TAMPERE UNIVERSITY
OF APPLIED SCIENCES

DESIGNING AND TESTING A GAZE TRACKER CALIBRATION GAME FOR SCHOOL CHILDREN

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Bachelor’s thesis
March 2018
Degree Programme in Media and Arts
Interactive Media

ABSTRACT

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Designing and Testing a Gaze Tracker Calibration Game for School Children

Bachelor's thesis 59 pages, appendices 17 pages
March 2018

The purpose of this paper is to describe what went into the process of designing a gamified gaze tracker calibration targeted at elementary school children. In the beginning, the gaze-tracking technology, the calibration process and the GaSP project are introduced. The challenge was to combine the technical and design requirements in order to create a motivating and gamified way for young children to perform a personal calibration independently.

In the project section, the design of the calibration game is discussed, as well as the user testing and the feedback analysis. Based on the testing, improvements were made to the game design. Through this process, a good understanding of the many aspects one must consider before, while and after designing a game or an app for children was gained. Working with and collecting feedback from young users gave valuable experience for further user testing opportunities.

The results show that a gamified calibration offers much better calibration results than the standard calibration method. With child users of the game mechanic based method, the calibration results were 11% better than with adults who calibrated under supervision using the standard calibration method.

Key words: gamification, gaze-tracking calibration, usability, game testing, games for children.

CONTENTS

ABBREVIATIONS AND TERMS

Human cognition	the mental process of acquiring knowledge and understanding through different interactions such as gaze.
GaSP	team of researchers specializing in Private and Shared Gaze.
Calibration	the process of configuring a device to provide accurate result.
Eye tracking	the process measuring the motion of an eye.
Gaze tracking	the process of measuring where the eyes are looking.
Headbox	specific area in front of an eye tracker, where the tracker cameras can correctly record the eye positions.
Hz	Hertz, a unit of frequency defined as one cycle per second..
Gaze Point	basic unit of measure in tracking visual attention.
Fixation	period of time in which the eyes are fixated on or towards a specific object.
Saccade	an extremely fast “jump” of the eyes between two fixations.
Spatial location	coordinates of where an object is located.
Smooth pursuit	eye movement that allows the eyes to closely follow a moving object.
Visual span	the amount of words a person is able to read without moving the eyes.

Methodology	a body of procedures and methods used in a particular area of study or activity.
Mechanic	a rule defining how things work in game design.
System	a collection of mechanics that produce an event.
Gamification	bringing concepts familiar from games into non-game contexts.
Core task	the most important main task a system is developed to perform.
Initial calibration	measurement of the gaze data on five separate points.
Validation	additional gaze data measurements if the initial calibration did not produce high enough quality calibration data.
Usability	the degree to which a system or a product can be used.
Intrinsic motivation	behaviour driven by internal motivation.
UI	user interface.
Control group	a group in an experiment or study that is used as a basis to measure the qualities of the studied group.
Affordance	a quality of an object or an environment that allows an action to be performed.

1 INTRODUCTION

We use our eyes almost constantly, and the human eye is always “on”. (Hyrskykari, 2006, 173.) The relationship between our eye movements and the human cognition is well established. As eye movements reflect attention, it makes sense that they can provide information about some of the processes going through our minds. Measuring and recording eye movement gives us information about where, when and what are we looking at, and for how long are we looking at it. Eye tracking is an important method in human behavior research, as it measures the eye movements (the visual attention) objectively and in real time. With this information we gain knowledge about things such as which visual elements attract our attention immediately, which hold them the longest and whether some visual stimuli are ignored or overlooked. (Williams, Eye movements and cognitive psychology: How eye movements work as window on mental processes?).

Although not a novel idea, and having studies stretching back more than 100 years, we are now, in the last few years, beginning to gain access to modern, effective and most importantly, unobtrusive eye tracking technologies. It has been used in psychological research, both academic and commercial, and it is an important consideration in design. As the applications and equipment we have today are getting more and more accessible and easy to use, the popularity of these tools is rapidly increasing. Some of the modern eye trackers are very small and can easily be attached to your laptop or computer screen.

One of the many possibilities of this technology could be to use it as a tool for learning to read. The GaSP team at the Tampere University, the computer-human interaction department (TAUCHI), is conducting studies to develop a tool for monitoring the reading progress of school children attending a reading class. This would enable the teacher to see which readers are having problems and localize the specific problem areas. Collecting this data would allow the teacher to monitor the progress of the students over time.

As the eye trackers need to be calibrated each time before starting a new session, a way to motivate the children to carefully and quickly calibrate their own devices has to be developed. The teacher cannot possibly supervise each child individually, so the method must be easy enough for the children to perform independently, and it must be fun and motivational to ensure an acceptable calibration each time. In this thesis the development, testing, and suggested improvements to the developed calibration game are explained.

2 GAZE TRACKING

2.1.1 Tracking and calibration

The gaze tracker measures and records the eye tracking data. The term *gaze tracking* is used instead of *eye tracking*, as the task is to measure the direction of gaze, and even more accurately, the point of gaze (Hyrskykari, 2006, 18). There are many different types of trackers available at the market today, but the main components generally include an infrared light source, and a camera. The light, not perceivable by the human eye, is directed towards the eye, and the tracker camera records where the light reflects from the cornea. The camera also tracks the pupils, and the tracking process is simply the camera tracking two points: the pupil center, and the reflection spot. The reflection spot always remains the same, and the measured distance to the pupil is the key to defining where the user is looking.

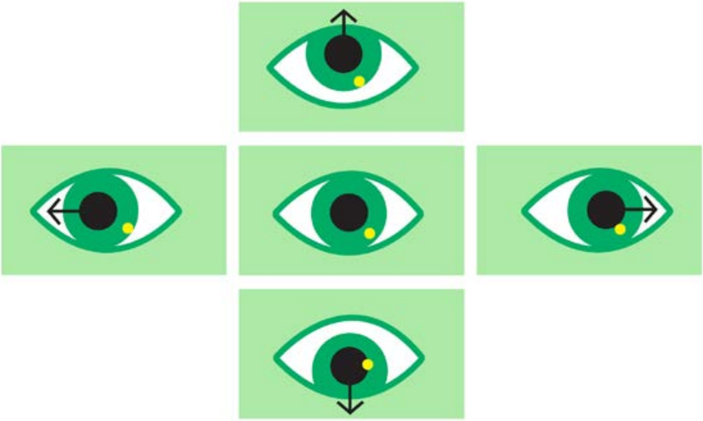


FIGURE 1. The relationship between the pupils and the infrared light reflections. (Illustration: Tobii Dynavox, 2018.)

The eye tracker must be taught the individual characteristics of each user's eyes. This is measured by how the eyes are positioned when different parts of the screen are being looked at. The accuracy usually decreases over time, especially with lower-cost trackers, so new calibration is necessary after a while. (Hyrskykari, 2006, 9). In the calibration process, the user is asked to follow a point or some other visual element on the screen so that the reader can record the different eye positions. The position data is collected either by triggering the collection point automatically, or by allowing the user to press a button when their gaze is in the correct spot. During the calibration the user is required to keep their eye on the object at all times, while maintaining a position inside the headbox area.

This is the area where the reader can successfully "see" the user's eyes, or one of them. The position inside the headbox area has to be maintained when the tracker is used, because obviously, if the cameras cannot see your eyes, the tracking won't work.

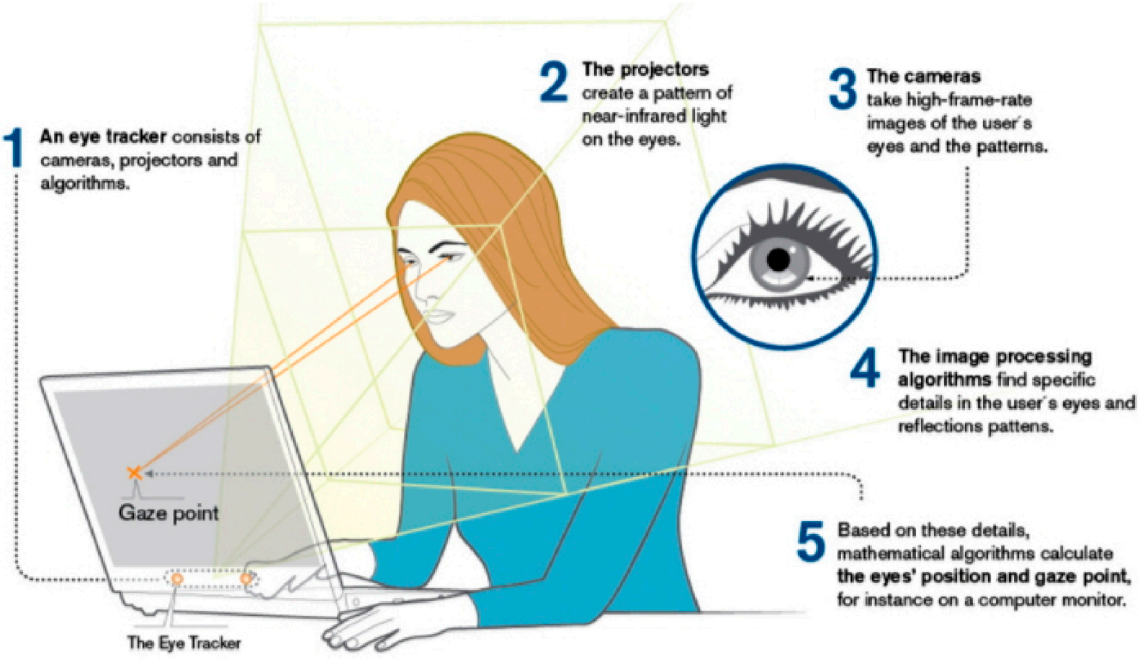

1 An eye tracker consists of cameras, projectors and algorithms.
2 The projectors create a pattern of near-infrared light on the eyes.
3 The cameras take high-frame-rate images of the user´s eyes and the patterns.
4 The image processing algorithms find specific details in the user´s eyes and reflections pattens.
5 Based on these details, mathematical algorithms calculate the eyes' position and gaze point, for instance on a computer monitor.
Gaze point
The Eye Tracker

FIGURE 2. How the eye tracker works. (Illustration: Haptic R&D Consulting SRL 2016.)

During the calibration the tracker filters the data and performs different calculations to create the personal calibration profile of the user. This data is then written to a file that can be accessed through analyzing software.

2.1.2 Gaze points, fixations and saccades

Gaze points are the basic unit of measure in gaze tracking. One gaze point equals one sample recorded by the tracker. The sampling frequency (sample rate) is one of the most important performance features of eye tracker systems. If the tracker is operating at 60 Hz, it will collect 60 individual gaze point per second.

When several gaze points are collected together, they form fixations. Fixations happen when our eyes stop looking around, and hold the attention towards a specific object or an area. What sets fixations apart from a single gaze point, is the fact that they have a duration, start and end timestamps and a spatial location (x, y). The duration of a single fixation typically varies between 100-800 milliseconds (0,1-0,8 seconds). Fixation allows the

brain to start processing the visual information received through the eyes. Fixations can provide insight on attention and cognitive processing, such as understanding. If a school child learning to read shows an increase in average fixation duration on a specific word, that could indicate that the word is difficult for them to read.
Analysing of the gaze paths of the user on a computer screen interface is one of the common methods used by researchers. These metrics can be analysed further to find answers on gaze-related questions, such as what part of an advertisement is noticed first or is being looked at for the longest.

Saccades are the rapid jumps of both eyes from one fixation to another. Because of the fast movement of the eye during a saccade, vision is largely supressed (saccadic suppression), so mostly the information intake happens during the fixations. Saccades can be triggered voluntarily, but they can also be involuntary. For example, when we are reading, the eyes do not travel smoothly, and the eyes tend to lock towards every third or fourth word. Visual span is a term used to define how many words we are able to read before and after a fixation. The average duration of a saccade is 20-40 milliseconds (0,02-0,04 seconds).

In contrast to saccades, smooth pursuit is a way to closely follow a slowly moving target while maintaining a stable eye position on it. During smooth pursuit any other objects besides the target are suppressed. If the object moves too fast to maintain the smooth pursuit, saccades occur to keep up with it.

2.2 The GaSP project

A group of researchers in the Tampere Unit for Computer-Human Interaction TAUCHI at the University of Tampere, funded by the Academy of Finland and working under the name GaSP (Private and Shared Gaze: Enablers, Applications, Experiences), are developing publicly available software that would enable gaze data collection. The research is specially focused in applications that share gaze data, and that could be utilized in everyday computer interactions. Their goals include creating a methodology for remote usability testing, and being a large-scale demonstrator of the potential of gaze data in the educational context. They produce scientific publications on gaze, attention, and education.

Currently one of the main focuses are in developing a collaborative reading aid, possibly an application, that would allow the gaze data of school children learning to read to be collected and used as an aid for the teacher. Teachers could be better able to offer targeted help for individual students, if they had access to the gaze-based performance data of each child. This would provide the chance to detect changes in performance, and a way to find problematic words.

The cost of the eye trackers should be relatively low, as many schools cannot afford the expensive, but more accurate trackers with higher sample rates. The affordable, low-sample trackers could provide sufficient data accuracy through the duration of a lesson, given that they are calibrated properly. The need for calibration brings up a dilemma: the children would need to calibrate their respective eye trackers each time they begin a reading lesson, and be able to do so unsupervised.

Successful implementation of the unsupervised tracker calibration can additionally provide the basis for further work such as gamifying reading.

3 GAME DESIGN

“Good game design is player-centric. That means that above all else, the player and their desires are truly considered.” (Brathwaite and Schreiber, 2009, 2.) There are rules in games, but good game design does not force the player to proceed by following them, it *motivates* them to continue to the direction predefined by the design. (2009, 2.)

Games generally consist of several building blocks. *Mechanics* define how things work in the game. A game mechanic is something that can commonly be called a rule. If the player does a thing X, a thing Y then occurs. A non-digital mechanic would be, for example, rolling a die. Common examples for mechanics in video games include running and jumping. *Actions* are the interactions between the player and the game, such as shooting an enemy. The rules for these interactions are defined by the mechanics. *Progression* and *goals* mark how far along the player has gotten within the game. Progress can be displayed by increasing player level, for example. Fulfilling goals provide rewards, that can in turn play an important role in the player progression. Goals are often referred to as missions or quests. The ultimate goal is of course victory, which is defined by the *victory condition*. Not all games, however have the ultimate victory condition, and it is a debated question whether *sand-box games*, for example, should be defined as games or not. *Infinite runner games* are a good example of a genre that does not have a victory condition, but are clearly defined as games because they have a goal. The player has to keep running for as long and far as they can, and generally high scores of the achievements are kept. A collection of game mechanics that produce an event or an outcome within a game, such as character creation or progressing to the next level, is called a *system*. (Brathwaite and Schreiber, 2009, 12, 28-31.)

Game thinking, and more specifically *gamification*, is a term that can mean many different things depending on who you ask, but in its most basic, it can be summarized as bringing concepts familiar from games into non-game contexts. Gamification commonly uses game design elements in order to improve user engagement and loyalty, solve problems and create better experiences (Marczewski, 2015, 15).

3.1 Game thinking in calibration

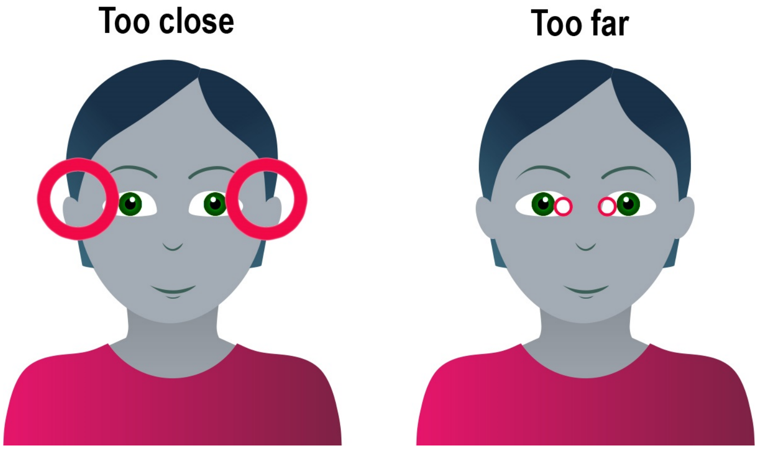
The reason for applying game thinking to the calibration is to give the user a motivation to perform the calibration with the attention and accuracy necessary to get a good calibration result. The assumption is that especially children need this additional incentive to complete a task that they could easily consider boring, as the child does not necessarily see the value in going through the calibration process. If they see the process as meaningless and unnecessary, the calibration quality can be compromised. The design must consider the point of view of the user; what is the reason for me doing this, what do I get out of it? And most importantly, why would I do this again? In short, the calibration should be fun.

Flatla, Gutwin, Nacke, Bateman, and Mandryk have conducted a study where they looked into the practices concerning a creation of calibration games. They approached the task by creating guidelines mapping the common types of calibration core tasks that provide the calibration data. Then they matched each of these tasks to common game mechanics usable for collecting calibration data and lastly implemented additional game elements to improve the final game. (Flatla et al. 2011, 403.) The design of calibration game should always begin from the standpoint of what is its main purpose. Building around the calibration core task instead of starting from the game's point of view is crucial in order to succeed. Flatla et al. remind us that the quality of the calibration data must be the priority. They concluded that well designed game elements do not necessarily compromise the data quality, but that it's important to consider if the added game elements change the user's strategies in a way that calibration itself can be compromised. (2011, 411.)

However, the technical requirements and restrictions are not the only things that need to be taken into account. The goal is to create an experience that is enjoyable, motivational and that has replay value. The personal calibration should not only be precise, but the process should also be fast and it should not take away from the limited time available during the class. Flatla et al. studies show that gamified calibrations are significantly more enjoyable than the standard procedures. (2011, 403.)

3.1.1 Adjusting the player’s position

The first thing to get right when starting a calibration is the user's position and making sure they are within the headbox area. The child needs to be sitting directly in front of the screen, in a comfortable position and in the appropriate distance. The idea for achieving this in a way that is easy for a child to understand without long written instructions was to use an avatar character to give them a visual example of the position they should be sitting in. The character would be facing the child, and they would have to sit in a spot where their eyes are on the same height and distance as the character. Circle guides representing their own eyes would appear on the screen and the child would need to adjust their position in a way that the circles are in the same spot and of the same size as the characters eyes. If the user is too close, the circles are too big and when they are too far away, they are too small.



PICTURE 1. The circle guides tell the player if they are sitting in an appropriate position.

During the calibration, it is important for the user to stay in a relatively still position and not to move their heads too much in order for the gaze tracker to give accurate readings. If, during the calibration or perhaps even after the calibration, during their reading exercises, the user started to move around and get out of the head box area, the avatar character could appear on the screen again to remind them to keep a good posture. In a situation like this, the avatar could change their face expression and thus underline the importance of remaining in the right position.

3.1.2 Initial calibration and validation

The initial calibration process measures the data of up to five separate points on the screen. These points can appear in any position on the screen, and the user needs to look precisely at these points, and keep looking at them while the eye position data is being collected. After the collection, the point disappears and a new point comes to the screen. After the initial calibration, the system needs to run the validation of the data. Validation happens in the same way as the initial calibration, by collecting the gaze data from different locations on the screen. Unless the data is of acceptable quality right away, the amount points where the user may have to concentrate their gaze can grow. This process is cumbersome and becomes a time-consuming chore especially when repeated several times. For this reason, according to Ohno, Hara and Inagaki (2008, 111-131), developing a way to track human gaze without personal calibration is one of the most important goals in the field of gaze tracking technology. As the development of affordable gaze trackers is not there yet, we are attempting to make the calibration process more motivational instead.

