

Luca Fleres

RAW OF AN APPLICATION FOR CHILDREN WITH  
AUTISM AND HEALTH CARE PROFESSIONALS

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# RAW OF AN APPLICATION FOR CHILDREN WITH AUTISM AND HEALTH CARE PROFESSIONALS

Fleres, Luca

Satakunnan ammattikorkeakoulu, Satakunta University of Applied Sciences

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The purpose of this thesis was to create the theoretical background and collect scientific evidence, to design the raw model of an application for children with autisms and health care professionals. The thesis justifies the use of rhythmic auditory cues as an effective tool that could be used, as key feature in the possible future creation of the designed application. A proof of concept is presented and opened up in this document, to clarify the main idea.

The topic what chosen after a meeting with a company located in Espoo, called Kuori tech. The company operates in the e-Health, and in cooperation with health care professionals. They brought up the need for a tool designed specifically for that group. The theoretical knowledge covered by the author's research, includes morphological and structural studies about autistic people's brain, and how their brain function and operates in comparison with typically developing people. The research also covers studies about the use of multi-stimuli input, with the aim of observing functional activation of the different brain areas in autistic people, always in comparison to typically developing subjects. The outcome of the author's research, showed that multi-stimuli, produces a brain response that is almost identical to typically developing people.

This theoretical knowledge was then combined by the author and applied into a practical creation of a raw model, where the auditory stimuli was used as a cuing system to facilitate motor planning during the observation of a specific motor skill, presented in a visual form.

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## 1 INTRODUCTION

Technology is everyday more present in our lives, replacing or simply adding some comfort to our daily routines. E-health is doing the exact same thing, just in a more specific field of work. It is therefore a must that we can adapt and take advantage of the resources offered to us as health care professionals.

It is no secret that evolution requires adaptation, and this applies to all the fields, including health care.

The author personal experience in researching applications and software designed for health care professionals, brought up a deficit concerning “autistic people and motor skills” applications. There are tens of software designed to support and help the socio-emotional aspect of the syndrome, but the author could not find any application that would help with gross motor skills.

The other fundamental aspect, was to find something that was designed for professionals, and not for the regular user, and also here, the author felt the need for something that would combine the two sides of this coin.

Coding is the language of a virtual world, a world in which we leave more and more, and this concern particularly younger generations, but involves all of us in some measure.

## 2 AIM AND OBJECTIVE OF THE THESIS

The aim of this thesis is to create a tool designed specifically to help autistic children reaching some very important gross motor skills, which have been seen they have a delay to achieve when compared to typically developing children.

The objective of the thesis was to combine therapeutic evidence based knowledge with technology and computer graphic, to design a raw model for an application.

The application was developed in the form of a proof of concept, it is not a finished product, however the prototype was designed for the YETI tablet possible use, a 55 inches tablet already in use in several rehabilitation centres. The main characteristic of the tablet is the possibility to interact with it by using external objects (ex. throwing a ball on the screen). To keep the project strictly related to physiotherapy, the author has focused only on one aspect of the autistic spectrum disorder, the gross motor skills development of children aged 5-10.

### 3 AUTISTIC SPECTRUM DISORDER

Autistic spectrum disorder (ASD) is a developmental disorder that is generally diagnosed already during the first two years of life and that affect the person throughout the whole life span (Website of National institute of mental health, 2019).

Common difficulties among people affected by ASD are difficulty with communication and interaction with other people, limited interests and obsessive/repetitive behaviours, clumsiness, difficulties in interpreting emotions and facial expressions, difficulties in interpreting meaning of a word, balance and coordination problems, gate abnormalities (Kupfer, 2015).

Autism is defined as a spectrum disorder, because it has such a big variety of symptoms that affect different domains as well. From social interactions to language impairments, to emotional status and anxiety, to deficit in motor skills. The diagnostic procedure can happen during the early stages of life or it can happen during adulthood, which makes it more complex because it could be confused with other mental disorders (Website of National institute of mental health, 2019).

Previous to the year 2013 the diagnosis of ASD was divided into three possible diagnoses, which included Autistic disorder, Asperger's' syndrome and Pervasive developmental disorder not otherwise specified (PDD-NOS). Nowadays the literature has changed the diagnoses to Autistic Spectrum Disorder (ASD), which incorporate all the previous diagnoses (Website of National institute of mental health, 2019).

### 3.1 Therapeutic approach

Applied behavior analysis (ABA), is the most recent intervention approach for children diagnosed with ASD. The goal is to reduce bad attitude and repetitive bad behavior, and reinforce the good attitude and behaviors by rewarding the children with positive feedback in a systematic and predictable way, and by breaking down the tasks into simpler steps and moving progressively to the goal. (Tecklin, 2015: 414).

