após introduzir um peixe os botões azuis permitem escolher qual a palavra que pensamos ser equivalente ao que ouvimos.
- O valor das figuras é aleatório, dentro de uma escala existente. O seu valor será calculado durante o jogo, pelo software. Mesmo uma figura "má" poderá valer pontos para o jogador. Mas também poderá subtrair pontos ao jogador, caso este tenha pontos.
- A resposta/identificação correta do par-minímo em questão duplicará o valor do peixe apanhado.
- O jogo termina quando todos os peixes tiverem sido "pescados". Não é obrigatório pescar todas as imagens (baú, caranguejos e polvo).

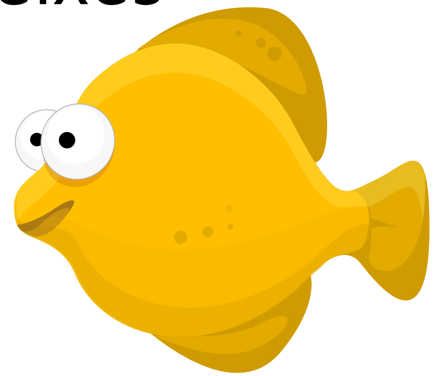
A6 – Fishing Game diagram



Fishing Game Diagram
Digital
Physical
Blue LED related
White LED related
Preload Bar
Title Screen "Atividade da Pesca ao Par--Mínimo"
Timer based
Choose Level
Level 01
Level 02
Calm sea scene
Rough sea scene
Player uses fishing pole
a set number of times
Caught a Figure ?
No
Yes
Player places figure into slit
RFID reads tag and transmits to Arduino
Arduino transmits tag value to laptop
A
Are more Fish available ?
No
Yes
Game over
Game continues
Other player presses "Change player" button
White LED changes from player X to player Z
On-screen player bar changes colour to address this change
Blue LEDs fade in and out
Is it a Fish ?
Yes
Calculate Fish Value (range)
On-screen present corresponding fish image; congratulate player; say value (score) of that fish
Timer based
On-screen present Minimal-pair image (should be sound only)
Ask minimal-pair that corresponds to fish
Player presses one of two blue buttons
Arduino transmits button press to laptop
Player answered correctly ?
Yes
Congratulate player; Double value of fish; Increase score;
No
Give Bad news to player; Tell him/her to keep on trying (positive reinforcement);
No
Is it a Treasure Chest ?
Yes
Show chest image on-screen; Congratulate player; Add value to score;
No
Does it take points away ?
No
Congratulate player; say value (score) of that figure; Increase score;
Yes
Give Bad news to player; Tell him/her to keep on trying (positive reinforcement);
Blue LEDs are fixed
A
A
A
A
A

A7 – Fish and figures collection

Peixes



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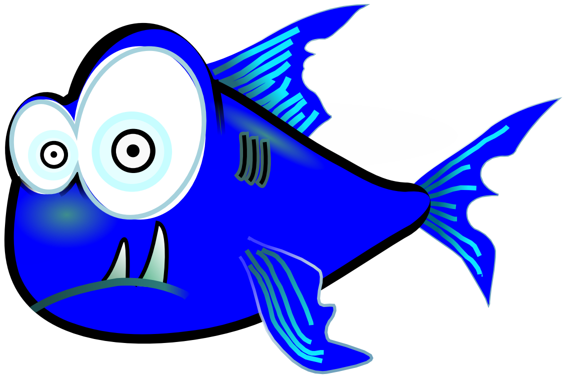

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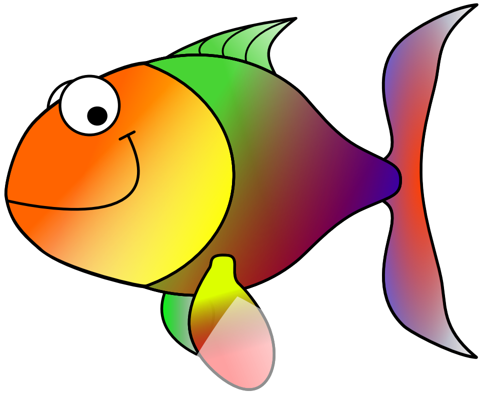