The idea for gamifying the initial calibration and validation was to make a sort of a mini game for each calibration point. The point would appear as a button that changes shapes. For the next point to appear, the player would need to catch the shape on a predefined option and activate it with a space bar press. In theory, the child would automatically concentrate on that spot to catch the right option. By using the space bar as the trigger button, it was assumed that it is easy for the child to just keep their finger on this one trigger and keep their concentration on the calibration screen. Using the mouse button is another option that came into consideration afterwards, because during testing some feedback suggested that the possibility of accidentally pressing the space button could be an issue for the more sensitive keyboards. Additionally, Heather Nam tells in her article about a key finding they discovered in four separate usability studies with children up to age 9. In their tests they observed that children prefer to use a mouse as a controller when using the computer. As children generally might not have a need for typing, they are not as comfortable with a keyboard as they are with pointing and clicking with a mouse. (Nam, 2010.)

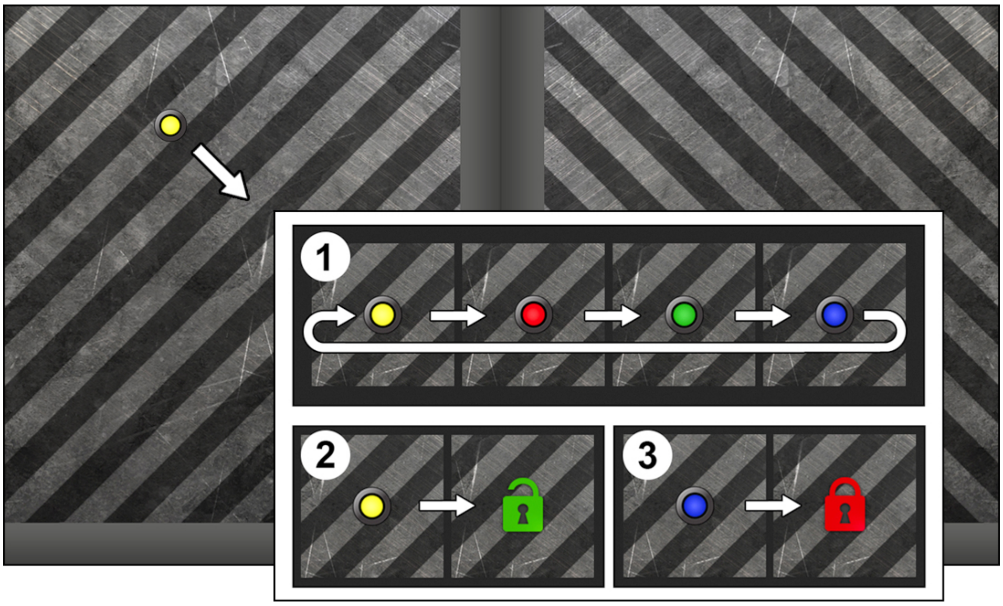


FIGURE 3. The mechanic of the catching the correct option.

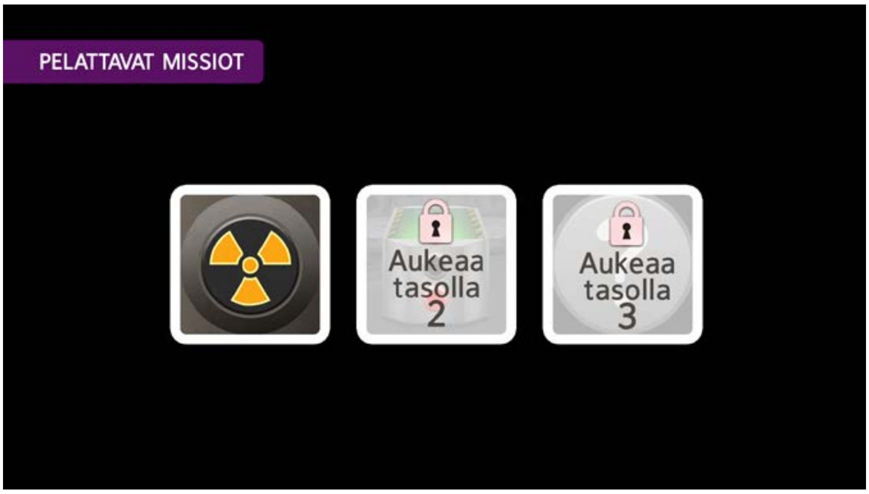
Figure 3 explains the mechanic that takes place in each data collection point. The button is quite small at 40x40px, and the point changes options in a continuous loop. Feedback about if the player caught the right option is displayed immediately after the click triggering the data collection. The green or red lock appears directly on top of the spot to keep the gaze on point for a little longer. This allows the data to be collected reliably, as the gaze data is collected when the player presses the mouse button. The game mechanic design must make sure that the player is looking at the spot the system assumes the player is looking at during the button press, for long enough to collect the data. For calibration purposes, it does not matter if the player catches the right option or not, but for the game purposes, additional motivation for the child to *want* to activate these buttons had to be thought of.

Initially the game would begin with a scenario where the player needs to catch enough of the buttons to open a locked door. Behind that door, they would find prizes, such as game currency and bonus items. This kind of a mission with its very simple core mechanic is possible to implement in many different scenarios, with different background stories, button shapes and colours. When the player has attempted to unlock all the game objects, the round ends and the results are revealed. In case there is a need for re-calibration, it could present itself in the form of a bonus level (when the player succeeded in the mission), or getting to try again (when the last mission was not successful). Here a future consideration would be to design this possibility in a way, that the player would not be able to try to get a bad result on purpose to get additional play time or more rewards.

3.1.3 Motivating with points and reward systems

"The designer must create a careful interplay of system and player, relentlessly testing those interactions to find that point between anxiety and boredom." (Zichermann, Cunningham, 2011, 17). The point and reward system is the most complex and potentially dangerous part of this game. Different factors including the speed of the blinking buttons, the amount of successful activations that would be required to open the door, the amount of points needed for receiving bonus items and how many coins would be received, just to mention the basics, had to be carefully considered. All of these calculations have to work without knowing exactly how many calibration points the player will need to go through. The quality of the reward versus the work that should be put in to receive it is one of the key elements that can make the game enjoyable and add replay value, or destroy the whole idea.

In this design, the buttons had four different options that blink in a loop, speeding up towards the end in two intervals. The player gets points based on how quickly they catch the right option. Those points collect into their personal experience bar, and eventually the player reaches a new player level. New playable Missions are unlocked as the player rises in level. In the beginning just the factory mission is available, but after the player has collected enough experience points, their character reaches player level 2 and a second mission is unlocked.



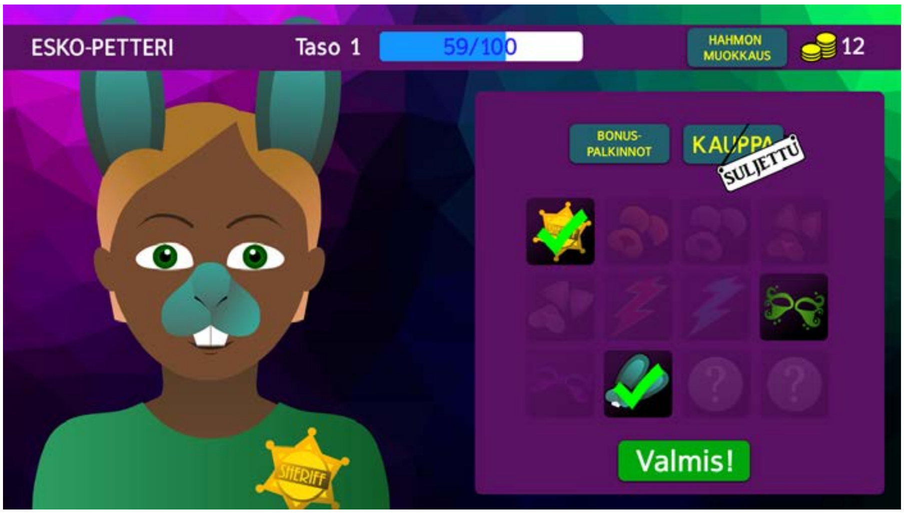
PICTURE 2. The playable missions to choose from. The last two are still locked.

The calibration game was designed for school children in elementary school, starting from second graders. In Finland children start school at age 7, so second graders would be about 8 years old. With an audience of quite a young age, finding the right balance is challenging. Balance is a term used to describe a game's system. It can be balanced or unbalanced. Unbalanced game is either too easy too difficult, while a balanced gameplay provides some target audience -appropriate challenge constantly without being overwhelming. (Brathwaite and Schreiber, 2009, 12.) It would be a mistake to underestimating the children's reflex and concentration skills, but a scenario where they would catch everything correctly right away and get bored due to a lack of challenge after a few plays needs to be avoided as well. If the game is too difficult, the player will become frustrated and lose focus. Especially for young children, continually failing will cause them to dislike the game making the possibility of a good calibration unlikely. Defining when the player gets a bonus item was also one point that needed careful consideration. It should not be a given that the player gets an item every time, as it should be an additional reward for doing especially well. Finding the right balance can usually be reached only through game testing. In the beginning, the designer can only make educated guesses on what the appropriate difficulty would be. If there already are similar games directed to the same age group, they could be used as references.

To keep a good flow during the game, the player needs to feel that they are making progress. This is achieved, among other things, through getting positive feedback and rewards. According to Chen it is a common mistake to only focus on balancing the system between challenge and ability and forget about the overall feel that the user gets from the game. (Chen, 2006.) In the spirit of this, further means for displaying the rewards gained from gameplay were added by the ability to modify one's player character.

3.1.4 Character customization

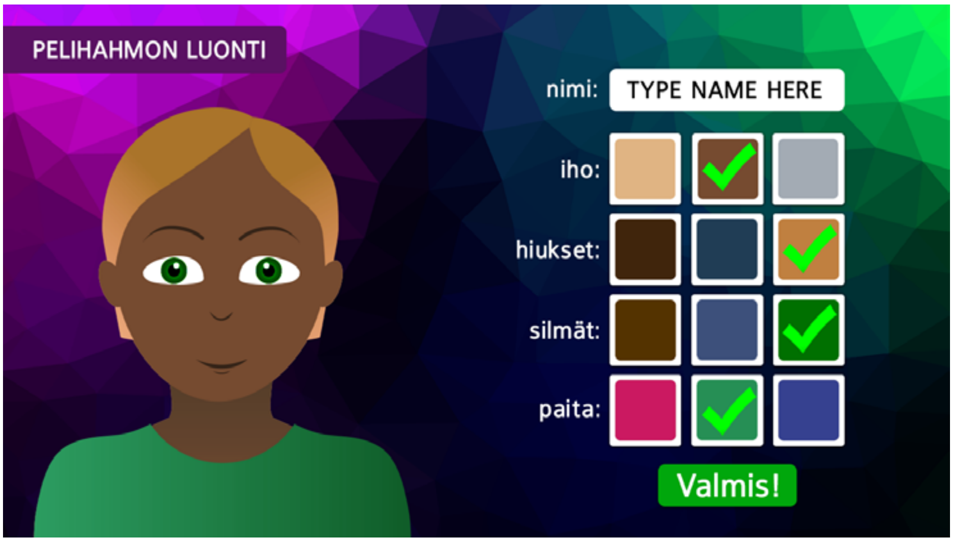
The user will see the character in the beginning of each session when they need to use the circle guides to adjust their position. The character is not visible during gameplay unless the player is required to adjust their position in the middle of a mission. The player has their own personal home screen, where they can modify their character and where the bonus items gained from successful missions are collected. They can spend the coins they earned in the store where additional modifications and items are available. A further design idea was to use this home page as a platform from where the students could begin to go through their reading tasks and lessons. In order for the children to not spend too long playing with their character, a good solution could be implementing a timer or limiting the amount of possible modifications allowed during one school lesson.



PICTURE 3. Home screen mock-up after clicking the “Customize”-button.

In Picture 3 the player has collected three different bonus items and selected to wear two of them. There was not enough time to make the shop functional, but the button to it was added anyway. During the game tests, the shop was kept closed, but the implication that there will be an option to go shopping later was there to offer the incentive and explanation for collecting the coins. The motivational aspect of this was however, due to the lack of time, not tested at all. The assumption remains that it could offer a significant amount of additional motivation, but more evaluation is required to make further claims.

Mostly out of convenience, but partly out of curiosity to what reactions, if any, the children would have, a gender for the player character was not provided. All the children used the same character that had four different options that they could change in the beginning: skin, hair, eye and shirt colour. These changes are only available once, and after that, the character would become their personal avatar. All the children seemed fine with this decision, and accepted it as is apart a single comment from a very perceptive individual. This student wanted to know if the character had to be a girl, and after that, the discussion with him and a classmate included interesting points about how the hair colour makes the character look like either a girl or a boy. They were in the group of second graders and addressed the topic during the initial character creation. The older groups did not mention the gender at all. Some testers, however, inquired about more options such as different hairstyles, which gives a reason to believe that at least some of the children found the character customization interesting, and that the possibility to buy more characteristics would work as an incentive.



PICTURE 4. The character customizing screen mock-up.

Allowing the player to cosmetically customize their game character attempts to create a feeling of personal ownership and empathy towards it. This way, collecting more items to wear and modifying the avatar further can work as an additional intrinsic motivation to continue playing. Customizations in games can be an important subcomponent in player motivation, even when it does not directly affect gameplay. A study by Cordova and Lepper (2006, 716) shows that even small, trivial seeming customization aspects such as picking a colour for a shirt, hair or a vehicle create a more meaningful and interesting experience and give the player feelings of ownership. They found that children who were given more control over their visual representation in a learning game environment enjoyed the game more and exhibited better learning. Several other studies have also found that playing with a personally customized character increases character identification, which in turn can make the experience more motivational and enjoyable. (Fischer, Kastenmüller and Greitemeyer 2010, 194; Turkay 2014, 18; Bailey, Wise and Bolls 2009, 281; Trepte and Reinecke 2011, 556).

3.2 Usability and UI for children

According to the online School of Game Design, when designing games for children, the age groups are generally broken down to ages 4-6, 7-9, 10-11, and 12-14. These age groups are all very different from each other. “In the youngest demographic you can’t guarantee that your audience will know how to read. The oldest group is much more socially aware than children just a few years younger than them.” (School of Game Design: Design Games for Kids). In this project, we worked with children aged 9-12. It is a challenge to design something that appeals to and motivates children of such drastically different ages. In two studies conducted by Jacob Nielsen, it was discovered that children are also very aware of age differences. The children in their usability tests reacted negatively to content that was designed for children that were even one year, or a school grade, below or above their own level. (Children's Websites: Usability Issues in Designing for Young People, 2010.)

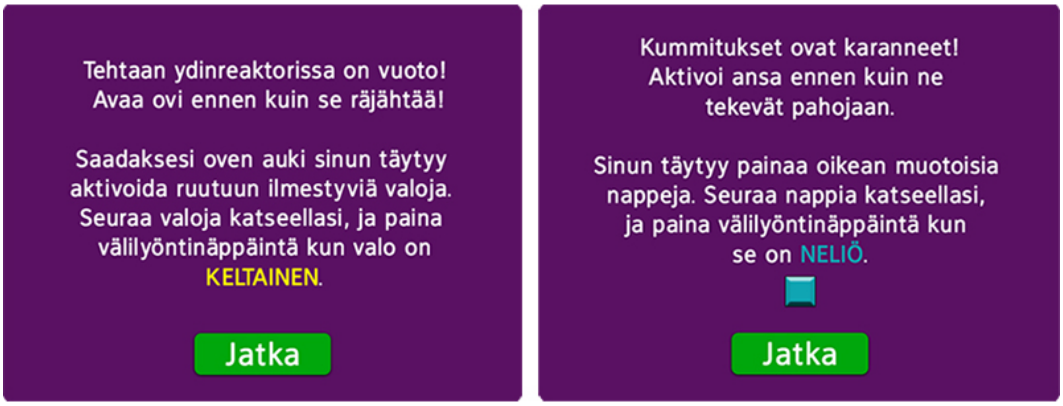
As the goal was to create a system that the children can use without adult help during each step, it was important that what the user was expected to do, was clear and easy to figure out. A consistent user experience throughout is extremely important, and the final product needs to have a simple, graphical and intuitive UI. While adults tend to find comfort in simplistic and non-distracting design, children thrive in environments with colourful and big pictures, as they hold their attention and help them navigate. (Gallavin, 2015.) The wide range of group diversity must also be considered, and the interface should work in a way that children with different skillsets can successfully calibrate their tracker, without offending the older children with too childish design choices. Additionally, for the younger children this might be their first experience with this type of a game, and many might not have yet a familiarity with computers and the basic functions that already feel obvious to adults. It is very easy to assume that a child would automatically know how to do something, especially when that something comes so naturally for us.

3.2.1 Game rules and how to play

From a player’s point of view, animated or highlighted in-game hints popping up whenever a new kind of action needs to take place could be the most fluent and effortless option. It is also important that when the player already knows what they need to do, they can easily skip the part where this is explained. Finding the right balance between too much and too little help requires a lot of user testing.

School of Game Design web resource explains that many players just skip written instructions altogether. Many even skip *all* the instructions, regardless of what form they are presented in. Like everything else in games, the instructions and tutorial should be interactive. If the player plays through the actions, it creates a better, more fluent experience. Throwing all the information at once at the player in the beginning of the game will most likely result in them forgetting it by the time they get to play. (School of Game Design: Good Video Game Tutorial). We need to make sure that the children understand exactly what they need to do before they begin the mission, so that their gaze remains in the areas where we want them to instead of browsing around the screen looking for information. If the child becomes confused during the calibration, the calibration results will suffer and a need for re-calibration might become inevitable. This is something to be avoided, as the time is quite limited.

When children are asked to read instructions, it is good to keep in mind that some children may find hyphenating the words helpful. The reading aid system developed by the GaSP team uses this in the reading exercises. If the system detects that the reader is spending a lot of time looking at a specific word, it becomes automatically hyphenated, as the assumption is that they are struggling to read it. Using easy and familiar words is a given. Children learning to read often remember words from how they look like. These are referred to as sight-words. (Fisher, 2015, 99). Hearing the instructions in audio form with karaoke-like highlight on the word spoken at that moment is also a good option if it does not disrupt the rest of the class.



Tehtaan ydinreaktorissa on vuoto!
Avaa ovi ennen kuin se räjähtää!

Saadaksesi oven auki sinun täytyy
aktivoida ruutuun ilmestyviä valoja.
Seuraa valoja katseellasi, ja paina
välilyöntinäppäintä kun valo on
KELTAINEN.

Kummitukset ovat karanneet!
Aktivoi ansa ennen kuin ne
tekevät pahojaan.

Sinun täytyy painaa oikean muotoisia
nappeja. Seuraa nappia katseellasi,
ja paina välilyöntinäppäintä kun
se on NELIÖ.

PICTURE 5. Instruction screens in the beginning of the first and second missions.

As the development time was extremely limited (about two weeks for design, creating graphics and implementation), there was no opportunity to develop a visualized way of displaying the rules. To compensate for the long instructions and balance their time-consuming effect, some visual clues were added to the UI and the children were told beforehand what the mission was and what they should keep an eye on. This worked reasonable well, and towards the end, when they had learned what to do, the testers skipped reading the long instruction and picked out the information needed.

There were two different missions, the first taking place in a nuclear factory where the task was to catch right coloured lights. The second, ghost-themed mission which unlocks after the player has reached player level 2, required the player to catch specific shapes. The original game design document can be reviewed in Appendix 1 on page 59. Coloured text and an image of the shape was incorporated in the rules screen, so that it was quick to understand what option the player should look for. This way, instead of every time reading the whole box of text, they could just look at the required shape or coloured text and continue the game. Which option to catch is random, so that the mission has some variety when played for the next time. Before a mission starts, a quick animation plays where the premise leading to the mission is set, and what the player should do is described the text box.