The therapist evaluates the patient's behavior, determining which are the actions and behavior that need to change or improve, based on the age and social status of the patient. The therapist can spend even up to 20 hours per week with kids under 4 years old, and the approach used is based on proven theories of learning behavior (Website of Association for Science in Autism Treatment, 2019).

Parents and school members have to be involved in the therapy, as to assure successful outcome, ABA therapy needs a constant monitoring and reassessment with consequential adjustments in the strategy (Reichow, 2012)

### 3.2 Therapy environment

Due to the diversity in sensory and tactile processing in people with ASD, it is important that the therapist creates the right environment for the children. If the child is experiencing fear of anxiety, he will not be open to learn. So, it is important that the child feels safe and comfortable within the treatment environment (Tecklin, 2015: 415).

Setting up the appropriate environment for a kid with autism, it is part of the therapy. As said above, they do process sensory information, sounds, colors and visual input in a different way, and some simple things might end up being overloading for them. A study conducted in France in 2016 was showing the atypical color preference in children with ASD, and what came up from the study was that there were differences in color preferences between the ASD group and the typically developing (TD) group, as some of the colors were perceived as sensory over-loading due to hyper-sensation in the ASD group. (Grandgeorge & Masataka, 2016).

### 3.3 Modalities of treatment: multimodal rather than unimodal

A study conducted in the US by Hames, with the goal of understanding how sensory processing is happening in the brain of ASD people, used Electroencephalography (EEG) and magnetic resonance imaging (BOLD fMRI) to observe the brain when exposed to cross modal sensory stimuli. Visual and auditory stimuli were provided simultaneously from different sources with a quite amazing result, as they concluded that “in ASD, combined audio-visual processing is more similar than unimodal processing to NTs” (Hames et al, 2016).

To repeat the same concept with simple words, people with autism are slower to respond to stimuli when these are isolated, but when the stimuli are combined, as in this case it was with the auditory and visual input, they overcome that processing impairment and appear to be almost at the same level with typically developing peers (Hames et al, 2016).

### 3.4 Rhythmic auditory cues

Rhythmic auditory cues refer to an auditory sound signal with a given regular interval, as it could be the sound from a metronome. “Applying external auditory cues provides the pace for planning the motor task, and at the same time it reduces the need for internal planning of the action, with the result of facilitating the preparation of the movement” (Hardy & Lagasse, 2013: 19).

Auditory cues stimulate a response from the spinal motor neurons, this response is “mediated at the reticulo-spinal level by auditory to motor efferent circuitry, which has particular relevance and applicability to clinical situations where motor planning is an issue” (Schneck, 2015: 285). The use of rhythmic auditory cues is a training technique that can help coordinate the sensory perception and motor planning of individuals whom suffer a motor planning deficit, as in the case of ASD people (Thaut & Abiru, 2010: 263).

Auditory cues have been widely used among rehabilitation processes in all sort of scenarios, however, rhythm cueing used to help motor functions in children with autism

is still quite a new field, and it just recently started to be explored (El Shemy & El Sayed, 2018).

#### 4 BRAIN CHARACTERISTICS IN AUTISM SPECTRUM DISORDER

Studies conducted with Magnetic Resonance Image (MRI), have demonstrated in many ways that there are neural developmental factors behind autistic spectrum disorder (ASD). Over the past decade, many studies conducted through structural MRI (sMRI) have also shown some abnormalities in the white and grey matter and also in some regions of the brain between autistic children and typically developing (TD) children. Attention has also been paid on the possible abnormal anatomy of the brain, in order to establish if there is a morphological and volumetric difference during the development in individuals with ASD. (Sungji Ha, 2015).

The finding that has the most evidence, is an abnormal brain growth in ASD children aged 2-4 years old, particularly the frontal and temporal lobe seem to have enlarged volume compared to TD children, this is then followed by a normal grow and possibly even a decline in growth around 10-15 years of age (Sungji Ha 2015).

The reason for this initial enlargement of the brain is still unclear, however recent studies have shown that this atypical enlargement might be caused by a faster expansion of the cortical surface (Sungji Ha 2015).

Neurologically, functional MRI and magnetoencephalography, allow researchers to explore possible differences in the brain functions of ASD. Many studies have shown that depending of the age of the subject, differences in the structure of the brain might occur. That makes necessary to observe and study the changes of the brain throughout the lifespan (Sungji Ha, 2015).

