Norwegian University of
Science and Technology

Mechatronic playtoy for improving various skills

A prestudy

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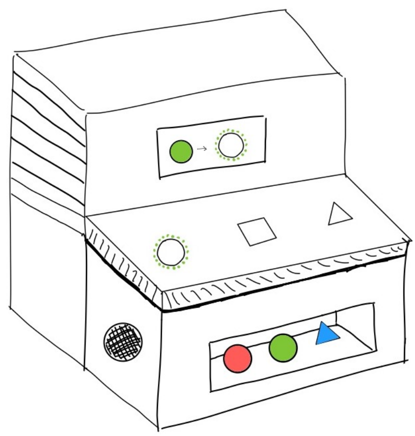

Summary

This report is a prestudy where a potential solution of a mechatronic system designed to assist individuals with fine motor skill impairments is presented. The system is intended to serve as an exercise tool for these individuals to either improve or maintain their fine motor skills. This will be done by implementing a block-fitting exercise based on a popular children's toy that is designed with the primary intention to develop fine motor skills, into the system.

A literature study of the use of gamification will show how these concepts can contribute to learning and motivation in the intended system. With implementation, the aim is that the system will become more enjoyable and motivating than already existing exercise tools. In addition, together with other technological solutions, the system will provide added value in the form of cognitive, as well as physical benefits.

The design suggestions are based on the principles of the block-fitting exercise but are adapted and modified in order to implement technology and game logic in an elegant way. The advantages and disadvantages of different solutions are considered as there is more than one right way of achieving the goals of the system. Different aspects based on usage and utility are also properly taken into consideration as this can affect the system in many ways in its overall design.

The conclusion is that the proposed mechatronic system is a feasible and promising solution for individuals with fine motor skill impairments. Not only does it introduce new, innovative elements, but it also builds upon proven techniques that have been shown to provide physical and cognitive benefits.

Preface

As someone with a background in both mechanical engineering and ICT solutions, the wish was to combine these two fields in a way that could be beneficial to others. With an understanding of how games can influence behavior and motivation, with many years of playing different video games, as well as a passion for creating physical devices, the focus quickly became exploring how game design concepts could be incorporated into a physical device to enhance an existing solution.

The possible solutions presented in this report have been inspired by the research done on fine motor skills and concepts related to gamification, as well as the candidate's own knowledge in the different fields.

The guidance from professor Amund Skavhaug has been of big help with coming up with design solutions as his knowledge and experience in different fields has shed a different light on the system than what the candidate could manage on their own.

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Chapter 1

Introduction

1.1 The project and its motivation

We live in a world where newer and better technology is being developed at a rapid pace. The new knowledge we gain from this gives us a chance to further improve lives, and help people in ways we have not been able to before. The project presented in this report is motivated by this and looks at an intended mechatronic system that can be used to achieve a different way of learning, both cognitive and muscular. The idea is to combine concepts from mechanical toys with principles of reward and feedback from computer games to make a gamified training system. By doing this you can make training fun, rewarding, and motivating in a whole new way.

Making training fun by combining it with games is not a new concept. Some of the earliest attempts at this were already in the 1980s with HighCycle by Autodesk and the Puffer by Atari [23]. Nintendo however made a breakthrough in the early 2000s with their Wii Sports and Wii Fit games [23]. They introduced a fun and easy way to train at home and it was wildly popular, with Wii sports, Wii fit, and Wii fit plus having sold roughly around 120 million units combined around the world today [25].

Even though the games simulate that of exercise they are not a replacement for the real thing. It has, however, been shown that energy expenditure during active play could be comparable to moderate-intensity walking [18]. Making it an entertaining way to promote exercise. This indicates that by implementing feedback and rewards systems you can reinvent an activity, by making it more fun for the user, while performing almost equally as well as with the same activity in the original form. In addition, you can redirect the focus of individuals so that a once tedious activity becomes more interesting and motivating.

Although these games and the system sought after in this project are very different in ways of what they want to achieve, it is this underlying concept that they will have in common and that this system will be based upon.