4 GAME TESTING

4.1 Research questions

We had four separate groups of children from three different schools who would test all the calibration methods. Each group consisted of one whole school class. During these tests the aim of the Gasp-team was to collect information for two studies.

The first study compares the data when the same students go through the same calibration procedures in several separate occasions. One group of second grade children would perform the testing on six different days so that we could compare their feedback and calibration results over the different sessions and find out whether there were changes. The assumption was that if the user finds the task boring and/or unrewarding, they will concentrate on it less and get worse calibration results. We had three different options for calibration, which they played in a different order each day.

The second study compares the results of children in different age groups, and if the age of the children has an impact on the calibration quality. We had two different groups of third graders (group A and B) and one group of fifth graders who would test all the games once. The results of just the first day with the seconds graders group would be used in this study.

4.2 Research ethics

“Ethical considerations in research are critical. Ethics are the norms or standards for conduct that distinguish between right and wrong. They help to determine the difference between acceptable and unacceptable behaviours.” (CIRT: Center for Innovation in Research and Teaching.)

We asked for permissions to conduct the studies from the schools directly. The schools then requested permissions from the parents. In some cases, the parents were asked for written permissions, and in others they were asked to inform the teachers if they did not want for their child to take part in the study. All of the children in the four different classes had the permission from the school and the parents to take part. Every child in each class took part, and all of the data collected was used without discrimination. Permissions for taking photos during the study were asked for, and in most cases granted. A few parents did not want their children photographed, and in these cases the group in which the child was, was not photographed at all. The research results will be published without any personal information, and the data collected is stored confidentially. One of the class teachers asked and was granted access to the individual children's calibration results, as this might offer valuable information about the students in order to consider personalized teaching methods.

The children were introduced to the study before the tests by a presentation held before the class. In the presentation, the team introduced themselves, the gaze trackers and the concept of calibration. The children were explained the premise that the team was trying to study better ways for personal calibration, and that the children were now the official game testers and we needed their feedback in order to better the designs. It was explained that the feedback they provide is confidential and that they were not required to sign their name in the evaluation forms.

TAMPEREEN YLIOPISTO
Virallinen pelitestaaja
STELLA
Kone 4
EEN
ISTO
nen pelitestaaja
LUKAS
Kone 6

PICTURE 6. Official game tester name tags given to the second graders' group.

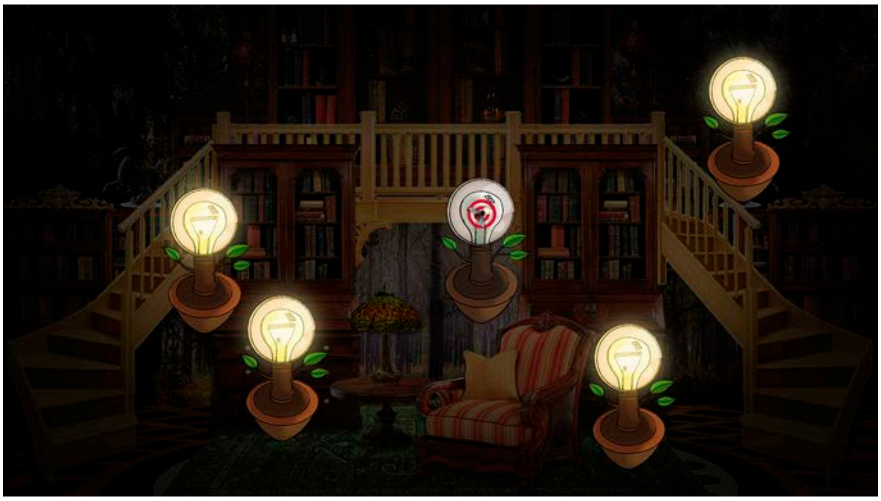
As an incentive to get school classes to join the study, we offered a visit to the University of Tampere, where the children could take part in a game design workshop, where they got to design their own game and learn about coding. In addition, the second graders' group received official game tester name tags that they were able to take home after the six testing sessions. The name tags served an additional purpose on assigning the correct computer to each student on the different days of testing.

4.3 Comparing three different calibrations

The first was the standard calibration, where the player is required to follow a ball moving on the screen with their eyes, without moving their heads too much. When the ball stops, the player needs to look at the spot for at least a second and then press a space bar. This would set a calibration point. To get comparable feedback, the standard calibration was called the Ball Game in the questionnaire, even though it really is just a ball moving on the screen which the player has no control over and does not have any game-like feedback available. Mainly we expected the standard calibration to be boring, or in the least become boring after several repetitions, thus reducing the accuracy of the calibration. The second game was something that had been designed a year before and delivered to the research team as a small student project. It was similar to the standard calibration, but it was visualized as a firefly flying on the screen and turning on lamps. Further introduction of the game is in the next section. The third game was the newly designed Mission Game.

4.3.1 Firefly calibration game

Originally, the room was intended to start appearing from the darkness as the firefly turned the lamps on one by one. The lights would also repel small trolls. Because the calibration point is quite small, with graphics only 45x45 pixels, a bullseye was made and put on top of the light bulb to which the user was instructed to look at.



PICTURE 7. Firefly game initial calibration in progress, the original design.

To gamify, in addition to visualize, a small game was planned for each calibration point, in which the fly would fly in pattern around the bullseye and the player would have to catch the fly when it was on top of it with a spacebar or mouse press. After that, the light would turn on and the trolls around it would be repelled. After all the lights were turned on, a room would appear where all the repelled trolls would be hiding, and the player gets to play a hidden object game where they had to find the trolls.

PICTURE 8. Finding the hidden trolls.

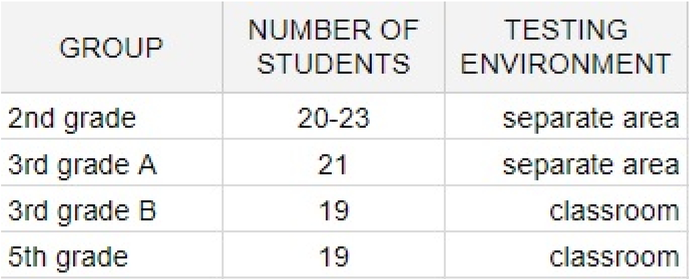
The troll hunt was first intended to be a reward for finishing the calibration and turning on all the lamps, but instead, it was transformed into a chance to validate the initial calibration. In the original plan both initial calibration and validation would have happened during the firefly-section, and if recalibrations were required, a troll would appear from the darkness to turn off the lamp correlating to that calibration point. Since the need was to know where the player is looking at that moment when they press the button, it could have been problematic to have additional things on the screen to distract their gaze from the calibration point.

For the story of the game, it was important to have the trolls lurking around the lamp and have the player catch the firefly on the bullseye to turn on the lamp, but for getting a good calibration result, it was not ideal. The game used in the testing did not have the slowly appearing room or the trolls around the lamps. This turned out to create some confusion with our game testers, as they did not understand that the troll hunting, lamps and firefly were all a part of the same game. After realizing this, attempts were made to make sure to tell the participants what the three games were before we started each testing session. However, I was still afterwards required to explain to several testers that the troll game was part of the firefly and lamps game.

4.4 Game testing setup and environment

We had a great collaboration with the class teacher of our second-grade tester group. We got our own room where we were able to set up the computers, and the teacher would send the children to the sessions in groups of six. We arranged the computers to have two rows of three facing each other.

In this setup, with a separate testing room close to the other classrooms, we had eliminated some of distractions that occur in regular lesson situations, but still had some comfort of having a small group of classmates doing the same exercises. This allowed them to perform the task in peace and give feedback more freely. As the second graders' group became more confident on the following testing days, they started to have discussions among themselves, while still playing, on which game they were now and what points they received. This is great feedback for the games, but probably not an ideal situation to have in a classroom while teaching, as it might disrupt the class.



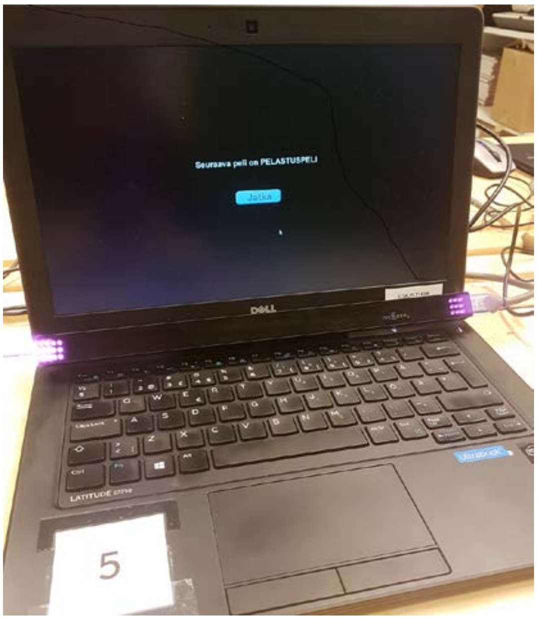
GROUP	NUMBER OF STUDENTS	TESTING ENVIRONMENT
2nd grade	20-23	separate area
3rd grade A	21	separate area
3rd grade B	19	classroom
5th grade	19	classroom

FIGURE 4. The different groups, the participant number and the testing environment.

Third graders group A also performed the tests in a private area where they arrived in groups of six. With the third graders group B and the fifth graders group, we performed the testing in one big classroom, where the rest of the students of the class were present. We set up the six computers in one part of the room, and the rest of the children were doing their homework or engaging in other activities freely while they were waiting for their turn. Normally the calibration would be done in a regular classroom before the reading lesson, so this was also a good opportunity to see how the environment influences the calibration results and the tester feedback.

4.4.1 Equipment

During the first session, one of the biggest challenges we found out were the ergonomics of the furniture. The tables were somewhat too high compared to the chairs used. Some of the second grade children were too small for the furniture, and therefore easily too far away or in a wrong angle from the screen. This was fixed the next day by bringing in pillows that were placed on the seats. This also seemed to improve the posture of some of the children. For the older students the pillows were no longer necessary. When setting up a testing area, it is important to keep in mind, especially with a product that relies on following the eyes of the user from a correct position, that the hardware and the environment is adjusted correctly. In this case, the tracker is pointing up in a slight angle, so it was very important for the child to be in a position where they were high enough for the tracker to detect their eyes.



PICTURE 10. One of the laptops used in the testing sessions.

The laptops (Dell E7520 with screen resolution of 1366 x 768 and a 12.5 inch screen) used were quite small, which worked well for children. Visual Interaction myGaze eye trackers operating at 30Hz were attached below the screen of each laptop. The computer mice used were gathered from the university, and they were all different. A few problems occurred with them, as some of them were quite large (clearly designed for adults) making it at times challenging for some of the children to reach or press properly. This required some encouragement and instructions from an adult on how to use the mouse.

4.4.2 Questionnaires

For the second graders, a simple smiley face survey was made that the children were asked to fill out after each session. In the survey they rated each game by choosing one out of five different smiley faces. The happiest face represented that they liked the game and that it was not boring at all, and the sad face would let us know that they found that game to be very boring. After all of the six sessions were done, we had five-minute interviews with the children which were recorded, while the children were still divided in their small groups. For the older children, a written feedback section was added to the survey, in which they were asked to tell the best part and the worst part of each game (appendix 3 on page 72).

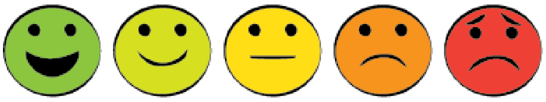


FIGURE 5. Smiley Face Survey Options.

In addition to the surveys, a team member was present at all the testing sessions to guide and aid the children, and during the process, was able to observe their reactions and receive immediate comments and feedback.

4.4.3 Observations

The second grade children were very concentrated and responsive, and after the first session, in which we still encountered some technical difficulties, they were able to perform the tests quickly, efficiently and mostly without our help. During the testing, it was important to have a team of people at standby, ready to step in and help our young testers if they needed assistance or advice. It was noticed quite early on that children tend to become somewhat frustrated if things do not run the way as they expect. The best response in this kind of situation seemed to be to offer support and positive reinforcement. The children got over the moment very quickly, if they were reassured that they were doing well.

PICTURE 9. Second graders testing the calibration games.

Out of the one-time testers, we got by far the best quality feedback from the third graders group A, that came out of the classroom in groups of six. This gave them peace and time to first test the games and then fill out the questionnaires in a separate desk area. The interaction between the class teacher and the children seemed to contribute to a different dynamic and to the very conscientious task making of this group. This group took the game test and the survey very seriously and spent a good amount of time constructing their answers. When comparing them to the third graders group B, who did the testing and feedback surveys in the classroom, the difference in enthusiasm was very noticeable.

The third graders group B seemed quite interested in the games and gave in general more written feedback in the surveys than the fifth graders. The overall dynamic of this group was enthusiastic and involved children wanting to play again and again. This created a social situation where the other children also wanted to play more, inspired by the keenest of the students. They did not seem to feel pressure to impress their peers, and were happy to share their experiences and what points they got with their classmates, unlike the fifth graders who mainly just played the games through and returned to their other activities.

When testing with the fifth graders, the assumption was that they will probably not be as easily impressed as the younger students. At age twelve, people have much more critical thinking, and based on age limits on many games, they can already be playing some of the same games as adults do. With the fifth graders, a few students were not as keen on the testing as the rest of the students. Two students sitting together even asked in between games if it was required that they finish all the parts, and seemed uninterested in the whole thing. None of the second or third graders expressed lack of motivation to continue. Of course, if a child, or any tester, really wants to stop during the session, they must be allowed to step away at any point without the requirement of giving a reason. In this case, a gentle nudge towards finishing was enough for them to continue. Based on the overall atmosphere of the classroom, the fifth graders seemed most distracted, wanting to engage in their own activities within their own group of friends rather than focus on the games or giving thought-out feedback. Many of the students returned the questionnaires without any written comments, and one tester even neglected to fill the smiley face rating.

4.4.4 The effects of game difficulty level on player feedback

The emotional development of the age group is an important factor when trying to understand the feedback. Fisher (2015, 145) observed that in general, children are far more likely to give up on a game if they find it difficult to succeed in. This is of course true with adults too, but the threshold is undoubtedly bigger for children who are still developing and learning to control their emotions. It might be even bigger factor for children in their tweens (ages 9-12) as this is the time when they are spending most of their time with peers, develop cliques and start to look for examples from their environment instead of mainly their parents and teachers.

While the expectation was that the older students would be better players, some of the fifth graders still gave feedback expressing that the Mission Game was too difficult and that the worst part of it was when they failed to catch the right option. Older students seemed to take not catching the right option more personally. The distractions in the classroom could have made concentrating on the game more difficult, and the pressure of possibly feeling embarrassed in front of their peers could have added to the trouble of concentrating. We did the testing in a classroom where everyone was potentially able to see what the testers were doing, and that could have created a more stressful environment. The testers themselves were facing a wall and could not see whether the other students were watching. These different factors make understanding the feedback again less straightforward.

Games and apps for children should be designed specifically for easy or even accidental success, and have quite a gradual incline in difficulty (Fisher, 2015, 145). This was a rule especially taken into consideration in the design of the Mission Game, where the blinking options would first change slowly and gradually get faster. Based on the collected feedback of all the students, this was not a success, as a good number of testers in each group found at least the last setting to be excessively difficult. Of course, we had also more experienced players who could get almost all the options correct, but they were not in the majority. The skill level between second and third grade was noticeable. The second graders played the game six times, and the best result that was discovered by observing the sessions was seven correct while the third graders reached this result during the one session. At least one third grader, as far as observed, even managed to catch all correctly with eleven calibration points.

4.5 Survey results

4.5.1 The Standard Calibration

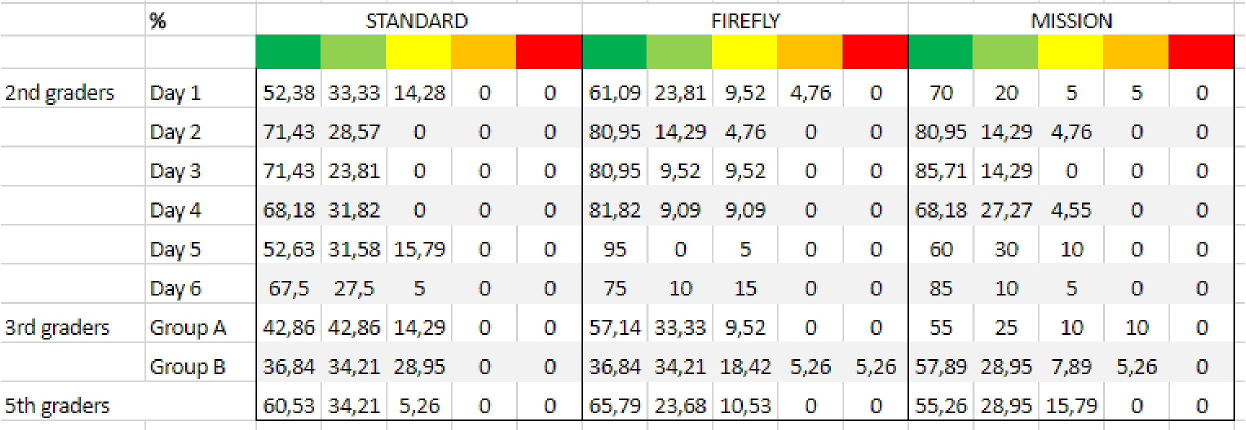
To our surprise, we were receiving very positive feedback about the standard calibration from the second graders while getting calibration results with a noticeable decline in quality, showing that they were in fact not performing it with the same attention and accuracy as before. In general, the biggest part of the smiley face ratings were very clearly on the positive side on all the games (appendix 2 on page 69). The Standard Calibration was received very well by the other groups as well, and overall 49% of all the reviewers gave it the highest, the green smiley face ranking (figure 6 and appendix 4.1 on page 73). With the older groups we did not have the opportunity to study the effect of multiple sessions, and could not prove declining quality in the calibration results as with the second graders. Very surprisingly the fifth graders gave it 61%, while the second graders overall average ranking after the six days was 55%. To compare the third graders, group A that did the testing in a peaceful environment rated it at 43% while group B that tested the games in a free roaming environment, rated it at 37%.

In both the third graders groups the two of the highest-ranking spots for the Standard Calibration had quite equally divided number of votes, and they had the bigger amount of neutral rankings with 3-5 students against one student in the second and fifth graders groups. The overall hypotheses is that these are perhaps a little too positive reviews considering that many students in all the groups also thought the standard calibration to be boring and too simple.

When interviewing the second graders, one question was which of the games they thought was the worst, and 10 out of the 20 students present on the last session ranked the standard as the worst out of the three. The positive things mentioned several times were the easiness of the game, and that many seemed to find it pleasant. Following the ball was considered as a positive feature, and many seemed to respond positively to the movement of the ball and that it was changing its size. Some thought it was nice that the ball waited for you to click, while others thought it was boring. The fact that the students felt they were doing well in the game, could have affected the overall smiley face rating.

4.5.2 The Firefly Game

The Firefly game divided opinions a bit more than the standard calibration, although overall it seemed to be more popular (figure 6 and appendix 4.2 on page 74). 58% of all votes were cast on the green smiley face. The highest amount of votes came from the second graders with 69%, followed by fifth graders with 66%. The third graders groups have a significant difference between each other. Group A rated the game at 57% with 33% for the second best rating and two students totalling at 10% rated it neutral. Group B on the other hand has ratings reaching all the way to the negative end of the spectrum with only 37% rating it with the green smiley face. 34% were given to the second highest rating while the rest of the votes are divided between the neutral and the negative options. Nine out of 20 second graders rated the Firefly game the best out of the three, and even three fifth graders added this note in their written feedback out of their own initiative. However, 10 of the second graders rated the game as the worst out of the three, equalling with the standard calibration.