Functional MRI have underlined hyper activation of the brain to interpret meaning of a word in individuals with ASD, hypo activation of the brain to interpret facial expressions associated with gestures during talking, hypo activation in brain regions related



to visual-motor sequence learning (it makes it difficult to challenge themselves with new patterns), which brings to those repetitive and compulsive behaviours, abnormal sensory processing due to hyper activation of bilateral occipital cortex, increased functional connectivity (FC) in toddlers and children, specifically in the frontotemporal, motor, and visual area, hypo connectivity in adolescents and adults during interpreting language, face processing including emotional face, visual-motor coordination, and hyper connectivity in visual-motor processing. These observations lead to the conclusion that ASD presents abnormality in the intra-connection between different areas of the brain, rather than isolated brain regions. (Sungji Ha, 2015).

## 5 HOW AUTISM AFFECTS MOTOR SKILLS

Autism is a wide spectrum, and there are several aspects of the syndrome, which differs between individuals, “if you met an autistic person, you only met that one specific individual” (Shore). The subjectivity of the syndrome characteristics, makes this project a real challenge, because it is not possible to make a product that fits everyone. However, studies have proven that there are some patterns, specially concerning the development of motor skills. Children with autism have shown to have a series of motor impairments, that includes poor coordination, clumsiness, problems in gate, abnormal execution of motor skills and a delay in planning the motor task, due to neuro-functional abnormality of the cerebellum. They suffer anticipatory motor deficit, that results in bad coordination and difficulties executing the movement compared with other children without the syndrome. To say it simply, they take more time to prepare and execute the task (Kaur et al, 2018).

Motor skills impairments and motor skill developmental delay, are not a diagnostic factor for ASD. However, evidence shows that children with ASD also have some serious motor skill delays and motor difficulties which causes have to be looked outside the neuro cognitive domain (McPhillips et al, 2014).

Motor skill deficits commonly observed in children with ASD include delays in gross and fine motor skills, gait problems related to proprioceptive abnormalities and the use

of sensory feedback, which also leads to poor posture, coordination and execution difficulties, as already mentioned above (Holloway, 2018).

Out of all the aspect of ASD affecting children, motor skill is the most under estimate domain. Recent developmental theories, underline the importance of a constant interaction between developmental domains for the children to develop properly, as the domains do not develop in isolation, as stated in the dynamic systems theory.

It is important to understand this correlation between domains, and to act when the children are still aged 3-5 years old. It is shown that there is a correlation between motor skills delay and social interaction. The person needs all the domain to be in synch in order to develop. (Holloway, 2018).

## 6 THE IDEA BEHIND THE APPLICATION

Reproducing a movement from a series of images, might seem a very easy thing to do, but for people with ASD it can be challenging. This raw model, wants to provide the health care professional with some multi-stimuli simple games, built up following the most recent discoveries in motor function delay about ASD children.

The author has limited the developing of this prototype to a proof of concept, as the resources available at the moment do not allow to develop it any further.

What comes out pretty clearly from the studies just mentioned in the previous paragraph, there is a neurological and structural difference in people with ASD. To simplify the concept, we could say that the brain make confusion when it comes to follow certain patters that are normal to TD people.

The concept of neuroplasticity here comes very handy and it becomes the key for the creation of this raw model. The aim is to re-educate the brain, to make it follow those same patterns or to use neuroplasticity to create new patterns that lead to the same outcome. ASD people process video and auditory information in a way that differs

from TD people, especially when those stimuli are provided independently from each other. (Hames et al, 2016).

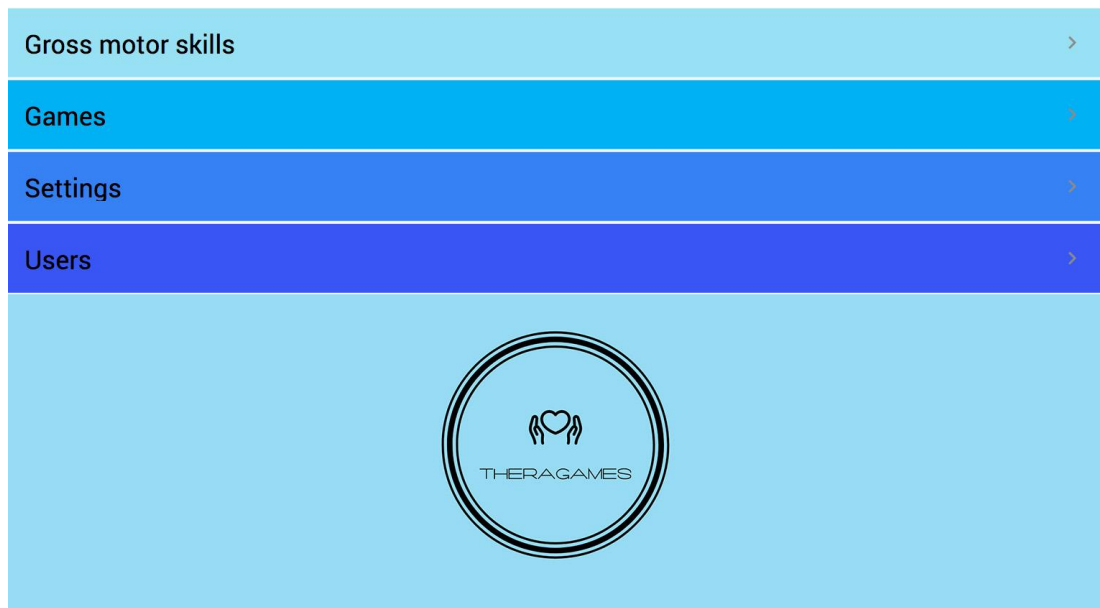
A study done by Hames in 2016 about sensory stimulation in autistic people, used Electroencephalography (EEG) and blood oxygen level dependent functional magnetic resonance imaging (BOLD fMRI) to assess the neuro-correlation of sensory processing of visual and auditory stimuli in 11 adults with autism (ASD) and 10 neuro-typical (NT) controls aged 20–28 (Hames et al, 2016).