Figure 1.1: Wii Fit [1]

Figure 1.2: Puffer by Atari [26]

1.2 How and why the system will help

The games presented above focus heavily on physical training and are good examples of getting general exercise in an alternate form. The focus of this project however will be to help a more narrow group of people that rely on specific training for improvement in their daily life. More accurately people who struggle with fine motor skills. This can be having trouble with writing with a pencil, using scissors, or any other activity that requires the ability to use the smaller muscles in the hands [24]. Which can have a significant impact on daily routines and life in general.

In addition to the system being of use for people who struggle with muscular abilities, you will also later in the report see how the system can incorporate and develop cognitive learning. Along with the implementation of feedback and reward systems, the idea of having different skill levels will help with this, with having to move on to a harder level after completing one, further challenging your abilities.

It is the use of mechatronics, which is a combination of mechanics and electronics that lets the system be a versatile multifunctional tool. Different electronic components such as microcontrollers, sensors, and diodes let us implement the concepts from games to a mechanical system smartly and efficiently which will be presented in later chapters.

1.3 Objectives

The intention behind this report is to come up with a design solution for making an exercise system to help users improve their fine motor skills through play. This will involve designing challenges and/or activities that require precise control and coordination in a way that makes it enjoyable and engaging for the users and encourages them to use it regularly. The system should therefore also be relatively cheap to produce so it can be bought and used by people for everyday use.
When designing, the 7 principles of universal design [33] should be taken into consideration in order to meet the needs and preferences of different users. In addition to implementing methods that are supposed to boost motivation the system should be flexible and general to be able to reach a larger group of people.

Because this report is a prestudy on making a mechatronic system the main objective of this report will be to present a feasible solution that can be developed into a prototype at a later point.

1.4 Structure of report

This report is written from an engineer's point of view and it will be other engineers that will get the most understanding of what a system like this could achieve and how it would do it. This report can however also be relevant to other professionals in the areas of psychology and rehabilitation of fine motor skills as much of the report is a literature study of why and how the system will help.

Further in this report, there will be a proper section about game logic and how and why it will be used and implemented in the system. There will also be a discussion about the user group and a chapter on previous work and similar systems. After having gone through that, and all of the theory needed to understand the physical implementation has been explained, a further look at the system will begin. Firstly by looking at requirements for the system based on different factors. Further, there will be presented design suggestions based on these requirements and how to implement them constructively. After this a discussion about how and what specifically the system will do and how it is intended to do that will follow. The report will finish with a general discussion about the different solutions where a final design will be presented. Lastly, a reflection on the work done in this report, a note on further work, and a conclusion will be presented.

It is important to note that this report is a prestudy of an imagined system. Everything that is discussed here is only suggestions and will be of help in developing the product at a later time.

Chapter 2

User group

As previously mentioned the system presented in this report will try to target people who struggle with fine motor skills. Motor skill or motor control is the ability to move your body in specific ways in order to perform certain tasks. It can be divided into two different subgroups, fine and gross motor skills. Gross refers to when the larger muscles are in use, for example when jumping, walking, or waving. Fine motor skill is smaller more controlled movements in hands. Having trouble with either one of them can therefore have a significant impact on people's daily lives and how much assistance one might need to perform simple tasks. Luckily practice makes perfect. Or rather, practice with a specific task will help learn it better and eventually make you improve with that task. This is also applicable for the training of fine motor skills [10].

The development of motor skills starts already in infancy and further develops during childhood. This time is critical for both physical and cognitive growth and research have shown several links between the development of fine motor skill and other abilities. For example, it has been shown that fine motor skills can have a direct effect on mathematical performance [16]. The importance of developing better fine motor skills at an early stage can therefore help children with their cognitive learning, and help them grow and adapt better through childhood.