	%	STANDARD					FIREFLY					MISSION				
		🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥
2nd graders	Day 1	52,38	33,33	14,28	0	0	61,09	23,81	9,52	4,76	0	70	20	5	5	0
	Day 2	71,43	28,57	0	0	0	80,95	14,29	4,76	0	0	80,95	14,29	4,76	0	0
	Day 3	71,43	23,81	0	0	0	80,95	9,52	9,52	0	0	85,71	14,29	0	0	0
	Day 4	68,18	31,82	0	0	0	81,82	9,09	9,09	0	0	68,18	27,27	4,55	0	0
	Day 5	52,63	31,58	15,79	0	0	95	0	5	0	0	60	30	10	0	0
	Day 6	67,5	27,5	5	0	0	75	10	15	0	0	85	10	5	0	0
3rd graders	Group A	42,86	42,86	14,29	0	0	57,14	33,33	9,52	0	0	55	25	10	10	0
	Group B	36,84	34,21	28,95	0	0	36,84	34,21	18,42	5,26	5,26	57,89	28,95	7,89	5,26	0
5th graders		60,53	34,21	5,26	0	0	65,79	23,68	10,53	0	0	55,26	28,95	15,79	0	0

FIGURE 6. Number of votes cast on the smiley face surveys shown in percentages.

The positive comments included turning on the lamps, the fly, and that the game was nice and easy. The troll hunting section of the game received a lot of attention with children coming to the supervisors asking where they can rate the troll game. As mentioned before, some of the testers were unclear on the fact that the trolls were a part of the Firefly-game, and were looking for an opportunity to rate it individually. Still, some feedback made their way into the surveys, and all of it was positive; except a few comments disapproving of the time limit on the troll hunt or the number of trolls being too few. This tells me that many of the children would have liked to play more of this specific game. Overall, the troll section was popular among all the testers, even in the cases where the lamp section was not.

As Fisher explains, starting from six years old, children become familiar with shapes and tend to enjoy finding hidden shapes inside other pictures (2015, 100). This development continues as they get older, and it was no surprise that all of the testers starting from the second graders, aged approximately nine years old, to the fifth graders at about twelve years old, seemed to enjoy the hidden troll hunt in the Firefly Game the most out of all the activities.

4.5.3 The Mission Game

The Mission Game is also somewhat dividing the opinions, but overall, especially considering that many found it too difficult, the feedback seems to be quite positive (figure 6 and appendix 4.3 on page 75). 61% of all votes are given to the green smiley face with the second graders group giving the most positive review with 75%. Rest of the groups are on somewhat similar levels between 55-58% positive.

11 out of the 20 second graders present at the final session ranked the Mission Game as the best out of the three. The gameplay received many positive comments including opening the locks, liking the shapes and finding the right timing and hence catching the right option. The background, story and the character (customization and the circle guides) had a few mentions as the most positive thing. On the negative side, the biggest complaint was that it was too difficult, and that they did not like it when they caught the wrong option.

Based on purely the average percentage of votes given in the smiley face reviews, the best received game out of the three was the Mission Game with 61% (average of all votes on green). Standard Calibration finished last with 49% and the Firefly Game was a very close second favourite with 57% of all votes cast on the green smiley face. Due to some confusion with the testers about where to give points to the much-liked troll hunting game, the Firefly including the troll hunt might have been more popular overall than the Mission Game.

In the end, the subjective survey results are very similar and do not offer undeniable evidence on which game was really preferred in the end, if any. The combined feedback and calibration results, however, give a good idea on what parts can be improved.

4.6 Calibration results for study 1

4.6.1 Accuracy and precision

The calibration results from the six different testing sessions with the second graders provided a good amount of comparable data. We measured the accuracy and precision of the calibrations, as well as the durations and the amount of recalibration required to get an acceptable result.

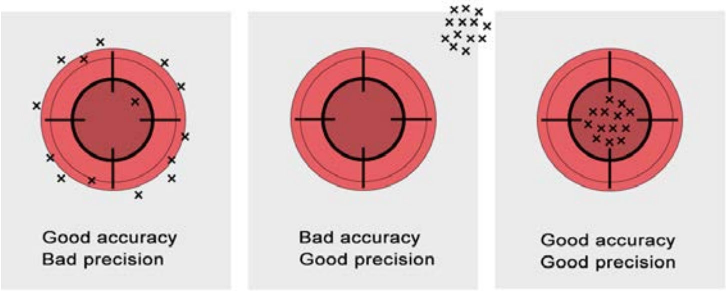


FIGURE 7. Accuracy vs. precision.

In Figure 7 the black crosses represent the gaze points that the reader is registering. Accuracy is telling us how close to the calibration point the gaze is. Precision tells how close to each other the gaze points are. If the data reported by the eye tracker shows variation around the general area of the calibration point, we can tell that the user is looking at that spot accurately, but that the gaze is not necessarily precise. Precision is independent of accuracy. It is possible for the gaze reading to be very precise but inaccurate, as in the middle example. It is also possible for the reading to be accurate but imprecise.

The accuracy and precision of all the individual calibration verification points were computed into averages. These averages were then displayed in centimetres in figure 8. The smaller the value, the higher the accuracy.

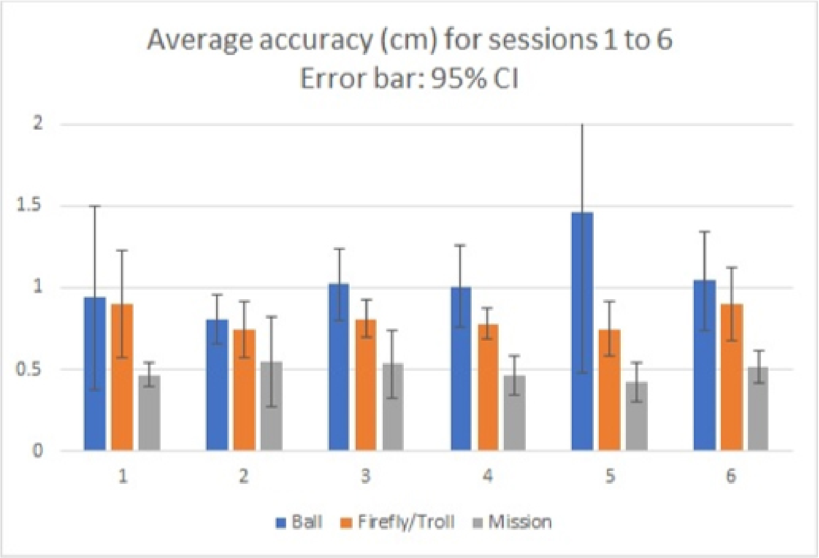


FIGURE 8. Average accuracy (cm), study 1, sessions 1 to 6. (Špakov et al., submitted for publication.)

The accuracy of the Mission Game was much better when compared with the standard calibration; it was about twice as good at about 0,5cm to the standard calibrations 1cm. Error bars are presented on top of both the accuracy and precision charts, and they tell us the possible error margin. Even when the possible error margin is considered, the accuracy remained clearly superior to the other two calibrations throughout all the sessions.

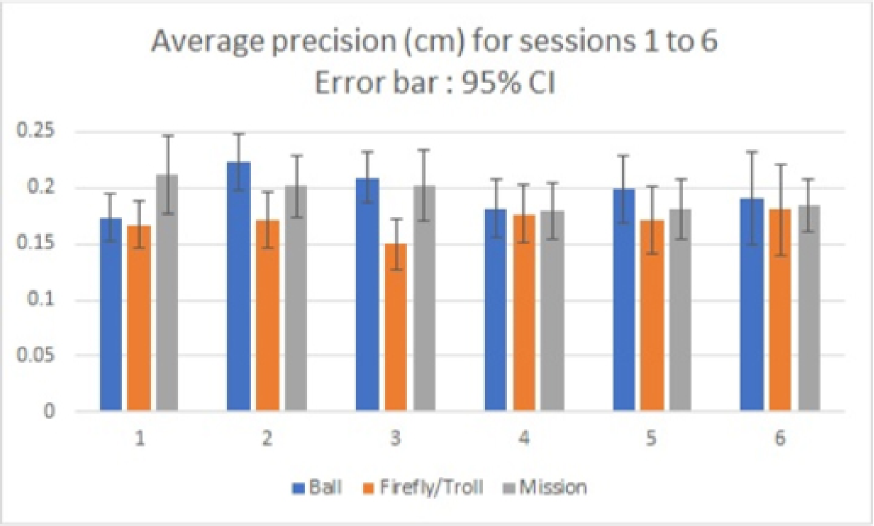


FIGURE 9. Average precision (cm), study 1, sessions 1 to 6. (Špakov et al., submitted for publication.)

The precision for the Mission game was relatively good, with the average variation between 0,15-0,2 cm. However, the precision measurements have only minor differences from game to game, and therefore the data does not provide solid enough evidence that a clear winner could be determined.

4.6.2 Recalibrations and calibration durations

The eye tracker reports data quality during the initial calibration, and a need for recalibration happens when the initial calibration quality is too low. The chart below (Figure 9) shows the average number of recalibrations needed on each day of the seconds graders' testing sessions.

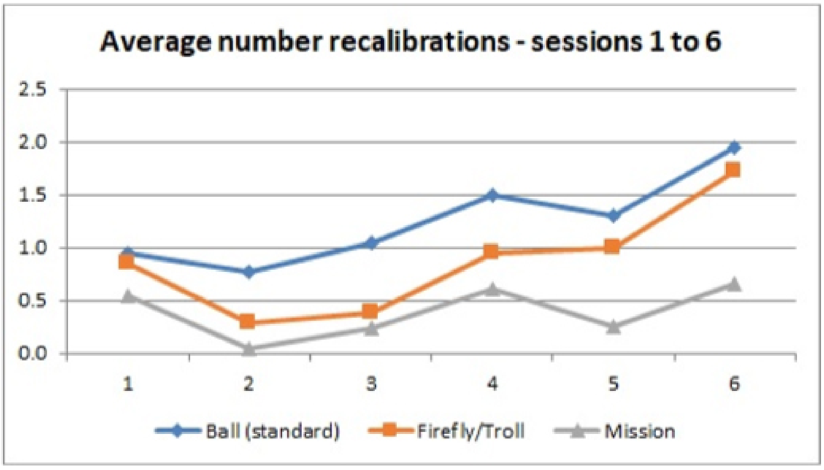


FIGURE 10. The average number of recalibrations for every 5 calibration points, study 1. (Špakov et al., submitted for publication.)

Due to the specific game mechanic, which keeps the user focused on the calibration spot very effectively, the Mission Game comes on top also when comparing the number of required recalibrations. The amount of recalibration doubles for the standard method over the following testing days, while the Mission Games amount remains basically the same through all the days.

The duration was measured in three different ways: the total duration, calibration duration and verification duration. The total duration shows how long each calibration method took from the beginning of the game until the end. It is quite clear to see that the overall duration of the Mission Game is higher than with the other methods.

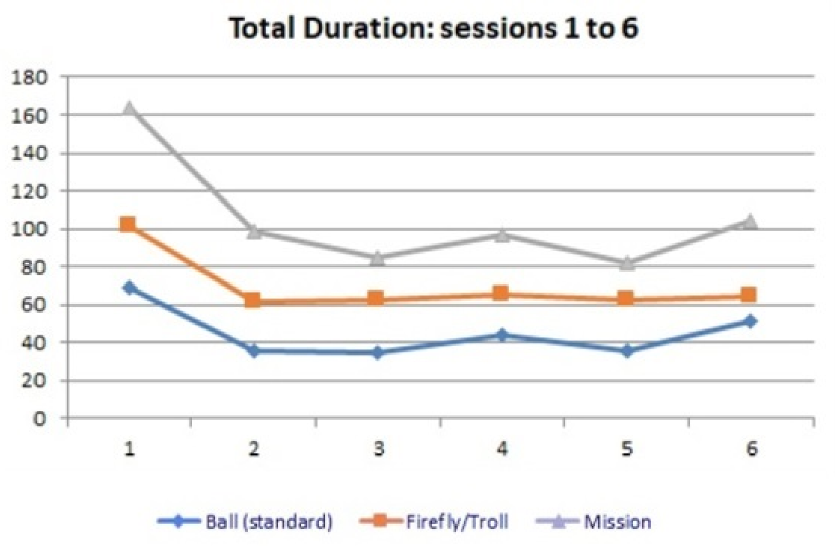


FIGURE 11. Calibration total durations, study 1. (Špakov et al., submitted for publication.)

As mentioned before, in the Firefly Game the calibration happened during the lamp section of the game, and verification during the hidden object game. For Mission Game and standard calibration, the first 4-5 calibration spots were for calibration and the following spots were for verification. The time used on recalibrations necessary in each game were included in the overall calibration time.

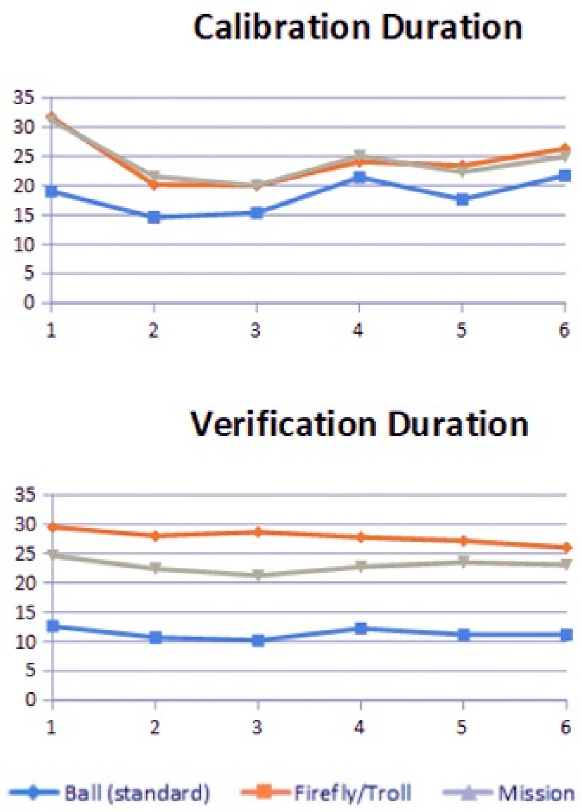


FIGURE 12. Calibration and verification duration averages, study 1. (Visually modified from original calculations and chart by Špakov et al., submitted for publication.)

On the first day, the children spent time on creating their character and reading the instructions. The time spent on the initial character creation explains the highest spike on the Mission Game, but on the following days, the duration normalizes to about 1,5 minutes, which is somewhat around 40 seconds more than with the standard calibration. The time spent on the Mission Game includes the short animations that are played to set the premise, the position adjustments, reading the instructions and the actual calibration. The standard version only includes one screen of instructions (that includes the position check) and the calibration itself. These times sound short and seconds are being counted, but the reason for this is to keep the time spent on calibration as short as possible, so that it does not take too much time away from the lesson.

The overall time spent on the game could be shortened with better UI so that the user does not have to spend so long on the instructions. From the chart, it can be estimated that the time spent on the menus and activities that were not used for calibration was 60 seconds. The calibration duration is similar at around 20+ seconds with all the games, but the verification duration seems to take somewhat over 10 seconds longer than with the standard system. This subtly tells that the players were perhaps spending a longer time waiting to catch the right option on the last, faster changing buttons. In addition to making them easier, a timer could be considered, so that the player does not wait for too long before attempting the catch.

4.7 Calibration by control group of adults

We ran an additional testing session with adults to see how good results the eye tracker we used could be expected to provide, when calibrated under supervision by cooperative adults. University staff and university students were asked to carefully calibrate the gaze tracker using the standard calibration (Ball Game). They were given the instructions in person and the calibration was monitored to assure that everything ran smoothly and that the testers were performing as they were asked to. These results were then compared to the unsupervised calibration results from the children.

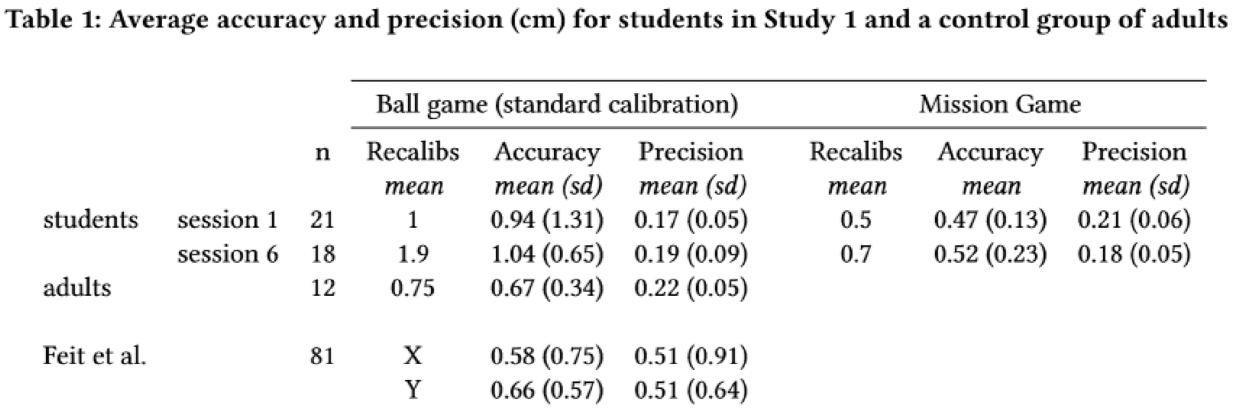


Table 1: Average accuracy and precision (cm) for students in Study 1 and a control group of adults

			Ball game (standard calibration)			Mission Game		
		n	Recalibs *mean*	Accuracy *mean (sd)*	Precision *mean (sd)*	Recalibs *mean*	Accuracy *mean*	Precision *mean (sd)*
students	session 1	21	1	0.94 (1.31)	0.17 (0.05)	0.5	0.47 (0.13)	0.21 (0.06)
	session 6	18	1.9	1.04 (0.65)	0.19 (0.09)	0.7	0.52 (0.23)	0.18 (0.05)
adults		12	0.75	0.67 (0.34)	0.22 (0.05)			
Feit et al.		81	X	0.58 (0.75)	0.51 (0.91)			
			Y	0.66 (0.57)	0.51 (0.64)			

FIGURE 13. Comparing supervised adults and unsupervised children’s results. (Špakov et al., submitted for publication.)

Supervised adults had undoubtedly better accuracy with the standard method than the unsupervised children, as expected. Adults were sitting further away from the screen at around 60cm average distance, while the children's distance was around 45cm. If the distance is taken into account, and the accuracy is calculated in degrees, the adults' calibration is 53% better than the children's is.

However, the significant and most important discovery here is that the unsupervised calibration by children, with the Mission Game, resulted in better calibration quality than supervised adults using the standard method by 11%. These results show that a gamified calibration based on this specific mechanic offers better calibration results than the standard calibration method.

4.8 Calibration results for study 2

The second research question was whether the age of the children makes a significant difference in calibration quality. The data from the first day of the second graders group was used and compared with the data from the two third graders groups and one fifth graders group performing the calibrations once. A modification was made to the Firefly-game's troll hunting section, to encourage our testers to keep their gaze on the selection area for long enough that we could be satisfied that the gaze fixation was on the estimated spot, when the button was clicked and the data was gathered. This is explained further in a following chapter, "Improved troll hunt".