The study concluded two main observations. First, the ASD group showed more differences in processing auditory stimuli rather than visual when compared to TD group, this could be seen with the use of both EEG and BOLD fMRI. Second, the presentation of multimodal stimuli minimized the differences seen between the ASD and NT groups; as evidenced by EEG and BOLD fMRI. “This study led to the conclusion, that simultaneously providing audio-visual stimuli to people with autism, produces a sensory response that is most similar to typically developing subjects.” (Hames et al, 2016).

## 6.1 Interface

The interface showed in picture 1, has been designed by the author to be intuitive and fairly easy to use. Although it is not the final version, it presents some of the main features already.

The gross motor skill included to this point is the overhand throw, and the games included are also a practical implementation of the overhand throw.

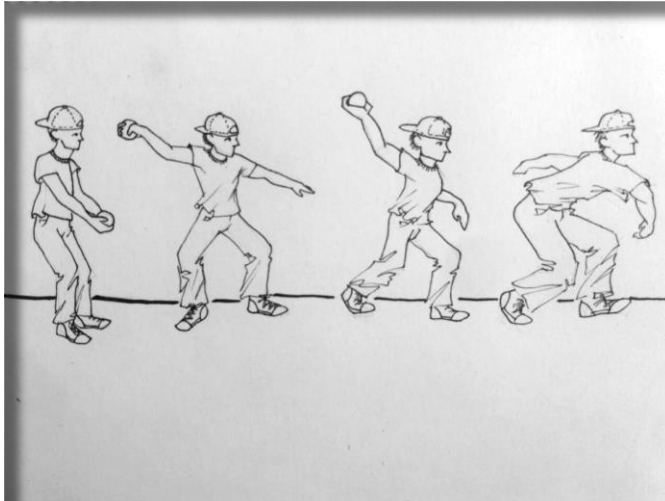


Picture 1. Simple and user-friendly interface created by Luca Fleres (2019).

## 6.2 Gross motor skills

As mentioned above, the motor skill chosen as proof of concept, is the overhand throw, here explained in pictures. The movement is first shown as a whole (picture 2), and then broken down in different stages. Specifically, the person is facing the target and the

body is at about 90 degrees from the target (picture 3); then side turning and taking a step backwards to ensure balance and have more range of movement, with the throwing shoulder externally rotated (picture 4); the following step requires a twist from the back foot, which is collecting the power from the ground and a weight shifting of the whole body towards the target, which initiates the throw (picture 5); and eventually the release and follow through, which main purpose is to decelerate the throwing arm (picture 6).

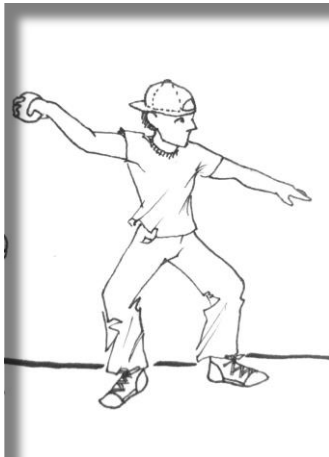


Picture 2. Designs from courtesy of Christina Bendandi (2019). Four stages of overhand throw.