But problems with fine motor skill is not only found amongst children. Adults who have had fine motor skills may experience damage of them at a later point in life. This can be due to an accident, injury, disease or age-related regression [24]. It is then possible to improve and develop those skills again with exercises specific to fine motor skills. An example can be drawing, folding clothes, or using scissors. But doing activities you used to excel at before with much struggle now can be very demotivating and feel like a perpetual project. Instead, by giving other types of exercises where you can later see the effects of them can therefore be very rewarding and give some motivation for continuing with the training. By making a new and original system, which is the aim of this report, you are also able to be creative by making exercises that are new, fun, and exciting. In addition, the goal is to make something that in the minds of the users is not thought of as something they have to do, but rather something they want to do which also will contribute to motivation.

Figure 2.1: Using scissors requires fine motor skill and control [9]

2.1 Testing

Not only can fine motor skills be a result of something, for example, an injury. It can also be an indication of certain neurodegenerative diseases [13]. Hence by doing simple tests with fine motor skills you can be able to help many people with early detection and give them better time or chances of dealing with a new disease.
As stated before, the system intended here is mainly planned as a way to train fine motor skills, not necessarily to work as a test. The focus is to make a system that will make the user forget the reason why they are using it. A test in that way will be the opposite of what trying to be achieved here. When knowing something is a test, not only will you be focused throughout it, with constantly thinking that you are being tested, pressure with doing well and knowing the consequences of not doing good will affect how you feel about the system as a whole [21]. It can then turn into something you will not necessarily feel very excited about doing, you can compare it to any form of test you have taken, exams for example. Was that something you looked forward to doing, and would gladly do again? Most

likely no.
However, the outcome of the rewards for using tests of fine motor skills as seen can be very large and good for individuals. And the system would be even more versatile if it could also work as a testing system. For the system to still mainly be a fun thing, the implementation of testing would need to be discrete and not the main focus.
With many tests of these kinds, it is normal for there to be a second party present to observe, often professionals. This also means that you usually have to go somewhere to complete the test. All of this can add to the negative feeling around testing and adds pressure. Being able to remove the second party and perform the test when and where you want could therefore be able to take away some of this pressure. By making the system independent and something that can be used in normal households, or put in everyday settings where you don't need anyone there to pay attention you can be able to achieve this.

Figure 2.2: Example of a testing environment [27]

2.2 Generaliztion

When making a system that is supposed to be used by people it is an advantage in an economical sense to make it very general. With the system appealing to more people there will be a bigger market for the product and it will then hopefully also earn more money. The hope with this system however is not necessarily that it will make much money, but rather be more general so that it can benefit many different people and be able to reach out to and help more people without the need for making a specialized system for each individual. Generalization of the system will therefore be seen as something positive as long it does not compromise its intended use.

With fine motor skills being a very general skill everyone possesses to some degree it is easy to think that giving one activity may help everyone. In reality, things are different. The skill itself is very general but it is how much trouble each individual struggles to use that skill that will define how they should train, to what extent they will manage to do an exercise and the purpose of the training. A child just beginning to show signs of late development have a larger advantage in how much they can do than people who just suffered a stroke and lost almost all of their fine motor skills. To what degree a person is able to use their fine motor skill should therefore be considered when making exercises. This can be done by implementing different skill levels in the system so people who are at different stages in their fine motor skills can all use the same system to exercise.

Age and age differences also need to be thought of with the system, as a 40-year-old may not be motivated by the same things as a 1-year-old. It is on the other hand very individual what motivates and appeals to different people. It can therefore be a good idea to have a concrete user group in mind when designing to make the process a bit easier, and rather add more general traits as you go along where it fits. If you can manage this you are suddenly able to reach both your target group and others as well which means more people are able to benefit from the system.

Based on the previous writing one can conclude that children may benefit the most from this type of training in the long run as training of fine motor skills can affect other abilities. Children will also be a larger user group for the intended system as everyone could benefit from this type of training independently of their level of fine motor skills. The system is therefore intended mostly for them, but as you will see later it will also be implemented with generalization in mind opening up the possibility of a larger user group.

Chapter 3

Game logic

3.1 Gamification

Earlier in this report, there have been mentions of so-called game logic and implementation of this in a system, but what does this entail? To begin grasping the concept there should first be an explanation of gamification.