As mentioned before, there were differences in the environment where the data was gathered. Third graders group A performed the calibrations in a separate area in small groups with the maximum of six students, while the third graders group B did so in a class room where the rest of the class was freely doing their homework or other tasks while waiting for their turn. The setup was similar to this with the fifth graders group.

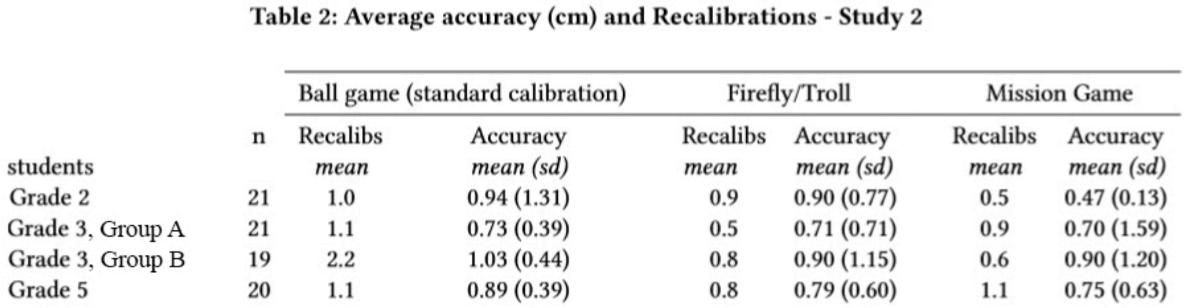


Table 2: Average accuracy (cm) and Recalibrations - Study 2

		Ball game (standard calibration)		Firefly/Troll		Mission Game	
	n	Recalibs	Accuracy	Recalibs	Accuracy	Recalibs	Accuracy
students		*mean*	*mean (sd)*	*mean*	*mean (sd)*	*mean*	*mean (sd)*
Grade 2	21	1.0	0.94 (1.31)	0.9	0.90 (0.77)	0.5	0.47 (0.13)
Grade 3, Group A	21	1.1	0.73 (0.39)	0.5	0.71 (0.71)	0.9	0.70 (1.59)
Grade 3, Group B	19	2.2	1.03 (0.44)	0.8	0.90 (1.15)	0.6	0.90 (1.20)
Grade 5	20	1.1	0.89 (0.39)	0.8	0.79 (0.60)	1.1	0.75 (0.63)

FIGURE 14. The average accuracy and number of recalibrations, study 2. (Modified from original calculations and chart by Špakov et al., submitted for publication.)

Like in study 1, the data on the average precision was so similar in each game and age group that it does not make sense to display further visualizations of it. The accuracy for Mission Game remains better compared to the standard calibration, but the difference gets subtler with the older groups. The Mission Game still requires fewer recalibrations as the other methods, with the exception of the fifth graders group who needed to recalibrate the same amount of times with the standard and the Mission Game methods, while the Firefly Game needed the least amount of recalibrations. Third graders group B has the highest number of recalibrations compared to all, but the spike is in fact due to two students, who both together required 17 recalibrations, dragging the average higher. These can be the result of the additional distraction in the class, as this group was very interested in the games and some of the student waiting for their turn to play came over to the testing area to see what the testers were doing.

Next to the second graders, they needed the least amount of recalibrations in the Mission Game, which could be considered as evidence towards an engaging game experience and higher concentration. The medians were calculated to reduce the impact of these individual students, and as a conclusion, the accuracy results are very much like the results from the study 1, proving no significant difference in accuracy between different age groups.

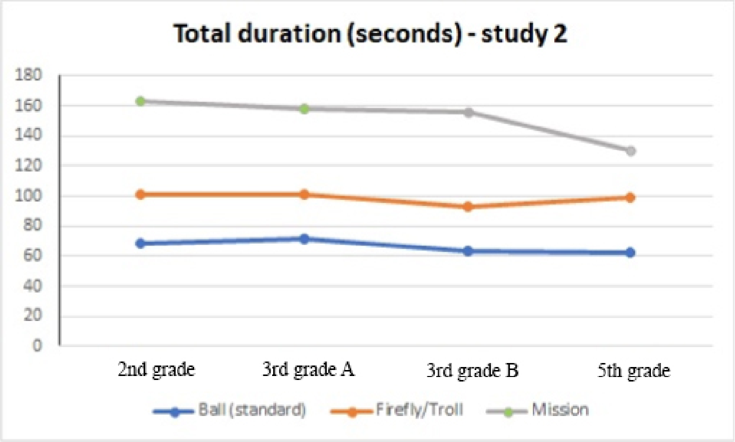


FIGURE 15. Calibration total durations, study 2. (Špakov and Istance, 2018)

All of the overall durations are quite similar with the exception of the fifth graders group during the Mission Game, where overall time used on the game decreased by 20 seconds. As the Mission Game was the option requiring the most reading, it is most likely due to the higher reading speed of older students. In conclusion, to the data obtained for study 2, there is no evidence towards making claims that age of the child has an impact on the calibration quality.

5 DISCUSSION

5.1 Points of interest after testing

Additional point of interest towards further studies comes from the age groups. A study was previously mentioned where the results show that children react negatively towards a design if they identify it to be made for younger children than they are. (Nielsen). In the studies conducted in this thesis, the children were not told that groups of different ages are testing the same games. It would be interesting to see if the survey results would have provided different information, if this fact had been disclosed with the testers. According to the Nielsen studies, the reactions could be assumed to be more negative. In the case of the fifth graders expressing the Mission Game to be too difficult, would knowing that even three years younger students had played them, had made a difference in attitude? Of course the second graders thought it was difficult as well, but based on their interviews, it was not considered as negative as with the fifth graders.

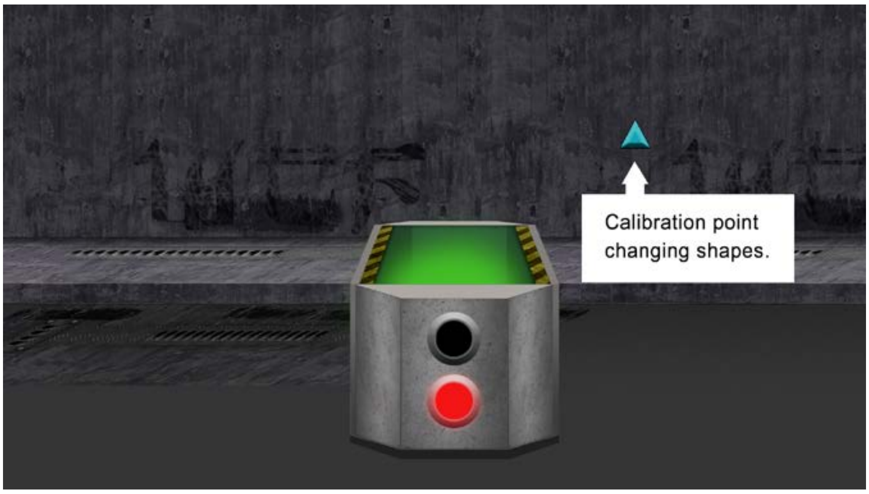
The Mission game was the only one out of the three calibration games to introduce the possibility of failure, which, in hindsight, was somewhat risky. It is crucial that the difficulty is on the appropriate level to avoid frustrating the testers. Another key difference between the Mission Game and the other games was that in the other games you follow an object, wait for it to stop and then take action. The children seemed to be responding to this quite positively, and surprisingly positively in the case of the plain ball game (standard calibration). In the mission game, the game object appeared randomly, which can break the momentum of following through one action. It would be interesting to perform further testing to compare these two different approaches and pay specific attention to which one the children like more. Some feedback suggests that finding the right spot on the game screen can be fun, but this was not a feature much addressed by the testers. In the Mission Game, it would be quite easy to add the element of movement to the gameplay. An object similar to the images rotating during the catch-section of the game (that can never be the correct option to click) would be visible when the object is moving. When it stops at the calibration spot, the rotating images activate and the player has to catch the right option just like in the original design.

As the children enjoyed the hidden trolls section of the Firefly game so much, it could be a good possibility to add more of these types of tasks inside the Mission Game to create more variety. These different games would then be available for selection before each session, and every user could choose the calibration method they like the most. This makes the calibration less of a mandatory task, and even users who do not usually play games or who feel like they do not have the skills for them, would have the opportunity to select the least annoying method. Even though the catching the right option mechanic is working extremely well for calibration, it seems to be possible to adjust the hidden object game to reach similar quality calibrations as well. As explained in chapter “Improved troll hunt”, the calibration accuracy can be improved by adding visualization to the spot that we want the player to be looking at when the calibration point gaze data is collected. Additionally, only one hidden object could be seen on the screen at any given time, thus reducing the possibility of the player already looking at the next object they want to click. The problem with the original hidden troll game was the location of the hidden objects. For verification purposes it was acceptable that the hidden objects were located on a ready image and that the verification points were defined by the picture. But for the initial calibration, the calibration spots appear on tracker defined spots that are not known beforehand, so the game would need to be modified in a way that the hidden objects could appear anywhere on the screen. This creates interesting challenges for the game graphics design.

The socializing element, which is one important factor in gamification, came into play when the children were sharing the points they made, which games they played and what rewards they received. However, the game itself does not have added socializing elements. Implementing different ways for the users to share their achievements or even gift items could be interesting, as these might improve the motivation to play the game. When these features are considered, the important thing to remember is the limited time that the users have available to use and if these elements would create disruptions during the lesson. The system GaSP is developing is based on the teacher being able to see what the students are doing, to evaluate when additional tutoring is required. If social elements are implemented, then an ability to enable or disable these activities could be added on the teacher’s version. This way, the teacher could give permission to use the additional elements based on the situation in the classroom.

5.2 Improvements on Mission Game

The second level should be first, as the majority of testers considered it to be more fun. This makes perfect sense, as the theme of the second mission is ghosts, and generally children respond much better to topics they already know and that inspire their imagination, whereas the nuclear factory in the first mission can be a more distant and unfamiliar topic especially for younger children. As children do not yet have a lot of life experiences, they are drawn to familiar, recognizable elements. In addition, the shapes seemed easier and more fun to the most of the children. The factory could be replaced altogether with a different story.



PICTURE 11. The second level of Mission Game, after the ghosts have escaped from the box.

With the colour catching, colour blindness could be an issue that may cause a problem at some point. In this case, there should be an alternative option for colour blind users. New background stories could include objects from nature, animals and other topics generally of interest to children. In addition, the use of the background picture during the calibration game was something that was thought about even before the testing. The calibration results of the second graders show a slight decrease in accuracy when a new background story, and with it a picture, is introduced. For the duration of the calibration, the background picture could be muted with a transparent layer so that it does not distract the user. This would be a feature especially beneficial and easy to implement, if new missions requiring animations with many components to explain the story are created.

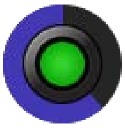
5.2.1 Difficulty level

Based on the feedback from the test groups, it is very clear that the levels need to be easier, as explained before. In addition, the point system needs revising to make it easier to get a bonus item. When testing with the second graders, not even one managed to get enough points to get a bonus item on their own. We adjusted the game ourselves before the second to last session in a way that all the children would reach level 2 and get a bonus item before the last session. Even then, two players failed to reach the very small amount of points needed to progress.

An adjustable difficulty level could be implemented to consider the variety of gaming skills among children. Implementation of a system that detects the skill level of the player would also help with the problem. If the system notices that the player is struggling to get the selection right, it should automatically make the task easier. If the player continues to do really well, the difficulty could be gradually increased to the level of the individual. This way the experience serves all the skill levels and does not punish the not so good players too much while boring the better players. After all, the point is to get the system calibrated, not to put the children in the order of who is the best player.
Schools may also have policies where leaderboards based on performance should not be used. The calibration game should be a rewarding and gratifying experience for all users. Of course, the children would still be able to compare their scores, levels and prizes later on, without necessarily knowing that difficulty adjusting mechanics are taking place inside the game system.

5.2.2 Shortening the time spent on each calibration point

The idea of a timer placed around each button to limit the time spent on one calibration spot had been introduced before, but we did not have time to implement it. If the timer runs out, that button would be counted as failed. This way, a player would not use too much time on one calibration point, waiting infinitely for the perfect timing to catch the correct option.

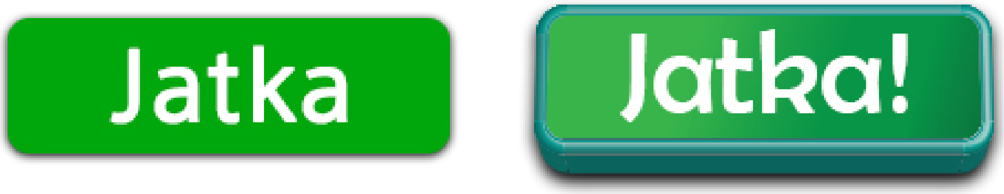


PICTURE 12. A timer around a calibration point.

In the tested version, the buttons had four different options in one cycle, and if the player missed it on one round, they would have to wait for it to come around again. For the first buttons, these options could be lowered to three or maybe even two for the first one to cut down on that time. As learned from before, many of the testers felt that the buttons were too difficult to catch because they were changing too fast especially in the end. With the second graders' group, we had several children who were unable to catch even one, or only one (to our surprise). The speed could be slower so that they would have a chance to get at least the first ones right. The right option could have a slightly longer turn in the cycle. Despite two testers expressing an opinion that the first speed setting was too slow, the amount of this feedback was not as significant as the opposite opinion. The amount of different options could have also contributed to the feeling that it was too slow, as they had to wait for all the options to cycle before they had a chance to try again. In theory, the player would spend less time on each button, if they felt a bit more confident that they could to catch the right option.

5.2.3 Affordances and fonts

Affordances in general are something that should have been considered more. An affordance is a quality of an object or an environment that allows an action to be performed. For example, a button affords clicking it. Children, who are now in elementary school, are growing up in a generation where using technology from a very early age on is common. Most six years olds can use a computer mouse, but they have likely been using mostly tablets before, where the main action triggers can often be buttons. The buttons need to be big and easy enough for them to click, because the children's fine motor skills are not fully developed until they are ten years old. (Falbe, 2015.) During the sessions, some of the testers seemed confused about what to do to continue, and the button to press had to be pointed out to several of the students, including one of the fifth graders. Using outlines on the buttons or adding drop shadows to them can make them look more interactive. Clickable items should draw the user's attention, as children are not as used to interfaces as adults are. They do not necessarily understand that an object is interactive if it does not wiggle or sparkle. (White, 2016).



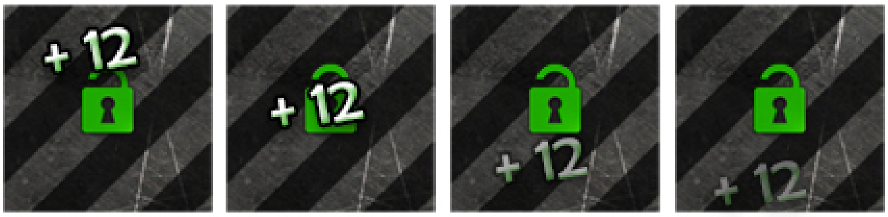
PICTURE 13. Original flat button vs. improved button.

The old button had a slight drop shadow applied, but it did not pop up enough from different backgrounds and looked too flat. The 3D-effect in the new button invites the user’s attention to it and is more clearly a clickable item. In addition, the button should start to glow after a time-out period, if it remains unclicked. A child-friendly font filling the qualifications mentioned in the next paragraph, called Berlin Sans FB was used. The font also looks more interesting, and it should appeal to young players.

Tim Murray (2015) suggests that using a font with one-story lowercase "a" and "g" rather than the double-story form might make the text more accessible to children. Children are not as used to recognizing different styles of letters as adults, so it is a good idea to keep the fonts simple, easy to understand and similar to the type of letters that the children start to learn in school. Adults simply compare the glyphs we see with the letter variations that we are already familiar with, and then decode the given glyph based on the closest comparison. Most of the time, we are right, and are not even aware of this process happening (Simply Robert: Fonts and Young Readers, 2009). Comic Sans and Futura, for example, are fonts that fill the qualifications with one-story lower cases and as a bonus have a closed 4 that makes the number easy to distinguish from the capital letter H or Y (McCullough, 2015). Important qualities to consider when choosing a font for children also includes checking how well the capital I can be told apart from lower case l and number 1. Developed readers are able to determine which letter they are looking at by the context of the word, but for children the similarity between those letters can be very confusing. (Simply Robert: Fonts and Young Readers, 2009).

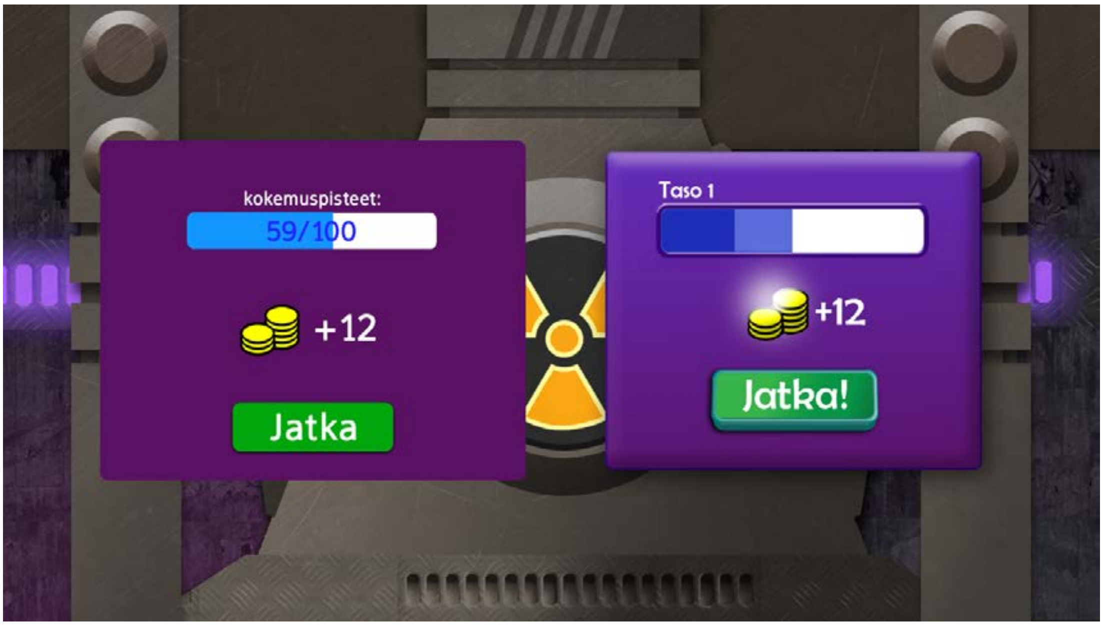
5.2.4 Improvements on visual feedback

It is especially beneficial for the motivation of a child to receive immediate feedback and rewards for doing well. This was an essential part of the mechanic-based calibration game, where in order for the players gaze to remain fixed on the calibration spot, a visualization of success or failure was displayed as a green or red lock. In addition to knowing if they succeeded or not, the player receives experience points and coins based on their score. These were not visualized at all in the original design, and for added motivation this should be fixed. The score should as well be visualized immediately during the game when theplayers catch the right option.