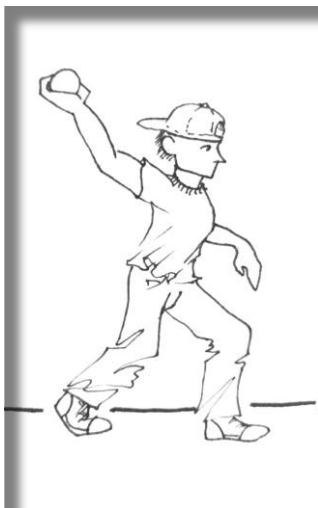
The concept is very simple. The stages of a given movement, are first broken down into smaller steps:



Picture 3. Step 1. Face target



Picture 4. Step 2. Turn and step (T position)



Picture 5. Step 3. Twist and throw



Picture 6. Step 4. Tickle knee

The reason why the motor skill is broken down is to counter attack the hyper activation of the bilateral occipital cortex, which process the sensory information. Less information is processed easily (Sungji Ha, 2015).

At this point, the health care professional is introducing the movement to the kid, in a sequence of silent images. The innovation consists in the introduction of auditory cues simultaneously provided together with the sequence of images, which velocity can be adjusted accordingly with the ability of the player.

External cues, specifically rhythmic auditory cues, can provide the motor centres of the brain with that input that quicken the motor execution and synchronization (El Shemy & El Sayed, 2018).

The goal is exactly this, to minimize the differences in sensory and motor processing, and this same concept can be applied to a wide variety of movements and motor skill. Following the instructive part of the process, in which the player practices the movement with both visual and audio stimuli, there is the implementation of it. Each motor skill, will have some practical and fun games to implement and practice the skill.

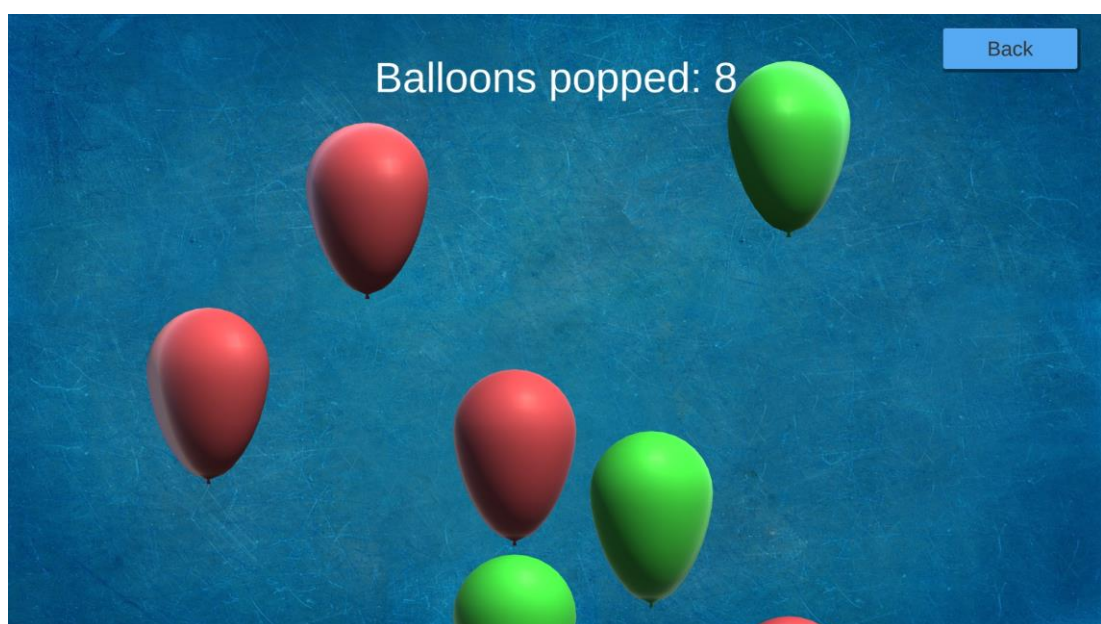
As proof of concept, two throwing games have been designed, a scoring game with a goalie, and a balloon popping game. The target group can vary, but these games are thought for 5-10 years old children, who are starting to develop and practice the chosen motor skills.

### 6.3 Implementation of the motor skills, the games

The first game presented for the implementation of the skill is a throwing game that as the aim of targeting floating balloons in order to pop them (picture 7). The score will be present on top of the screen (picture 8). The velocity and number of balloons can be set and adjusted to fit the skill level of the player and also to add progression. Progression, in fact, is one of the element that would be included, the games would evolve from a very basic level to a harder level. This can be considered a beginner game.