Gamification is the concept of adding game elements, mechanics, and game-based thinking to non-game environments like a website, classroom, or business to create similar experiences to when playing games [22]. This can be the inclusion of levels, feedback, progress or rewards systems, etc. Gamification is a rather new concept where it first entered the mainstream vocabulary around 2010. One of the reasons for its growing popularity lies in the belief in its potential to foster motivation [14]. For this reason, it has been very popular in the last couple of years to implement gamification in educational environments. Although research in this area is rather new, meaning nothing can be said of certainty when it comes to the effects of this long term, promising research has been conducted on the use of it and the participants' motivation towards learning. It has for instance been shown that gamification actually has the potential to increase student motivation and that students following a gamified version of learning get better scores on practical assignments [15]. Several other studies also conclude that gamification can have a positive effect on learning and motivation [11] [17].

On the other hand, it can also be debated whether or not there is a need for gamification in different settings. If the goal is to use it in school and learning, many studies also show that while it can contribute to something positive, the effects of it may be rather small [29]. Another important point to shed light on is the use of game elements in a system that can be used by elderly people. It is a common myth to assume that elderly people do not play games or like to play

games and therefore will not like gamification. But according to Entertainment Software Association's 2013 report "*Gamers Over 50 Study: You're Never Too Old to Play*" 48% of adults age 50 and older say they play video games [22]. Hence implementing gamification by itself will not be age-limiting for its users.
In addition, it can be debated whether it can be problematic to mix a learning environment with something mainly thought of as a leisure activity. As it will then affect how effective the gamification is in its use [32].

The system intended in this report is, as mentioned, not going to be used as a pure learning tool, but more as an exercise tool that can contribute to learning. Because of this the arguments that debates the necessity of gamification will not be entirely applicable in this setting. The main thing to take from all of this however is that it is proven that gamification can have, if not small, a positive effect on motivation. And as discussed in the previous chapter, motivation is something very important for the use of the intended system and its users.
By implementing gamification in a new intended system one could therefore argue that it can have a positive effect on its users. More accurately, in relation to this system, the hope is that gamification is able to achieve and channel its positive effects which will make exercising more fun in a new way that the users can be excited about.

3.2 Keep it simple stupid

When implementing concepts to a system that is supposed to be an easy and fun tool, there have to be some limitations as to how many concepts, and how much extra you can add without making it very complicated. The goal is therefore to implement just enough gaming logic to simulate similar experiences to playing a game while still keeping it simple and user-friendly. Also keeping in mind that children are the main target use, the system should be self-explanatory to the extent that it is intuitive and will not require much assistance when used.

Keeping in mind that when it comes to principles of what motivates people there is no "right" answer since everyone is different and therefore will be motivated by different things. Feedback and rewards systems on the other hand have been shown in several settings to be a good tool for motivation [8] in general. These are not necessarily specific to games but are often used in ways of progressing and how you progress through levels and it is this way they will be used in this system as well.

The concept of a reward system is a commonly known concept when it comes to motivation. In the real world, salary can for instance be looked at as a form of reward system where you get paid for a job well done. In games, these rewards are often items or tools to help you when you get to harder levels, or they can be benefits for finding something or doing something good in a game to keep you going. For example take the classic super Mario bros game [Figure 3.1]. By completing a level the reward you get is to progress to the next one, which in return gets you closer to the goal of the game, saving princess peach. In addition, you can gain rewards throughout the levels in form of power-ups or extra lives which will help you complete the levels. All of this gives motivation for you to continue the quest of saving the princess because the game makes the quest attainable by giving you help and resources to complete it.

Figure 3.1: By getting a special mushroom Mario can grow and destroy all in his path, making it easier to progress through the level [2].