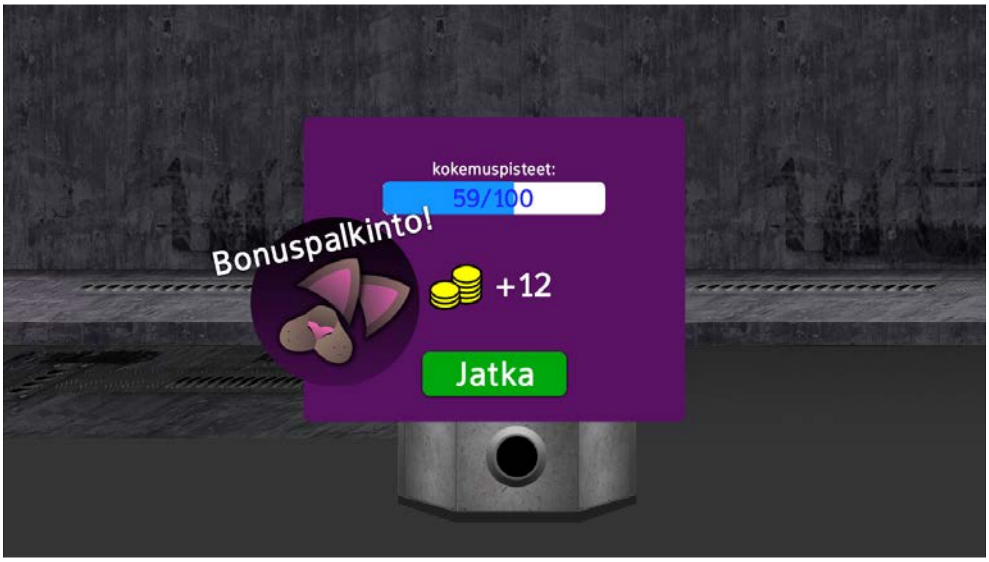
PICTURE 14. Player sees the points they get immediately, displayed over the icon visualizing the correct selection.

This way, in addition to the satisfaction of getting the selection correct, the child gets an immediate value reward as well. The points need to be displayed only for a second, appearing on top of the green symbol and falling out of the screen. In addition, more attention should be brought to the feedback given to the player after attempting to catch all the buttons, when all the scores are tallied. Attention grabbing graphics and effects are necessary to catch the attention of a young user. As receiving feedback whenever anything happens is crucial for children, the design has to offer extremely clear signs when something important happens. (Designing Apps for Kids is Not Child’s Play, 2016).



PICTURE 15. Improvements for tallying total points and coins.

The player should be able to see the experience bar filling while the new points are added, and be able to distinguish between the new points received and the ones they already had. The amount of coins received on this round should be displayed with a number starting from zero, and increasing in value until the prize amount is reached. This amount is then added to the already existing amount of coins. The display box should also be more accented, and pop out from the screen to better bring the players attention to it. Text “experience points” is replaced with the current level to simplify the implied message that the points are converted into the experience bar thus bringing the player closer to a level up.



PICTURE 16. Original points screen mockup after receiving a bonus item.

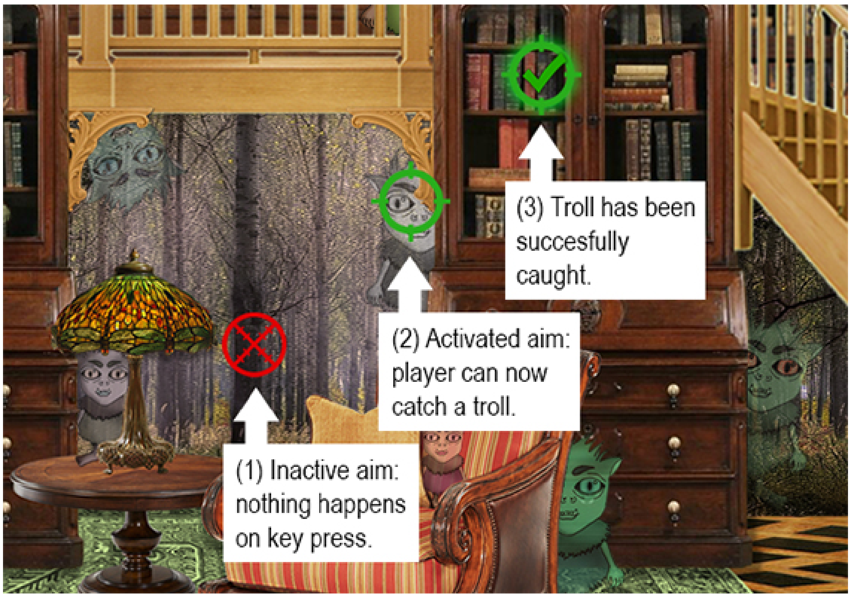
Only a few testers noticed that they had in fact reached the second level and gained the item. Many did not pay attention to the points screen for long enough to see this. For the few children who realized that they had reached the second level and got the bonus item, the reaction was as hoped. The children seemed very happy about their accomplishment and prizes, and one even turned around with a huge smile and excitement on his face. This was exactly the effect that was being attempted to create. To make sure that the reward is significant enough, receiving the price needs to be an event on itself and it should not be possible for it to go unnoticed.

An improved scene for when a player gains a level or a bonus item could be as follows: Before the prize box, animated fireworks fill the screen for 1-2 seconds. An empty bonus reward circle appears in the middle of the screen, followed by the “Bonus reward” text. The random reward received appears on the circle. The circle levitates on the screen for 1-2 seconds and then moves to the assigned spot on the prize box. If the player reached a new level, the text “level x” would appear in the similar way, first bigger on the screen and after some flaunting around moving to its assigned spot on the box. The new level achievement would play before the bonus item.

5.3 Improved troll hunt

During the first sessions, the troll hunt was based on the assumption that the player would be looking at the troll at the same moment as they clicked the mouse to catch it. This proved to be incorrect, and they were already looking for the next troll by the time they clicked the button. As Hyrskykari (39, 2006) points out, the eyes always move on the target first, and the cursor follows after. There needed to be a way to lure their attention to the exact spot where the troll was hiding. Because the troll hunt was not a part of the initial calibration, there were no calibration spots to measure. We still needed to know what spot the player was looking at when they pressed the button in order to validate the calibration made during the lamp section of the game.

We added a condition where the invisible gaze controlled cursor had to be in the same area as the one that the player could see and control with the mouse. The difficulty with this option is that if the initial calibration was not precise enough, then these cursors would not be together in the same spot and the player could not catch the troll. This was compensated with a higher tolerance for the distance allowed between these two spots. Knowing the distance enables the programmer to make calculations on the location. The cursors were drawn in a more visualized way to bring the players attention to it. It would be red (1) when it was not on top of a troll or the visible and invisible cursors were not aligned, and nothing would happen if the player clicked at that time. When the cursor was in a correct spot, and the distance between the visible cursor and the invisible gaze controlled cursor was less than the threshold value, it would turn green (2) and have an animation of it getting bigger and smaller. In order to hold the players attention a little longer, a third pointer (3) to visualize a successfully caught troll was added. After these changes, the calibration results got better.


(3) Troll has been succesfully caught.
(2) Activated aim: player can now catch a troll.
(1) Inactive aim: nothing happens on key press.

PICTURE 17. The different phases of the aim cursor in the hidden trolls -game.

The cursors could still be more obviously visualized, as some of the testers did not see or understand the difference between the red and the green cursor. This was something that had to be specifically told many of the testers and they needed to be reminded to look directly at the troll. In some cases, there was some delay in getting the cursor to turn green, and a few times, it did not change at all, but mostly the solution seemed to work well and did not disrupt the smoothness of the gameplay in a significant way.

6 CONCLUSION

Both studies show that gamified calibration method, specifically the Mission Game based on the specific mechanic, provide a good incentive for school children to carefully calibrate their eye trackers while maintaining a good calibration accuracy. The calibration data shows that out of the three tested options significantly better calibration results come from the Mission Game, even when the children are performing the calibration independently. The testing sessions provided good information on the calibration quality of the different methods, while the subjective feedback somewhat failed to show the expected outcome of children finding the standard calibration boring.

The subjective feedback could have been collected in a different way, to produce more detailed information. When we started the testing with the second graders, the survey was very simple, and focused on the testers to choose from options between fun and boring. After it became clear that the children were rating all the games pretty much the same, contrary to the comments made during the testing, we ended up having to do interviews in order to get more specific information. Gunnar Tvedt explains in his paper “How to design for children” that in user testing situations, children are unlikely to give any analytical feedback, which means that the developers have to rely on observations on the behaviour and reactions of the children in order to find out whether they like the product or not. (2016, 8.)

Given the option to do the surveys again, it might be a better idea to ask the children to put the games into order starting from the most liked one and ending in the least favorite one. It should also be emphasized that the children are rating the game itself, not their own performance. We did not want to take too much of each group’ time after each session, but a few pre-planned questions could be fitted into the time frame by having an additional person waiting right outside the testing area or going around in the class room asking the questions and making notes of the answers. The questions should provide information such as what were the most enjoyable / disliked aspects of a specific game. The children could also be asked to rate the difficulty level of each game, and comment on if they find it to be a good or a bad thing.

Overall, considering the tight schedule, the project could be considered successful. If given the chance to redo the game design and the testing sessions, many improvements could still be made based on this experience. If the previously suggested improvements would be made to the game(s), the time spent on them could be reduced, they would be more user-friendly, motivational and in general a more fluent experience for the players. At this point there is already a good amount of data on the standard calibration, so further user testing could be made specifically to improve the gamified calibration method. Based on the experiences and feedback collected during these testing sessions, it seems quite realistic to expect that a gamified calibration can be an effective and motivational way for school children to calibrate their eye trackers before each use. With more work, improvements, user testing and further customized options to accommodate a variety of age groups, the calibration game could become a product suitable for using in many different schools.

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APPENDICES

Appendix 1. The first game design document without improvements

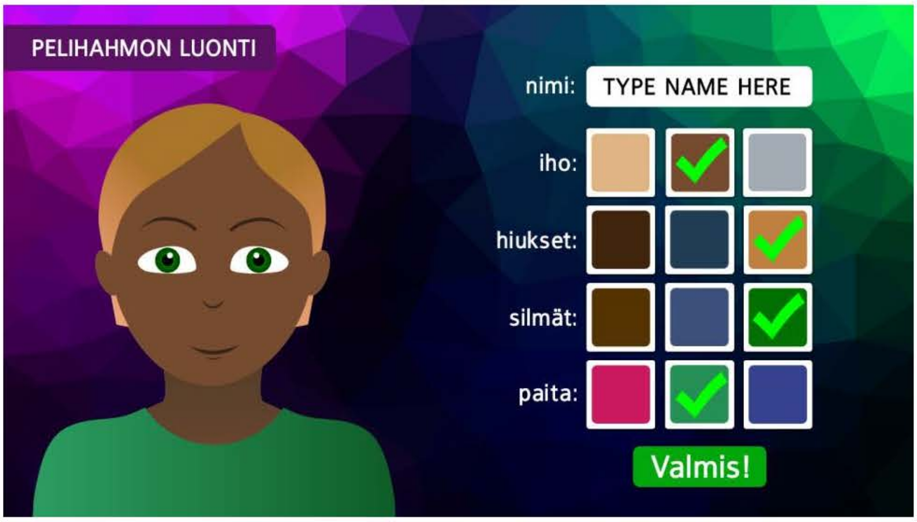
Playing for the first time

Phase 1, character creation

The first screen is where the player can create their character. The player types the name in using the keyboard (automatic capital letters).

The buttons on the side change the appearance of the character. The player can choose each characteristic from 3 different options. The selections in the beginning can be random or then the default setting is selection 1 for all the options.

Once the character is ready, the player presses the button "Valmis!" to continue.



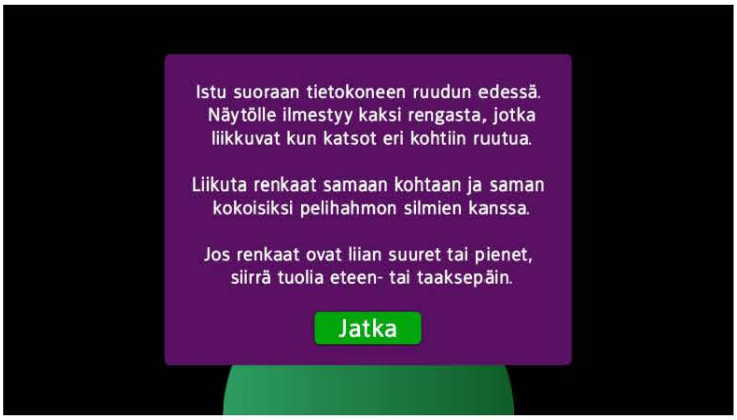
Phase 2, position adjustment

Now we have the ready character displayed in the middle of the screen. The background is basic black. First an instructions box appears. Once the player has read the instructions, they can press "Jatka" to continue. The text in the box is this (I have provided also empty boxed in case the text needs hyphenation.):

Istu suoraan tietokoneen ruudun edessä. Näytölle ilmestyy kaksi rengasta, jotka liikkuvat kun katsot eri kohtiin ruutua.

Liikuta renkaat samaan kohtaan ja saman kokoisiksi pelihahmon silmien kanssa.

Jos renkaat ovat liian suuret tai pienet, siirrä tuolia eteen- tai taaksepäin.


Istu suoraan tietokoneen ruudun edessä.
Näytölle ilmestyy kaksi rengasta, jotka
liikkuvat kun katsot eri kohtiin ruutua.

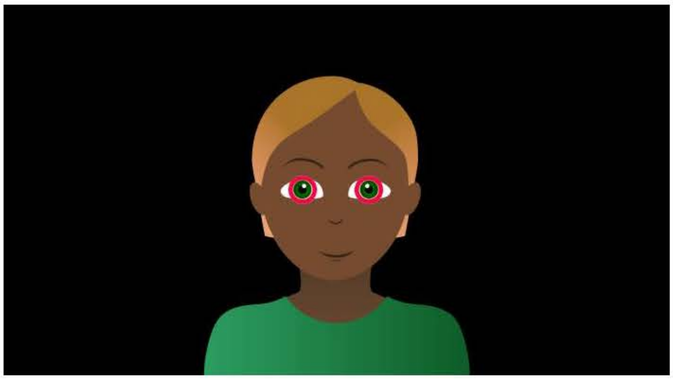
Liikuta renkaat samaan kohtaan ja saman
kokoisiksi pelihahmon silmien kanssa.

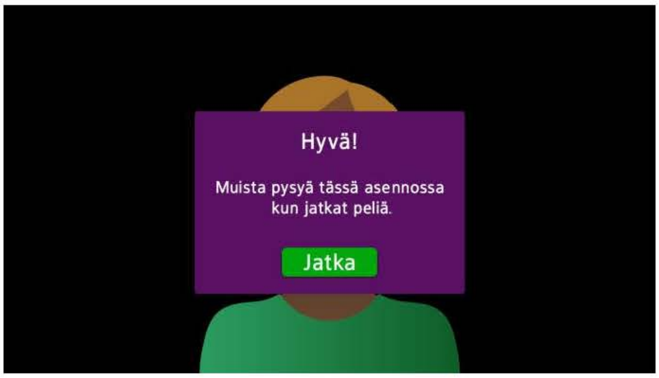
Jos renkaat ovat liian suuret tai pienet,
siirrä tuolia eteen- tai taaksepäin.

The box disappears and the circle guides appear. Once the player has them in the correct spot and the correct distance (size of the guides is same as the character eyes), a second instructions box appears. Again, once the player has read the instructions, they can press “Jatka” to continue.The text in the box is this:

Hyvä!

Muista pysyä tässä asennossa
kun jatkat peliä.



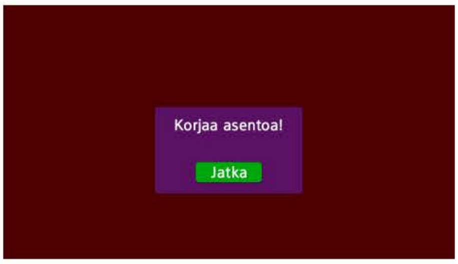


Hyvä!

Muista pysyä tässä asennossa
kun jatkat peliä.

During calibration game

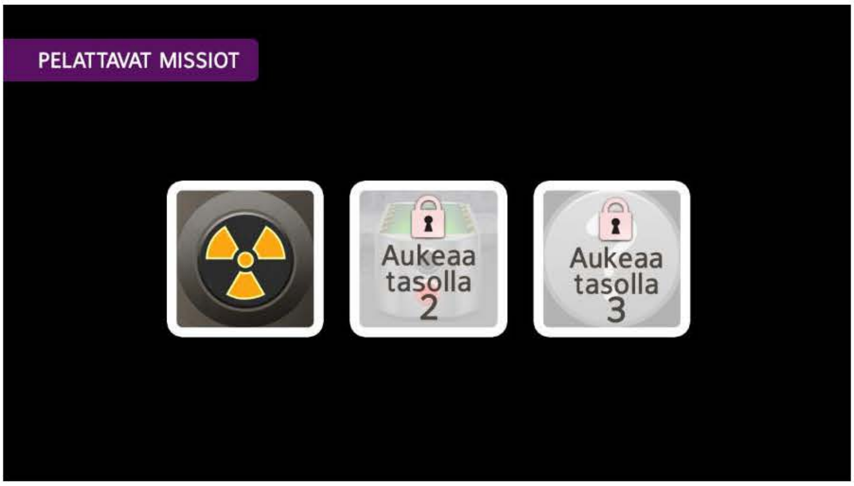
If the player moves too much, or stops paying attention to the game, a screen asking them to fix their position pops up. After they pressed continue on that screen, they will be directed to adjust the circle guides again. (image above).



Korjaa asentoa!

Phase 3, mission selection

Mission selection screen. The player will see the mission selection screen, where the first level mission is unlocked and available to play. The other missions are visible, but they have a lock on them with a text “unlocks at level 2”, “unlocks at level 3” and so on.



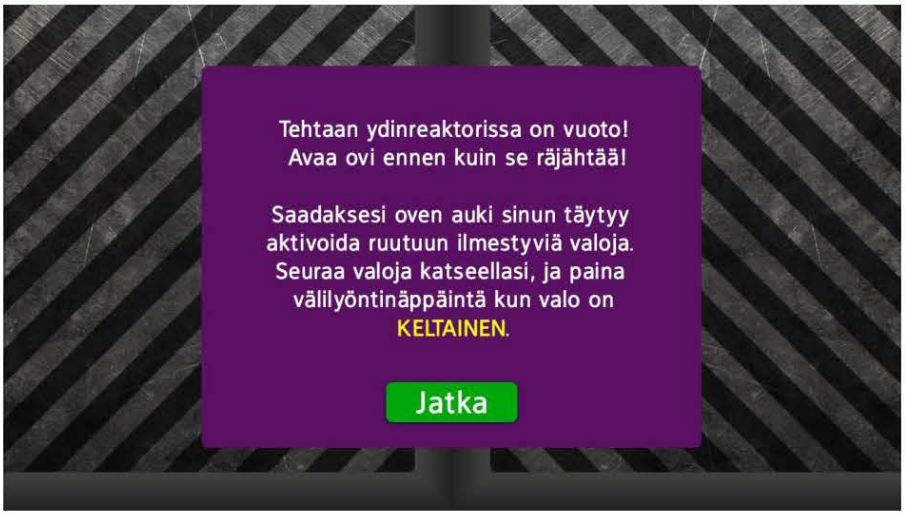
Phase 4, gameplay, mission 1

The mission can start. The screen starts with a background picture of an overheating factory reactor (flashing red light for about 3 s).

The doors come down.
Instruction box appears. The function of this box is to describe the specific mission. It will be different for different missions.

The text in the box for mission 1 is:
Tehtaan ydinreaktorissa on vuoto!
Avaa ovi ennen kuin se räjähtää!

Saadaksesi oven auki sinun täytyy
aktivoida ruutuun ilmestyviä valoja.
Seuraa valoja katseellasi, ja paina
välilyöntinäppäintä kun valo on
KELTAINEN / SININEN / PUNAINEN / VIHREÄ.
The color required should be random and change with every play. Additional color options can be added for more difficulty.