Picture 7. Balloon popping

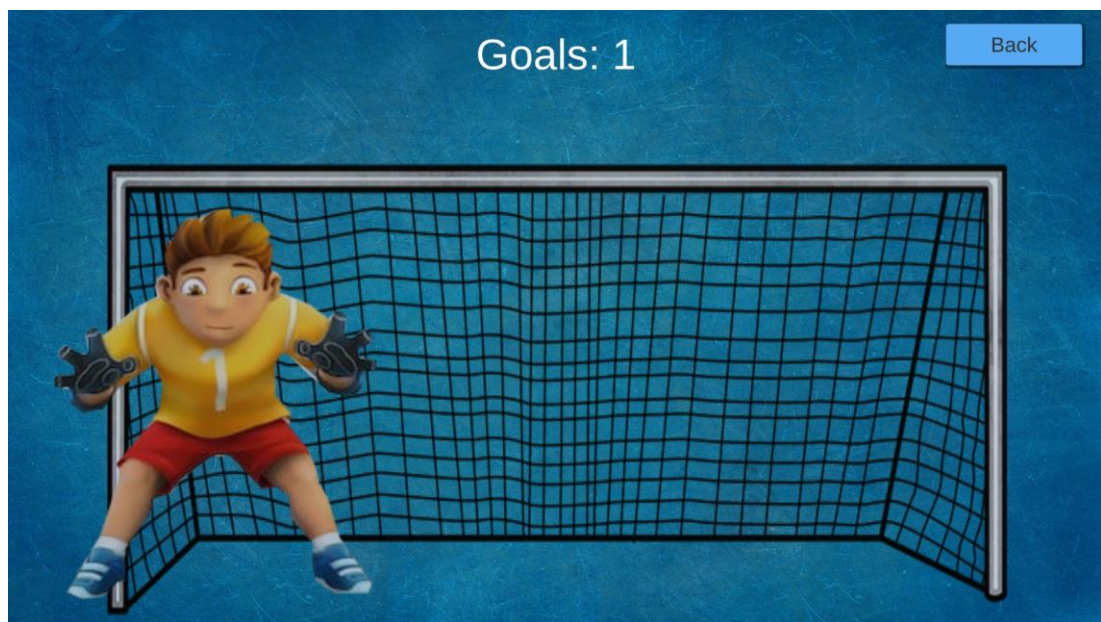


Picture 8. Balloon popping 2. Score is counted in the top screen



The second game (picture 9), is also a beginner level game, but it has a more specific target (a goal), and a hostile element (a goalkeeper); therefore, requires greater eye-hand coordination during the throw compared to the first game. The objective of the game is to throw a soft ball to the screen and try to score goals avoiding the goalkeeper, which is moving from one side of the goal to the other (pictures 10-11-12).

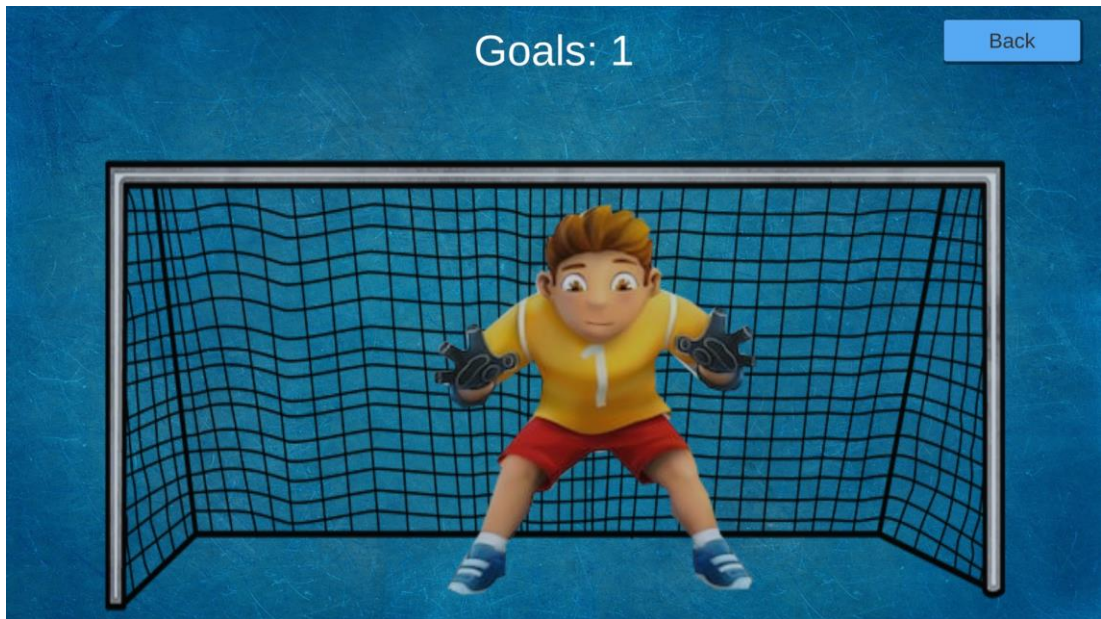
The speed of the goalkeeper can also be adjusted to have progression of the skill.