Games are able to use progress as a reward in itself because they often have a story they follow or a quest that needs completion. An exercise system will not have the same opportunity for story-making in that sense. On the other hand, one could be able to make progress the reward by having some way of indicating how far you have come in your training. The Wii fit game [Figure 1.1] for instance uses this. After completing a level you are able to see how much further you have come in your exercise, how many calories you have burned etc. Because of this, you are able to see the progress you are making after each session with the system and you will be able to always see the goal, making it more reachable.
With the implementation of this in a mechanical system the basic idea is to have a general place where you are able to see where you are at, how much is left, and how far you have come so far. With the intended system here being a mechanical thing you can use to exercise, the most logical way to implement this will therefore be with the help of a LED screen in some way. This can then provide the user

with useful information while not disturbing the task at hand.

Feedback is a concept closely connected to that of reward systems as a reward is a concrete result of getting feedback. Above it is explained how this is when doing something right, but there is also feedback for when doing something wrong, often in the form of punishments. In Super Mario Bros this can be walking into an enemy for instance. If you are tiny this will punish you with death and you have to start the level all over again.

Feedback can be explained as the underlying concept used to make players learn how the game works, whereas rewards contribute to motivation. A big reward may give a bigger motivation in thinking the next level will be easier, while a smaller reward may not be that exciting and demotivate the player to continue. By receiving punishments or rewards, the user is told what is good and bad in the game and will then learn how to play the game and progress through the levels. Feedback is however not only an important feature in games, it is also stated by Don Norman in his design principles from "*Design of Everyday things*" [30]. Here feedback is described as a crucial part of any form of design to give information to the user about what is happening at any point. This can for instance be when you download something online and see a progress bar of how far the download has gotten. So in some form or another in order for the system to have a good design, feedback should be involved. So by combining it as a design principle and game concept you are able to utilize the concept to the fullest in a good way so that the users hopefully will be able to get the most out of the intended use.

Chapter 4

Previous work

As mentioned at the outset we live in a world today with access to a lot of new technology and with much more gained knowledge on different subjects as a result. This has helped us evolve and develop many tools and aids for making the world a better place to live in for everyone. Much focus with the development of technology throughout the years has been this, and to help and aid those that cannot function normally. It is the technology that drives the progress in the world today, and in this chapter, we will look at what already exists and why it is important to see what has been done before, in order to create something new.

4.1 Children's toys

Since trouble with fine motor skills is something affecting many people in the world, as mentioned in chapter 2 there has been much development for different tools to use in order to train these skills or enhance them. As previously concluded it is children who will benefit the most from such tools in the long run, which is why there exist several designs specifically for them on the market today. In addition, one can say that children are the easiest market to sell to since parents are prone to easily buy things for their children if they think it will benefit or make them happy.

Figure 4.1: Lacing cards toy [3].

Figure 4.2: Peg toy [4]

The figures above show some examples of different toys that have been made for children. They are made with the intention that the skills gained by them are transferable to everyday activities that require fine motor skills. Take for instance the lacing cards toy [Figure 4.1], the purpose here is to move a string in and out of holes on a board or an object. This requires a lot of control and is the same skill used when lacing shoes. So by using this toy a child can be able to train on tying their shoelaces without it being as complicated as that. The same goes for the Peg toy [Figure 4.2] where having to be precise in the placing of the blocks, the user challenges their fine motor skills. The toys manage to take a rather complicated activity and make it simpler in order for the children to train their fine motor skills at their level.

Figure 4.3: Box toy [5]

Figure 4.3 shows one of the more popular toys when it comes to the training of fine motor skills for children. Here you are supposed to grab different shapes and get them into the right holes. By doing this a child are able to train their fine motor skills, but also their cognitive skills as they have to use their logic to match one shape to a hole and figure out how to put them in. With the potential this toy has to benefit two areas at once, fine motor- and cognitive skills, the system presented in this report will be largely based on this toy as you will see later.

Other types of toys and games that are not necessarily made for the purpose of training, but rather for pure enjoyment also exist on the market today. Many of them can however be used as tools for exercising fine motor skills, for example, puzzles. They are made to be a fun activity and something challenging for people to do together. But with pieces being very small it requires very good fine motor skills to be able to pick the pieces up and put them in the right places. This way you are able to train or maintain your fine motor skills whilst having a good time.