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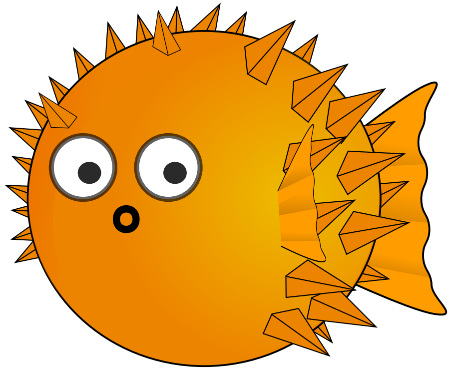

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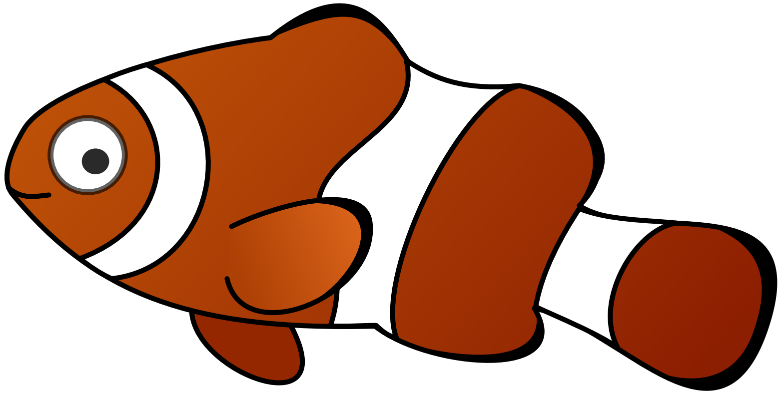

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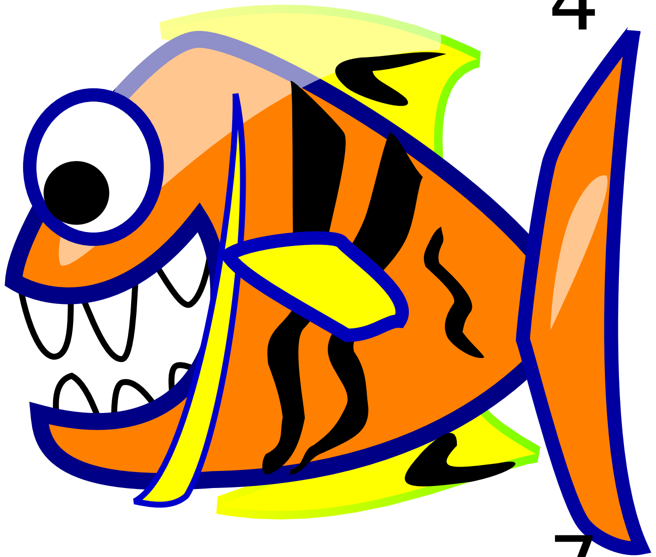

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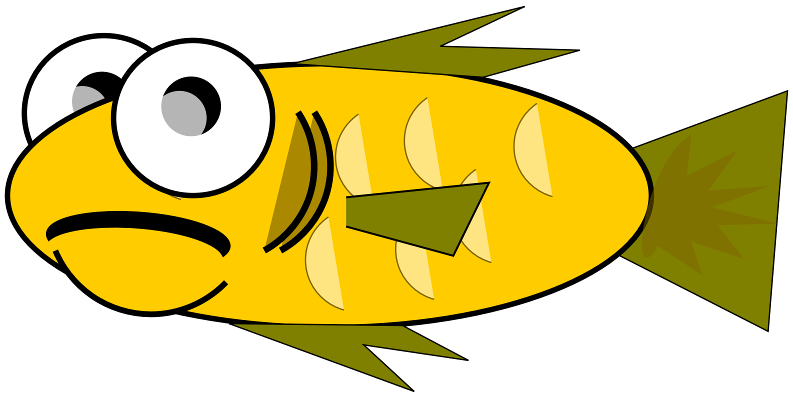