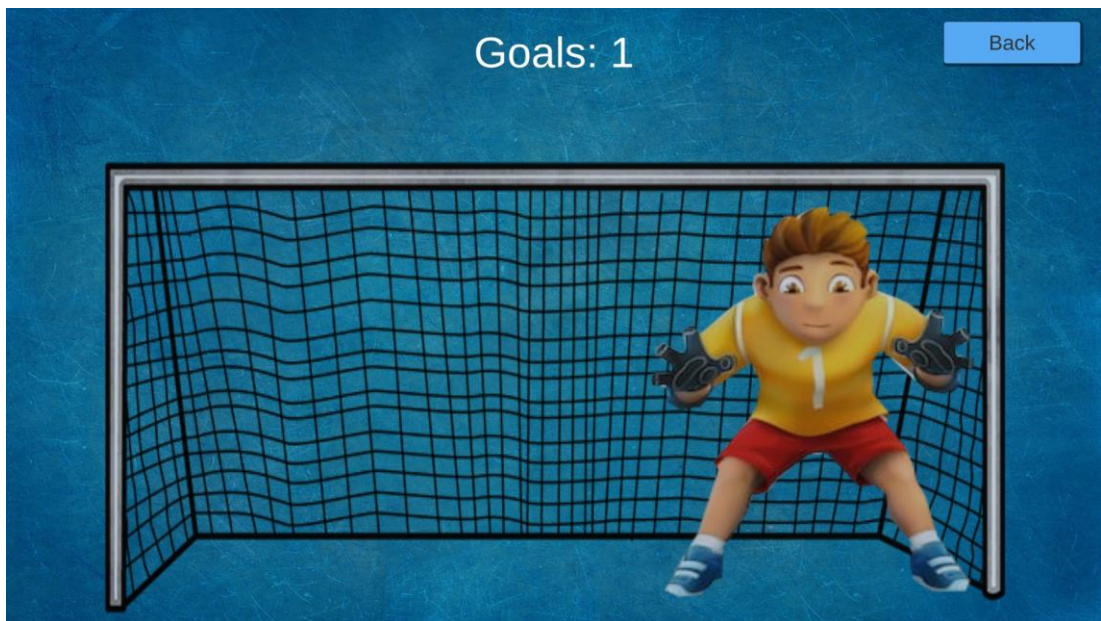
Picture 9. Goalie game 1



Picture 10. Goalie game 2



Picture 11. Goalie game 3

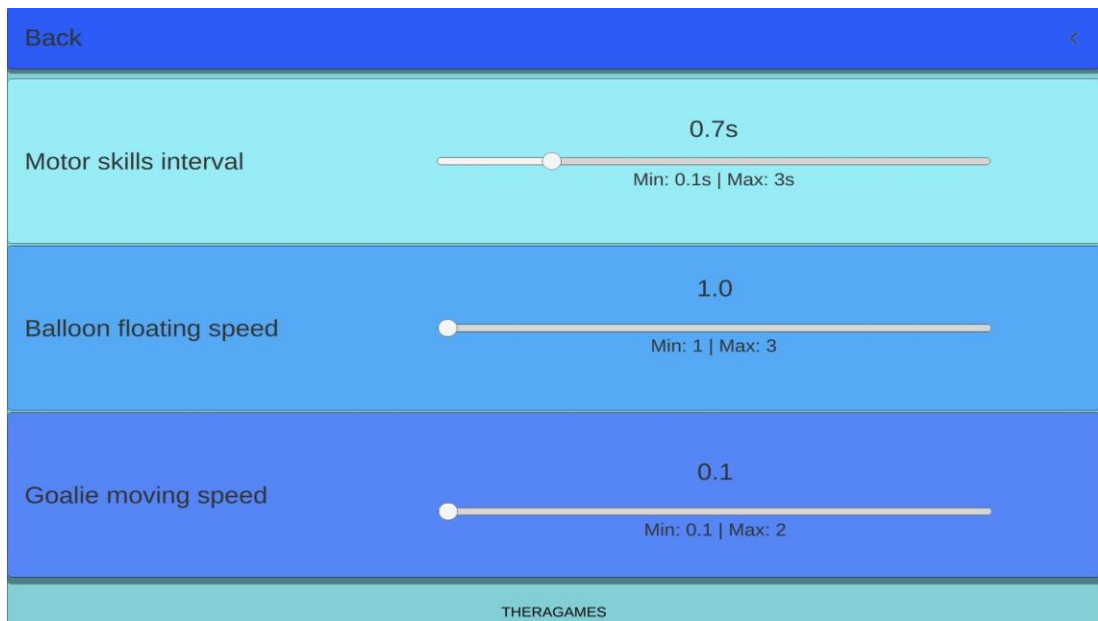


Picture 12. Goalie game 4

## 6.4 Setting options

The motor skill interval can be adjusted by the therapist, and that will automatically adjust the auditory cues as well (picture 13).