Figure 4.4: A puzzle of Moomin Valley characters

Even though these types of games are not intended as exercise tools they still highlight the concept mentioned earlier with the Wii fit game. Which is about being able to enjoy something without realizing that you are in fact exercising. This is why the use of gamification can benefit the intended system, by transforming it into more of a game you can be able to take the focus of exercising away.

4.2 Digital solutions

The discussion above was about physical games and how they work, but as talked about it is the growth of technology and its possibilities that is interesting, and much of the basis for this system.
We live in a digital era where smartphones or tablets are, in Norway, introduced to children already in primary school [19]. The toys presented above are almost too old-fashioned for the world we live in today, where many hobbies or replacements for physical activities now can be found online or digitally. There exist for example many different apps you can download on your phone or tablet to keep you entertained for hours. Amongst them you can for instance download apps that let you puzzle, color, or draw.

When it comes to some of these however they can not substitute the real thing in what they are accomplishing with the training of fine motor skills. Take for instance the puzzle app, in reality, you are able to grab the pieces and move them around, while on the tablet all you do is drag the piece from one place to another using just one finger. Even though that still requires some fine motor skills it will not give the same benefits as doing a puzzle in real life, and it will not be the same activity anymore. On the other hand, computer technology has been shown to help support learning and is especially useful in developing skills of critical thinking, analysis and scientific inquiry [28]. In so technology is able to teach and support learning differently than with physical objects. By mixing something physical with technology you are therefore able to get the different perks from the two worlds all combined into one.

4.3 Mechatronics

As mentioned at the outset mechatronics is the mix of electronic and mechanical parts and it is this blend that is able to achieve the points discussed above. There already exists some mechatronic solutions to the rehabilitation of fine motor skills today. One of them is the Robotic rehabilitation glove from Syrebo.

It is a glove that can "*...help patients master fingers flexion and extension, reduce hand muscle tension, relieve edema and stiffness, promote rehabilitation of brain nerve injury through exercise, improve hand activity and accelerate the rehabilitation of hand function.*" As Syrebo website explains [6]. With the use of mechanical parts, the glove moves your fingers for you in order to achieve these results. It can also mimic movements from a different glove on another hand so that you can get your disabled hand to move in different ways. Because the use is so general, and the fact that they have made different sizes to fit smaller hands as well it

Figure 4.5: Syrebo glove [6]

can be used by almost everyone. Also by being so general, easy to use, and small it is a great device to have at home and with you wherever you want. On the other hand, the functionality of the device is rather limited as to how the user can contribute. You have almost no way of training and learning on your own with this which limits its potential to be a fun way to exercise.

Another mechatronic system that focuses more on the fun part with training is the Amadeo from Tyromotion [7]. The goal here is more specific training of the fine motor skills by being able to have movement in each individual finger. It is a heavily sensor-based device where it can measure how you use it and give this feedback to the user for further improvement. You use the device by playing a game on the screen by moving your fingers where the game is adapted to consider age, as motivation can be very individual and age dependant, as discussed in section 2.2.

Figure 4.6: Amadeo from Tyromotion [7]

When it comes to the design of the intended system in this report, the aim is to be something in between the two systems presented above. The glove is an elegant design solution when it comes to its portability, but lacks in its functionality. The Amebo is the other way around, it can not be moved simply as it is a rather large and complex system, but a user can benefit greatly from its functionality in many ways.

Chapter 5

Requirements

As previously mentioned in this report certain delimitations and requirements have to be looked at with the system. Some of these points have previously been mentioned, but here is the main overview of the basic needs the system requires in accordance with the objectives in section 1.3:

- **Not feel like a test**
  - For the system to be fun it should not feel like a test. Being used in regular settings for the user will make it feel more normal, as discussed in section 2.1. In addition, you should also be able to use the system on your own without help.
- **Actively used**
  - Since the target group is children and the system is intended for everyday use, as mentioned above, it needs to be robust. It has to endure that it will be treated without the love it may deserve.
- **Small enough**
  - As discussed in section 4.3 the goal of the design is to be a middle ground between the two systems presented. Since the system is supposed to be able to use at home or in other settings normal to the user, for example in schools or kindergarten, it has to be small enough so as to not take up too much space and be a big distraction.
- **Universal design**
  - As stated before it is important to consider generality in design and implementation. By following the 7 principles of universal design [33] you are able to accommodate a broader user group.
- **Adaptable**

  - In order to make the system usable for a larger group of people it needs to be flexible and adaptable in its motivation and to different skill levels to accommodate different users.