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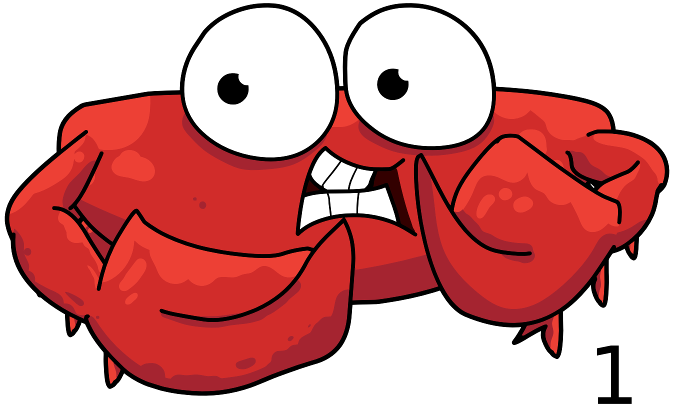
Caranguejo



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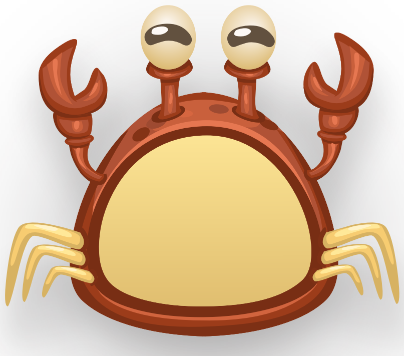
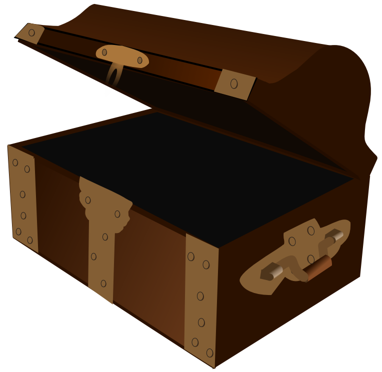


2

Baús


1


2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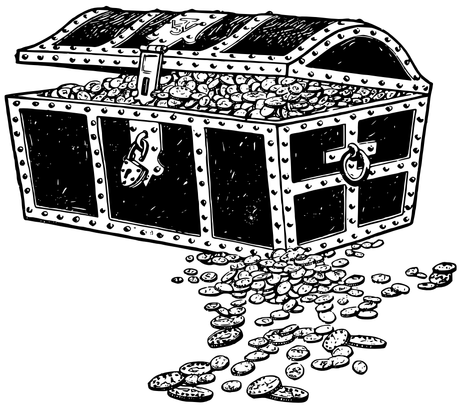
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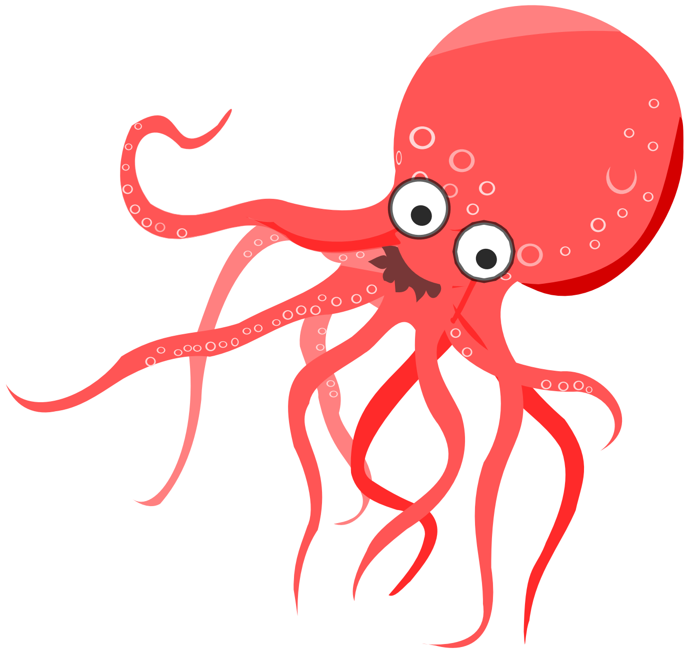
Polvos



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