Also, the game speed can be adjusted, making it more or less challenging for the player, based on its own skills level, and allowing progression.



Picture 13. Setting options adjustable to player skills level

## 7 POSSIBLE FEATURES AND USE

The raw model of this application has been thought for autistic children but it would not be limited to that. In fact, auditory cues are used also for post-stroke motor impairment, Parkinson's disease and Huntington's disease, just to mention some other pathologies (Schaefer, 2014).

The application could incorporate a selection of different pathologies in the main menu that the health care professional can select based on the user, and have a list of motor skills, as for example “gate training for Parkinson disease”, which has widely been proven to benefit from auditory cuing in terms of gate velocity and stride length (Ghai et al, 2018).

One of the features the author wants to incorporate in the application is a realistic walking experience for anyone who is not physically able to go for a walk out in the open. A series of first person point of view videos would be filmed and collected in the application, offering a variety of different scenarios to choose from when wanting to practice some walking on a treadmill or similar equipment. The videos would offer a full immersion walking in the forest, on the beach, on a hill etc., there is little limitation to the location, and the audio would intensify the experience.

Once again, this idea is related to the use of a big screen, as the YETY tablet is, and a proper setting, with a treadmill and possibly headphones, to have a proper realistic experience. The application would offer at the same time the possibility to use auditory cues during the walking for whoever needs it, or just be an alternative way to exercise.

## 8 THESIS PROCESS AND METHOD

The table 1 presents the thesis process. It has had small changes during this last year but it has been consistent with the main idea. What inspired the author was a nord-plus abroad project where the author participated in Sweden, in 2018. The combination of technology and health care was the main topic of that course.



The method used by the author consisted in a theoretical research of scientific evidence about autism characteristics and physiological implications in the brain functionality and activity, morphology of the brain affected by this disorder, and use of external auditory stimuli effects on the brain function. This knowledge was then combined and used for the creation of the raw model that has been explained in the previous part of the thesis.

Table 1. Thesis process

First contact with Sari Merilampi, head of the welfare technology department	21.05.2018
Discussion about topic and meetings with coders in Espoo and SAMK	June-July 2018
Agreement thesis with welfare technology department	January 2019
Research theoretical background	January-March 2019
Meetings with coder in SAMK and planning of the application	March-May 2019
Creation of original graphic content and collection copyright free images	June-July 2019
Finishing up and refining both references and content of the thesis	August-September 2019
Returning thesis to tutor teacher	15 <sup>th</sup> November 2019
Presenting thesis	22 <sup>nd</sup> November 2019

## 9 DISCUSSION

The starting idea of this thesis process was to create a finished product that could have been already used, or at least shown. However, a series of unfortunate events and the actual complexity of coding a proper application, had the author limiting the whole project to a blueprint for a potential application. Therefore, the content of this thesis is different from the initial objective.

The author was still able, despite the changes in the objective, to maintain the same aims and to create some content, that can be used as a starting point for a bigger project. The topic is very wide and open to future studies and investments, both in terms of time and resources. This material and ideas the author has collected, can be used in the near future to create an evidence based application for health care professionals.

The power of auditory cues and visual stimuli is something that has a lot to be studied and tested. If this application would be developed, it would need to be tested and implemented with autistic children to have a response and a real feedback, and based on that, move forward of apply some changes.

Autistic spectrum disorder is, like the word says, a spectrum, it presents a variety of aspects and domains that are affected.

Future studies within this thesis, should focus on how those domains could be included in the application, as we mentioned the importance of domains inter-correlation in the development of the child.

Other pathologies can also benefit from auditory cues, like mentioned previously, and it opens up the need for research and study, to identify all the pathologies that can benefit from this combination of auditory and visual stimuli, and create a training therapy based on the specifics of each of them.

The importance of incorporating technology into health care is raising every day, as technology is in constant changing and evolution. There is infinite potential and the only limit is having official organizations to invest in innovation.

Throughout this study process, the author has faced several unexpected factors that have inevitably changed the planning and had required adjustments and problem-solving skills. It was a process of growth and learning that has enriched and motivated the author, and pushed him towards wanting to continue working on this projects beside the adversities.

The author personal hope is to be able to keep working on this project together with other experts after graduation, or to keep working on the project independently, as he believes that there is a still a lot to be studied and great potential content to be created.

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