- **Implementation of gamification**
  - This will allow the system to have more functionality and be a training device that is motivating and fun for its users as discussed in chapter 3.

In addition to this the most important thing the system need is a proper function. With the discussion about how beneficial physical activity can be the system should have a concrete activity for the user to perform in order to train their fine motor skills. From chapter 4 it is clear that there exist several ways of activating your hands, but to follow point three of the 7 principles of universal design [33] it needs to be simple and intuitive to use. In order to achieve this there will only be one main activity to perform with the system. The user group, independent of age, will be people who struggle with fine motor skills to different degrees, the activity should therefore not be too complicated or too intricate. The lacing cards toy [Figure 4.1] is a good way to train your skills, but it also requires more precision and control than for example the box with holes [Figure 4.3]. This box is a very good and general way of training fine motor skills which is also why it is a wildly popular toy. It also has a lot of potential with the system intended here. With being adjustable to different levels with the size of holes and blocks it is also something that can train cognitive skills by matching the right block to the right hole. In addition, it will be easy to maintain with blocks being easily replaced and fixed.

The basic idea of the system is therefore that it will be a mechatronic version of the popular box. By basing the system on something known to most people it will also help make the system less frightening and complex in the minds of new potential buyers and users because it is something familiar. The overall design of the system should therefore reflect this. In Figure 5.1 you can see a possible solution to this where the system itself is shaped like a box with holes on top.

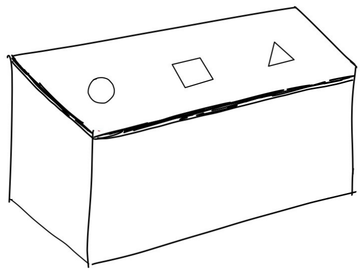


Figure 5.1: Overall design suggestion

By having the overall concept of the system in place more specific requirements can be looked at for the intended mechatronic playtoy.

Things that should be incorporated:

- **A removable board with holes**
  - Makes it possible to implement different levels in accordance with gamification.
- **Extraction of blocks**
  - A way to extract the blocks that you put in the holes in an elegant matter.
- **A display**
  - For giving various kinds of feedback and/or rewards.
- **Speakers**
  - Or a way to plug in earphones, for giving feedback to users not dependant on sight, conforming to principle four of the 7 design principles of universal design [33].
- **Electrical components**
  - Such as sensors for example to indicate whether the right block was put in the right hole or measure movement or touch. LEDs can be used as another way for feedback, rewards, or as a part of the "game". Microcontrollers for communication in the system and much more.

The systems design should therefore aim to reflect these points, and look at possible solutions to each of them.

Chapter 6

Design suggestions

As illustrated in Figure 5.1 the system is presented to have a similar shape to that of the box toy. By having a simple shape, in this case, a square prism, the system will be more robust and therefore also more suited for use with unpredictable and prolonged use. Now let us look at the other requirements and how to design solutions with Figure 5.1 as a basis.

6.1 Boards

As mentioned the system should be able to have switchable boards, so the next logical question will therefore be where to store these boards. The two obvious solutions are here to either have them in a separate subsystem or integrated into the system as a whole. The two suggestions are illustrated in Figure 6.1 and 6.2.