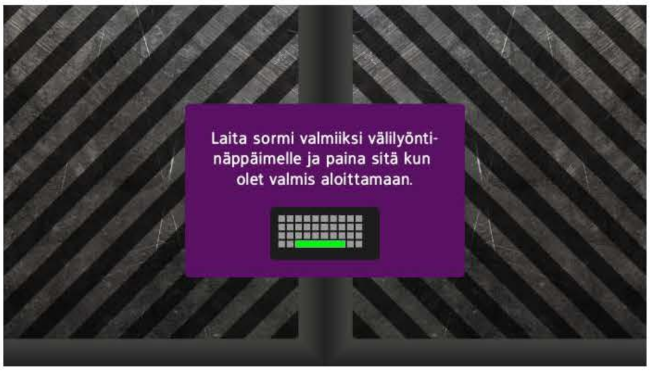


Tehtaan ydinreaktorissa on vuoto!
Avaa ovi ennen kuin se räjähtää!

Saadaksesi oven auki sinun täytyy
aktivoida ruutuun ilmestyviä valoja.
Seuraa valoja katseellasi, ja paina
välilyöntinäppäintä kun valo on
KELTAINEN.

The player presses Jatka to continue, and the last instruction box before the game begins will appear on the screen. This will be the same for all the missions. The text in the box:

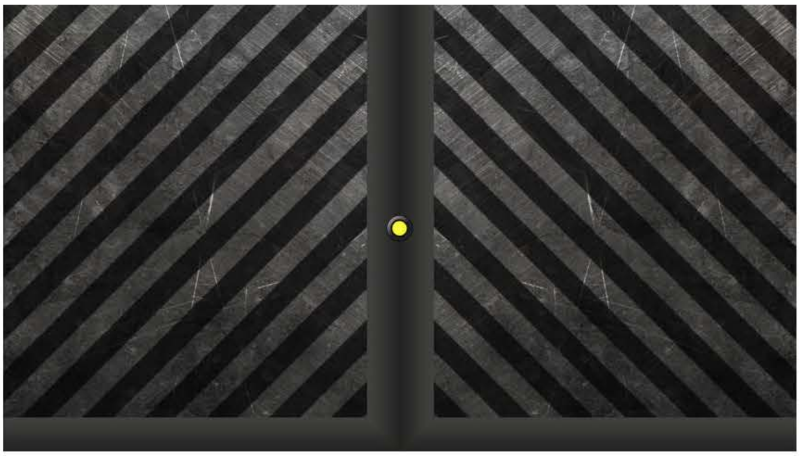
Laita sormi valmiiksi välilyönti-näppäimelle ja paina sitä kun olet valmis aloittamaan.



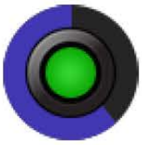
Laita sormi valmiiksi välilyönti-
näppäimelle ja paina sitä kun
olet valmis aloittamaan.

After the player presses the spacebar, the box disappears and the game begins. The buttons appear on the screen with blinking lights. Animation for light changing should be color, off, color, off, color, off… with the off-setting at 0,2 seconds/blink. The speed of the changing colors is slower on the first 2-3 lights (0,5 seconds/blink), a bit faster for the next 3-5 (0,4 seconds) and fastest for the last 2 (0,3 seconds).

When the player hits the spacebar on the correct moment, a "lock" opens. This is visualized with a green padlock showing on top of the button before the next one appears. If they press the spacebar on a wrong color, the "lock" doesn't open and this is visualized with a red padlock showing on top of the button.



Timer around the button prevents the player from getting stuck. Player has limited time, say 15-20 s/button to attempt to open it.

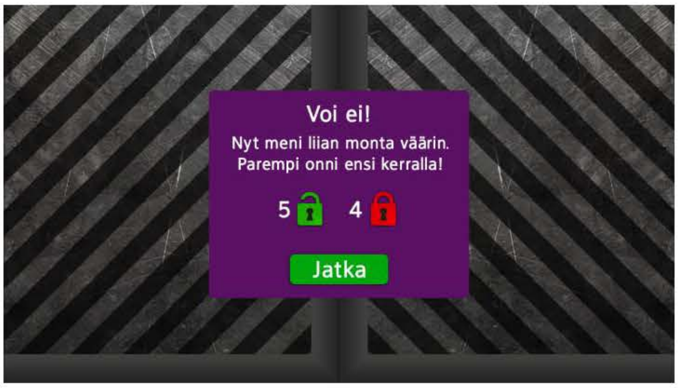


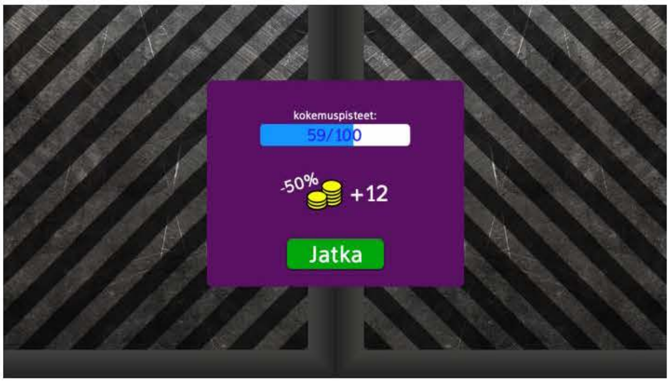
Option A: If the player doesn't open enough locks, the doors remain closed and the get a message box with the results. The text is:

Voi ei!

Nyt meni liian monta väärin.
Parempi onni ensi kerralla!

After they click Jatka, their points and coins are added to their saldo. (Shown on a separate screen.)


Voi ei!
Nyt meni liian monta väärin.
Parempi onni ensi kerralla!



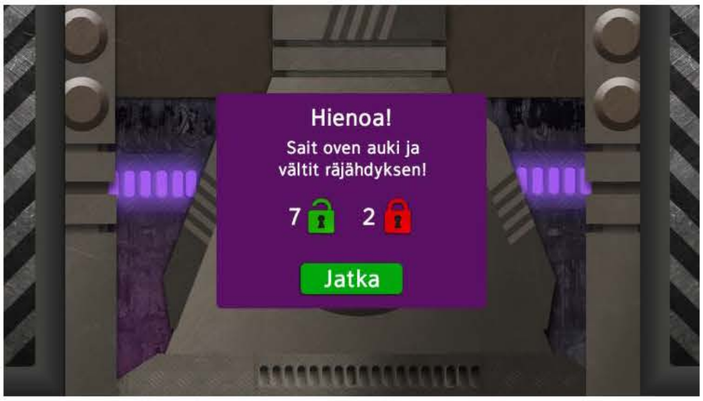
The points collect to an experience bar, that displays the amount of points gained and the amount of points required to reach the next level. Player also receives 50% of the coins they earned (if any). **Can we show visually the experience bar advancing and the coins increasing/decreasing?** On the fail screen the player first sees the amount of coins gained, which then decreases (one coin at a time) to 50% of the original amount. After clicking Jatka they continue to their game home screen.

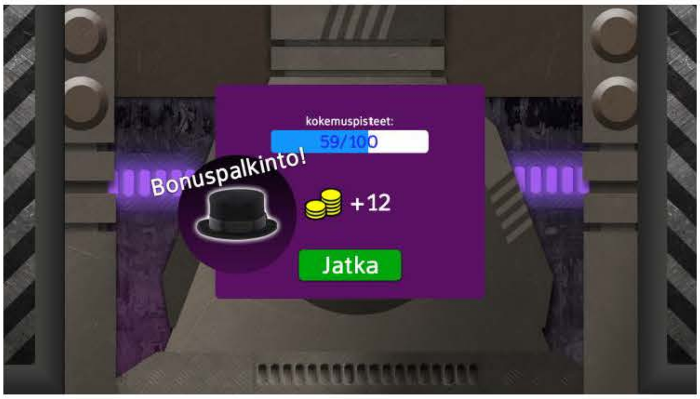
Option B: If player gets enough correct, the doors open and the red light inside the factory is no longer blinking. After the doors have opened, the message box with the results appears. The text is:

Hienoa!

Sait oven auki ja
vältit räjähdyksen!

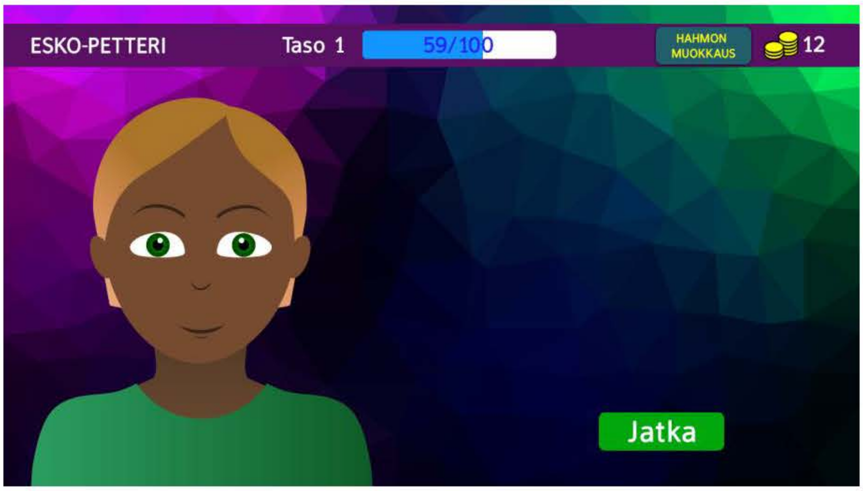
After they click Jatka, their points, coins and possible item reward are added to their saldo. (Shown on a separate screen.)


Hienoa!
Sait oven auki ja
vältit räjähdyksen!



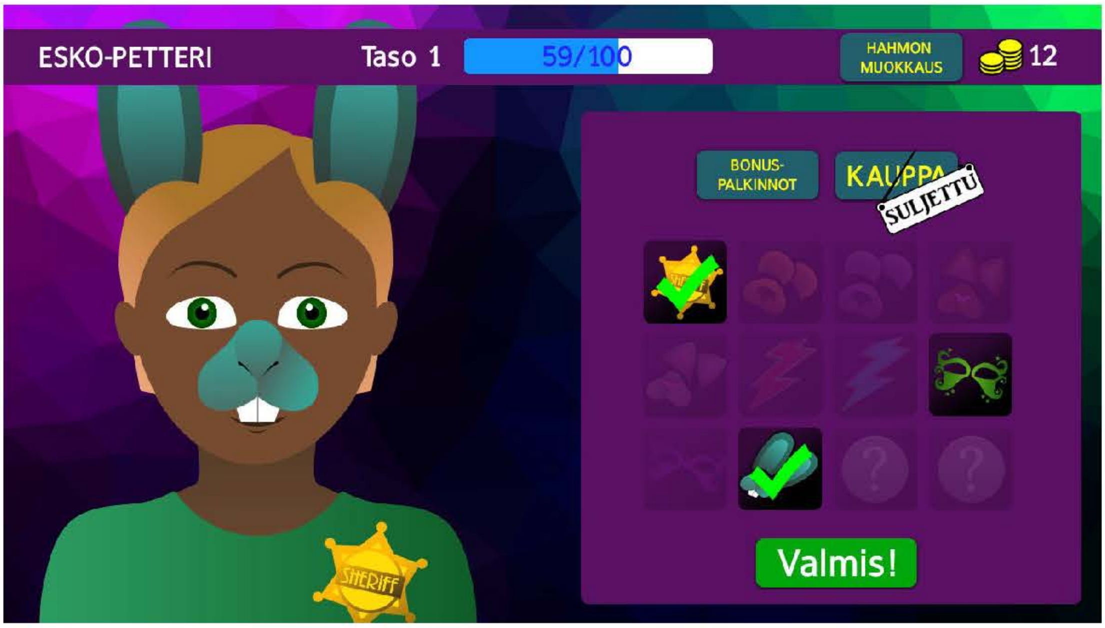
Player receives the points and the coins normally. If the conditions are met to receive the bonus item reward, the Bonuspalkinto graphic appears on top of the regular text box. There should a short delay between the regular box and the bonus prize (1 s?). The bonus prize items will be shown on top of the circle. After clicking Jatka they continue to their game home screen.

Phase 5, home screen



Home screen.

At the home screen the player can see their points, money and what level their character is currently on. When they press the button "Hahmon muokkaus", a window opens where they can see what items they own.



In the picture above the player has opened the "Hahmon muokkaus" -screen. The store is closed, as we don't have time(?) to make it before the tests. If it would be open, the player could click on the "Kauppa"-button to open a different menu where they could spend their coins to buy different things.
In the example, the player has unlocked 3 different bonus items, and has selected to wear 2 of them. After they are happy with the look of their character, they press "Valmis" and the menu disappears.

Points and level ups

Preliminary point system to be reviewed and tested.

Points (added to progress bar) / **coins** received on CORRECT space press:

Button speed	**Space pressed**			
	within 4 s	within 7 s	within 10 s	Past 10 s
0,5 s	10 / 11	7 / 7	5 / 4	2 / 1
0,4 s	11 / 12	8 / 8	6 / 5	3 / 2
0,3 s	12 / 13	9 / 9	7 / 6	4 / 3

- **Door opens at 80% correct space presses and**
  - player receives all the points.
  - player receives all the coins.
  - IF the player has reached 50% or more of max.possible points/mission, they also receive a bonus item award.

- When door remains closed player receives all the points and 50% of the coins.

To level up, the player needs to collect x amount of points. For additional levels they need to collect 20% more points than in the previous level.

Playing after the first time

Phase 1, position adjustment

The game opens by giving the player's name. First they see their home screen. After clicking "Jatka" the player continues normally to the position adjustment section of the game.

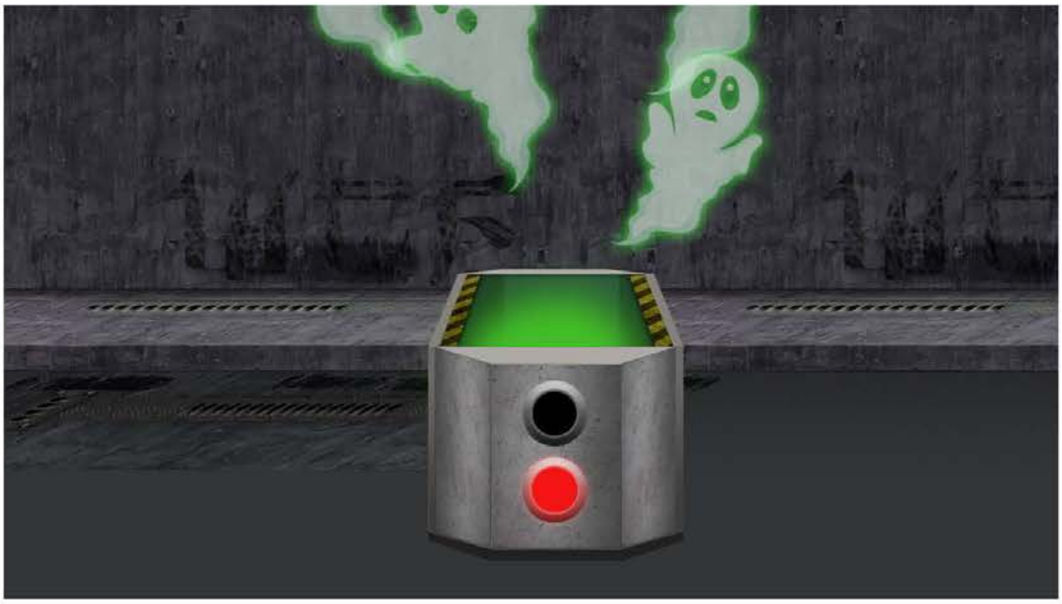
Phase 2, mission selection

Phase 3, gameplay

Phase 4, home screen

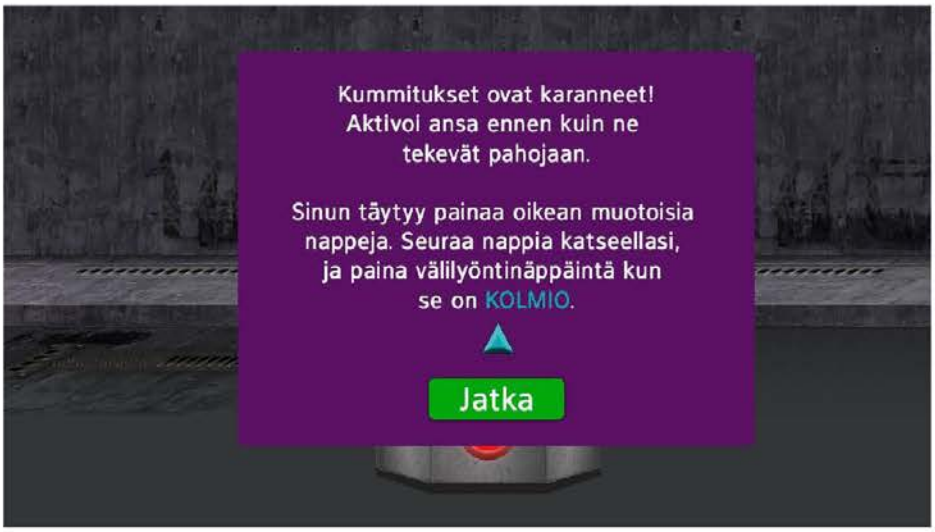
Mission 2 description

The scenario starts with a background image of a ghost trap with a green button activated. The game plays a short animation of the trap. First the green light starts to blink and after 1-2 s it changes into a red light. Then the trap opens and the ghosts escape.



After the animation has played, the instruction box appears on top of the background image. Instruction text reads:

Kummitukset ovat karanneet!
Aktivoi ansa ennenkuin ne tekevät pahojaan.
Sinun täytyy painaa oikean muotoisia nappeja.
Seuraa nappia katseellasi, ja paina välilyöntinäppäintä
kun se on KOLMIO/NELIÖ/YMPYRÄ/TÄHTI.

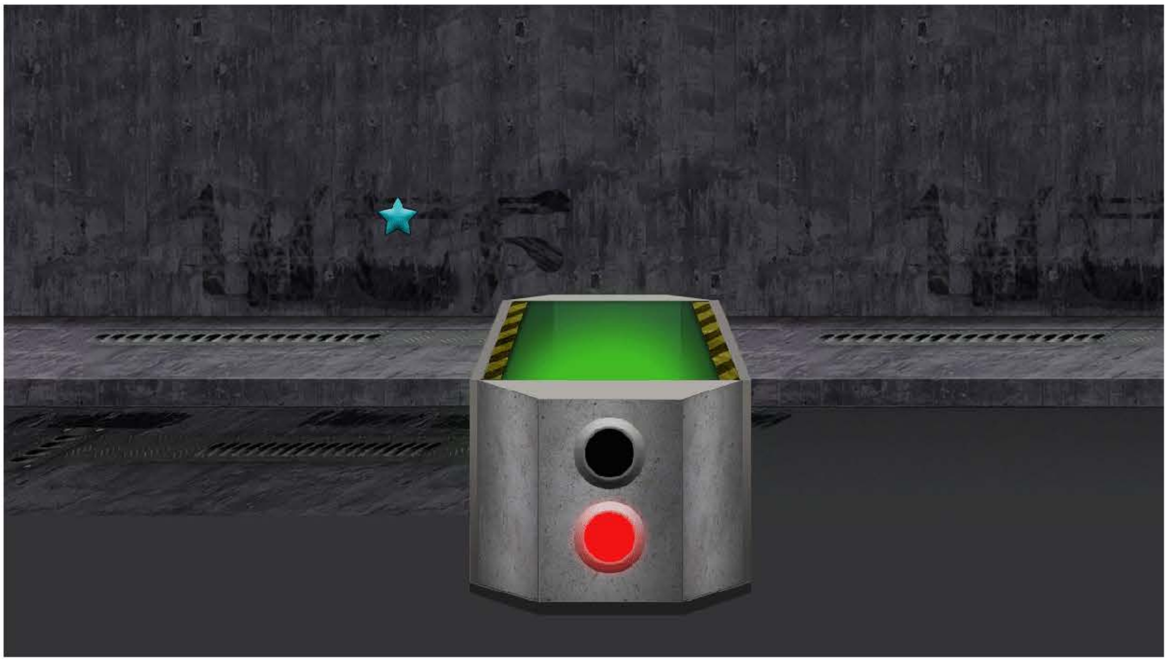


Kummitukset ovat karanneet!
Aktivoi ansa ennen kuin ne
tekevät pahojaan.

Sinun täytyy painaa oikean muotoisia
nappeja. Seuraa nappia katseellasi,
ja paina välilyöntinäppäintä kun
se on KOLMIO.

▲

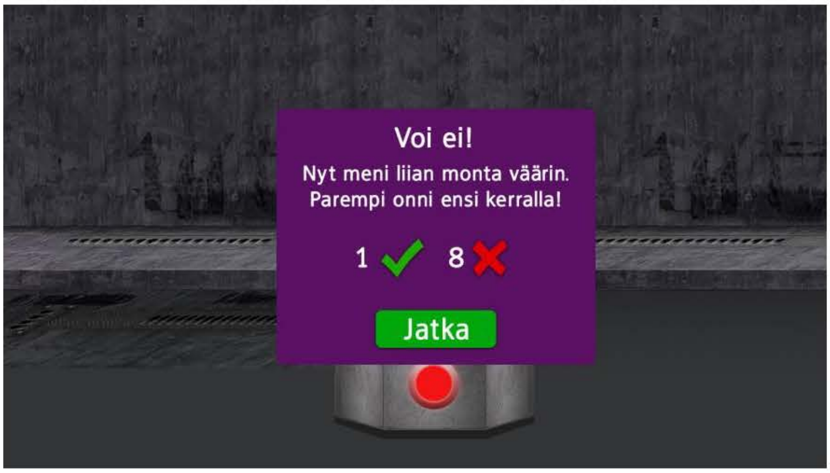
The game begins. Player must trap the ghosts by pressing spacebar on the correct shape. Shapes are a triangle, a square, a circle and a star. With a successful spacebar press the player sees a green check mark on top of the shape. With an unsuccessful attempt the player sees a red cross mark.



Option A: If the player doesn't get enough shapes correct, the trap remains open and the message box with the results appears. The text is:

Voi ei!

Nyt meni liian monta väärin.
Parempi onni ensi kerralla!

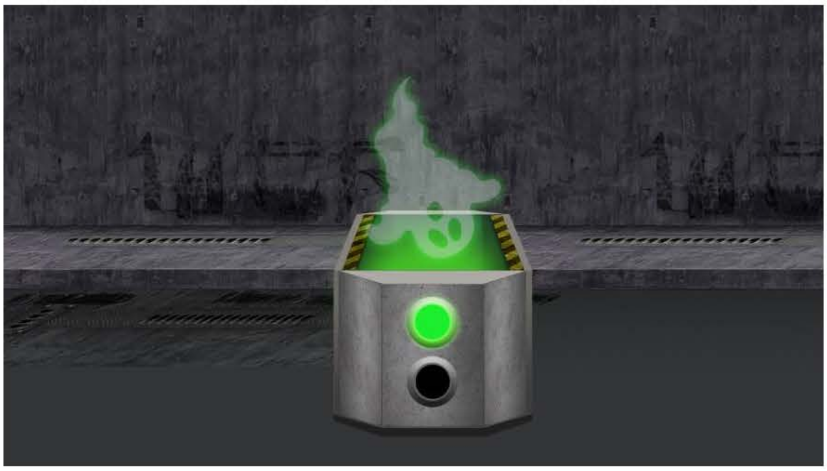


Voi ei!

Nyt meni liian monta väärin.
Parempi onni ensi kerralla!

1 ✓ 8 ✗

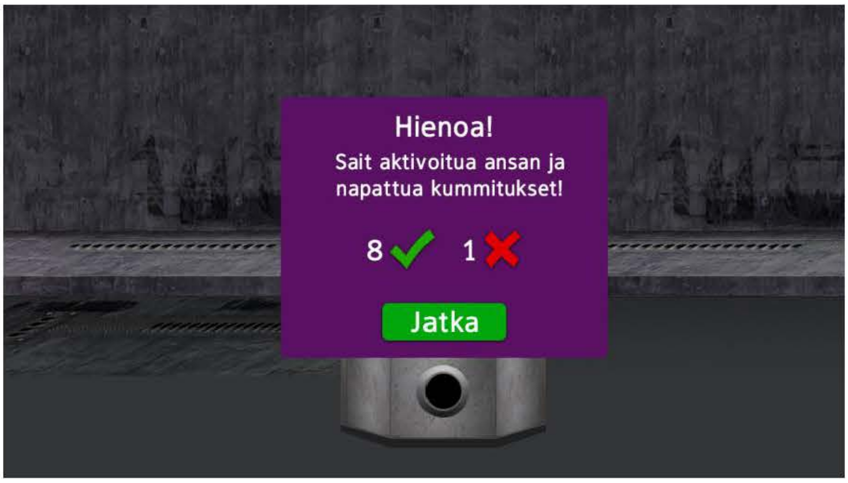
Option B: If player gets enough shapes correct, the animation of the ghost being re-trapped plays.



After the animation has stopped, the message box with the results appears. The text is:

Hienoa!

Sait aktivoitua ansan ja napattua kummitukset!



Hienoa!

Sait aktivoitua ansan ja napattua kummitukset!

8 ✓ 1 ✗

Appendix 2. Second graders survey results

Second graders survey results

We asked their opinion on how boring each game was.
Green means "not boring at all" and red means "very boring".
Empty space means that the student was absent to that game.

	BALL GAME					LAMP GAME					RESCUE GAME				
	🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥
Day 1															
Computer 1															
P1			1			1					1				
P2	1					1					1				
P3		1							1				1		
P4			1				1				1				
Computer 2															
P5	1					1						1			
P6	1						1				1				
P7	1					1					1				
P8	1					1					1				
Computer 3															
P9	1					1						1			
P10	1						1					1			
P11		1				1					1				
P12		1				1					1				
Computer 4															
P13	1					1					1				
P14	1					1						1			
P15															
P16	1					1					1				
Computer 5															
P17		1				1					1				
P18		1					1				1				
P19															
P20		1						1			1				
Computer 6															
P21		1				1					1				
P22	1						1								
P23			1					1						1	
Day 2															
Computer 1															
P1	1					1					1				
P2	1					1					1				
P3		1						1				1			
P4		1				1					1				
Computer 2															
P5	1					1							1		
P6	1					1					1				
P7	1					1					1				
P8	1					1					1				
Computer 3															
P9	1					1					1				
P10	1					1						1			
P11		1				1					1				
P12	1					1					1				
Computer 4															
P13	1					1					1				
P14	1					1						1			
P15															
P16	1					1					1				
Computer 5															
P17	1						1				1				
P18		1					1				1				
P19															
P20	1					1					1				
Computer 6															
P21		1				1					1				
P22	1					1					1				
P23		1					1				1				
Day 3															
Computer 1															
P1	1					1					1				
P2	1					1					1				
P3		1						1				1			
P4	1					1					1				
Computer 2															
P5	1					1					1				
P6	1					1					1				
P7		1				1					1				
P8	1					1					1				
Computer 3															
P9	1					1					1				
P10	1					1						1			

Comparing individual student´s reviews

	BALL GAME					LAMP GAME					RESCUE GAME				
	🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥	🟩	🟩	🟨	🟧	🟥
P1															
Day 1			x			x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5			x			x							x		
Day 6	x							x					x		
P2															
Day 1	x					x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5	x					x					x				
Day 6	x						x				x				
P3															
Day 1		x							x				x		
Day 2		x						x				x			
Day 3		x						x				x			
Day 4		x						x				x			
Day 5		x						x				x			
Day 6		x						x				x			
P4															
Day 1			x				x				x				
Day 2		x				x					x				
Day 3	x					x					x				
Day 4		x				x					x				
Day 5	x					x					x				
Day 6	x					x					x				
P5															
Day 1	x					x						x			
Day 2	x					x							x		
Day 3	x					x					x				
Day 4	x					x							x		
Day 5	x					x					x				
Day 6	x					x					x				
P6															
Day 1	x						x				x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x						x			
Day 5		x				x						x			
Day 6	x					x					x				
P7															
Day 1	x					x					x				
Day 2	x					x					x				
Day 3		x				x					x				
Day 4		x				x					x				
Day 5		x				x					x				
Day 6															
P8															
Day 1	x					x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5	x					x					x				
Day 6	x					x					x				
P9															
Day 1	x					x						x			
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5	x					x					x				
Day 6	x					x					x				
P10															
Day 1	x						x					x			
Day 2	x					x						x			
Day 3	x					x						x			
Day 4	x					x						x			
Day 5	x					x						x			
Day 6	x					x						x			
P11															
Day 1		x				x					x				
Day 2		x				x					x				

P11	1					1					1				
P12	1					1					1				
Computer 4															
P13	1					1					1				
P14	1					1					1				
P15															
P16	1					1					1				
Computer 5															
P17		1					1				1				
P18		1					1				1				
P19															
P20	1					1					1				
Computer 6															
P21	1					1						1			
P22	1					1					1				
P23		1						1			1				
Day 4															
Computer 1															
P1	1					1					1				
P2	1					1					1				
P3		1						1				1			
P4		1				1					1				
Computer 2															
P5	1					1							1		
P6	1					1						1			
P7		1				1					1				
P8	1					1					1				
Computer 3															
P9	1					1					1				
P10	1					1						1			
P11	1					1						1			
P12	1					1					1				
Computer 4															
P13	1					1					1				
P14															
P15	1					1					1				
P16	1					1					1				
Computer 5															
P17	1					1					1				
P18		1					1				1				
P19		1					1				1				
P20		1				1					1				
Computer 6															
P21	1					1						1			
P22	1					1					1				
P23		1						1				1			
Day 5															
Computer 1															
P1			1			1							1		
P2	1					1					1				
P3		1						1				1			
P4	1					1					1				
Computer 2															
P5	1					1					1				
P6		1				1						1			
P7		1				1					1				
P8	1					1					1				
Computer 3															
P9	1					1					1				
P10	1					1						1			
P11		1				1						1			
P12						1					1				
Computer 4															
P13	1					1					1				
P14		1				1					1				
P15															
P16	1					1							1		
Computer 5															
P17	1					1					1				
P18															
P19															
P20			1			1					1				
Computer 6															
P21	1					1						1			
P22		1				1					1				
P23			1			1						1			
Day 6															
Computer 1															
P1	1							1					1		
P2	1						1				1				
P3		1						1				1			
P4	1					1					1				
Computer 2															

Day 3	x					x					x				
Day 4	x					x						x			
Day 5		x				x						x			
Day 6		x				x					x				
P12															
Day 1		x				x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5						x					x				
Day 6	x					x					x				
P13															
Day 1	x					x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5	x					x					x				
Day 6	x					x					x				
P14															
Day 1	x					x						x			
Day 2	x					x						x			
Day 3	x					x					x				
Day 4															
Day 5		x				x					x				
Day 6		x				x					x				
P15															
Day 1															
Day 2															
Day 3															
Day 4	x					x					x				
Day 5															
Day 6															
P16															
Day 1	x					x					x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5	x					x							x		
Day 6	x					x					x				
P17															
Day 1		x				x					x				
Day 2	x						x				x				
Day 3		x					x				x				
Day 4	x					x					x				
Day 5	x					x					x				
Day 6	x					x					x				
P18															
Day 1		x					x				x				
Day 2		x					x				x				
Day 3		x					x				x				
Day 4		x					x				x				
Day 5															
Day 6															
P19															
Day 1															
Day 2															
Day 3															
Day 4		x					x				x				
Day 5															
Day 6	x					x					x				
P20															
Day 1		x						x			x				
Day 2	x					x					x				
Day 3	x					x					x				
Day 4		x				x					x				
Day 5			x			x					x				
Day 6		x						x			x				
P21															
Day 1		x				x					x				
Day 2		x				x					x				
Day 3	x					x						x			
Day 4	x					x						x			
Day 5	x					x						x			
Day 6		x				x					x				
P22															
Day 1	x						x								
Day 2	x					x					x				
Day 3	x					x					x				
Day 4	x					x					x				
Day 5		x				x					x				
Day 6	x	x				x					x				
P23															
Day 1			x					x						x	

P5	1			1			1		
P6	1			1			1		
P7									
P8	1			1			1		
Computer 3									
P9	1			1			1		
P10	1			1				1	
P11		1		1			1		
P12	1			1			1		
Computer 4									
P13	1			1			1		
P14		1		1			1		
P15									
P16	1			1			1		
Computer 5									
P17	1			1			1		
P18									
P19	1			1			1		
P20		1				1	1		
Computer 6									
P21		1		1			1		
P22	0,5	0,5		1			1		
P23			1		1		1		

Day 2		x			x		x		
Day 3		x				x	x		
Day 4		x				x		x	
Day 5			x	x				x	
Day 6			x		x		x		

Appendix 3. Example of a filled survey

Mielipidekysely /

Kone 5 / **Pelaaja** 51 - 3L

PALLOPELI

Todella kiva 😃 🙂 [✓ 😐] 🙁 😟 **Todella tylsä**

Mikä oli parasta? kun saa seurata palloa.

Mikä oli huonointa? Vähän tylsä, tai siis yksinkertainen.

LAMPPUPELI

Todella kiva [✓ 😃] 🙂 😐 🙁 😟 **Todella tylsä**

Mikä oli parasta? Kiva keksintö!

Mikä oli huonointa? ei mikään

PELASTUSPELI

Todella kiva [✓ 😃] 🙂 😐 🙁 😟 **Todella tylsä**

Mikä oli parasta? Kun saa, Siis pitää etsiä joku tietty kuvio.

Mikä oli huonointa? Kun vähän lopussa mä painoin Siitä mut se hopeentu niin Et se otti aina jonkun väärän. Lopussa

Appendix 4. Survey results by game

Survey Results, Calibration Games tested 29.11.-14.12.2017

STANDARD CALIBRATION

	POSITIVES
2nd graders	The ball got bigger and smaller The ball moved a lot and in different directions
3rd graders group A	It was nice (x3) The ball waited for me to click / getting to press after a second (x2) Following the ball / when you have to move your eyes (x2) When the ball changed size The ball was nice
3rd graders group B	It was easy The ball was moving / the ball moved after a mouse click When the ball moved with your gaze When I won the game
5th graders	Following the ball (x2) It was quick and easy (x3) It was nice
	NEGATIVES
2nd graders	It was the worst of the 3 games (x10) The ball moved a lot and in different directions It was boring because you just had to wait and click Boring because you had to wait first and then click It was too slow
3rd graders group A	Waiting for the second to click (x2) Bit boring and simple (x6) Quite fast / short (x3) Did not really get to do anything
3rd graders group B	It was too easy Hurt my eyes
5th graders	Hurt my eyes It moved too fast It was pretty long Boring The ball changing size

	😀	🙂	😐	🙁	😟
2nd gr. *20-23 students/day*	13,25 55,20%	6,08 29,44%	1,17 3,47%	0	0
3rd gr. A *21 students*	9 =42,86%	9 =42,86%	3 =14,29%	0	0
3rd gr. B *19 students*	7 =36,84%	6,5 =34,21%	5,5 =28,95%	0	0
5th gr. *19 students* *(18 surveys filled)*	11,5 =60,53%	6,5 =34,21%	1 =5,26%	0	0

(average of all 6 days, deviation from missing students.)

Survey Results, Calibration Games tested 29.11.-14.12.2017

FIREFLY

POSITIVES

2nd graders

The best game out of all 3 (x9)
Liked the trolls / Looking for the trolls (x2)
Making a high score
It looked nice

3rd graders group A

Liked the fly / Fly was a good guy (x2)
Turning on the lamps / Following lamps / Clicking the bullseye (x5)
You could see the fly
Was easy
Was fun / Nice idea (x2)
A bit difficult
The trolls / Shooting the trolls (x2)

3rd graders group B

It was (really) fun (x2)
Searching (for the trolls)
The fly
It was easy

5th graders

The best game out of the 3
It was nice / Liked it (x3)
It was easy
The fly (x2)

NEGATIVES

2nd graders

It was the worst of the 3 games (x10)
Too easy (x2)
The fly was annoying
Not enough trolls
The lamp part / following / only clicking was boring (x3)

3rd graders group A

Too many lamps
Didn't see the bullseye
The clicking
Lit lamp was too bright
Time limit on troll hunt
Went a bit too quickly

3rd graders group B

It was too difficult
It was too easy

5th graders

Couldn't catch a troll even when clicking many times
The fly was slow

	😁	🙂	😐	🙁	😣
2nd gr. *20-23 students/day*	16,5 68,95%	2,33 11,12%	1,82 8,82%	0,17 0,79%	0
3rd gr. A *21 students*	12 =57,14%	7 =33,33%	2 =9,52%	0	0
3rd gr. B *19 students*	7 =36,84%	6,5 =34,21%	3,5 =18,42%	1 = 5,26%	1 =5,26%
5th gr. *19 students* *(18 surveys filled)*	12,5 =65,79%	4,5 =23,68%	2 =10,52%	0	0

(average of all 6 days, deviation from missing students.)

Survey Results, Calibration Games tested 29.11.-14.12.2017

MISSION

POSITIVES

2nd graders
The best game out of all 3 (x11)
Opening the locks
The shapes were nice / nicer and easier than colors (x2)
Making high score (amount of locks opened)
A bit difficult, but not too much
The ghosts

3rd graders group A
The story / Maybe the rescue (x2)
When the shape was a triangle/square / When the shapes changed (x3)
Catching the correct shape / Opening the locks (x2)
Looking for the shape (where it was on the screen)
The colors
Finding right timing towards the end / It went alright in the end (x2)
It was difficult / It was nice that it was a bit tricky. (x2)
Background was best
Getting points

3rd graders group B
Moving the circles with your gaze on top of the avatar (x2)
Changing clothes / Making the character (x2)
Exploding door

5th graders
The bluffs (kun tuli hämyjä)
Looking at the lights and I got 7 right / Catching the right option (x2)
It was nice / good (x2)
It was nice to have action
the boogieman

NEGATIVES

2nd graders
The colors changed too fast / Too fast towards the end (that was annoying) (x2)
Accidentaly pressing the space button and getting wrong color (sensitive button)
Too slow in the beginning
Only pressing the space bar was boring

3rd graders group A
Didn't first understand what to do
Pretty slow in the beginning
Was a bit difficult / Difficult towards the end / Changed too fast (x10)
I got so many wrong / messing up (x2)

3rd graders group B
It was only ok
Couldn't change the name *(we used predefined names for the one-time testers)*

5th graders
Didn't always catch the right color (x2)
Changed too fast

	😀	🙂	😐	🙁	😟
2nd gr. *20-23 students/day*	15,5 74,97%	4 19,31%	6 4,89%	1 0,83%	0
3rd gr. A *21 students* *(20 surveys filled)*	11 =55%	5 =25%	2 =10%	2 =10%	0
3rd gr. B *19 students*	11 =57,89%	5,5 =28,95%	1,5 =7,89%	1 =5,26%	0
5th gr. *19 students* *(18 surveys filled)*	10,5 =55,26%	5,5 =28,95%	3 =15,79%	0	0

(average of all 6 days, deviation from missing students.)