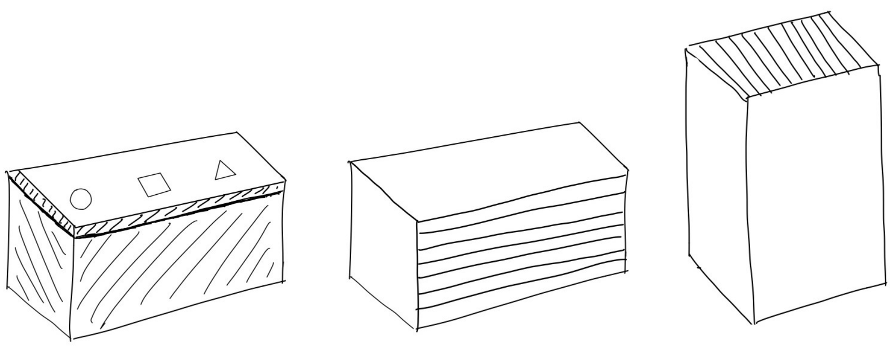


Figure 6.1: Separate subsystems

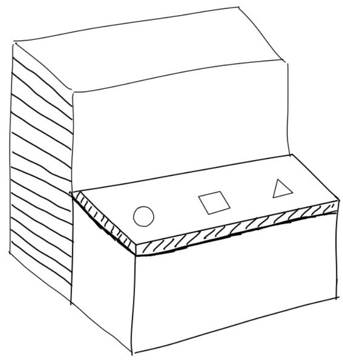


Figure 6.2: Integrated design

With the design in Figure 6.1 the boards will be stored on shelves and have to be taken out and placed on the box. With the goal that the system should work independently without much need for help from others, this will be a poor solution for small children. The system itself aims to be relatively small but it still may need to be bigger than a small child, so they will need help to change the boards from someone capable of doing that with this solution. On the other hand for older people, the activity of switching the boards themselves can be a good practical way of also being able to train some fine motor skills and eye-hand coordination with having to take small boards out of their places and put them in the right place.
By having a separate system for the boards the system will on the other hand seem smaller and less complex than by having it all in one. If the system is to be used at home for example you are able to put the box in one space and the boards in another so that it does not seem very big and does not draw too much attention.

With the Integrated design [Figure 6.2] you have more possibilities when changing the boards. You can also here use the same solution as with the separate system, having to take the boards out and put them back in place, where it now will be a shorter distance to move the board since it is a part of the system. By placing the boards behind the box itself, as shown in Figure 6.3 you can however be able to make the boards slide into place by pushing them from behind and into the board making the process more smooth and more elegant, and with less work from the user. In addition, you can also implement a mechanical solution of moving the boards up and down on the side so that the only work the user has to do is remove the boards and put them back into the shelves after use.

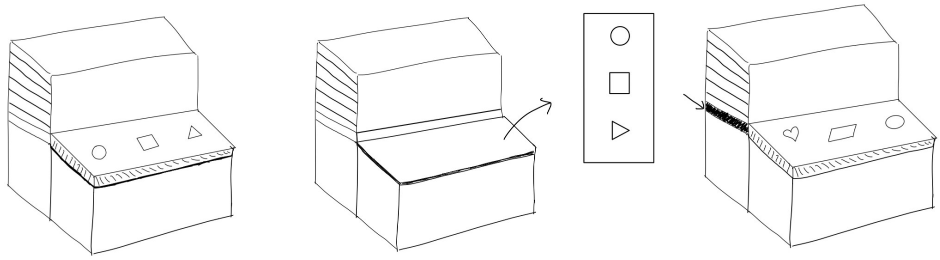


Figure 6.3: How to change board with integrated design

A possible third solution to store the boards can be to combine the two presented above. This can simply be done by having the shelving box from the integrated solution be able to detach from the box. Then you are able to store the shelves somewhere else while being able to use the box as you would.

Regardless of the solution for storing the boards, there needs to be an easy way to affix the boards to the box. With the integrated system, the boards are meant to slide into place so the box itself will either need some rails and wheels on it or a way to easily drag the board into place. In addition, a locking mechanism will be needed when the board reaches the edge. This can be done by having a small edge upwards that stops the board from sliding off the box. Or you can lock the board in place when it reaches the edge where for example a lever or button will push the board up in order for the user to easily take it off again. This sliding system with rails can also be implemented in the separate subsystem solution, but here you can choose more freely in which direction it will slide. The most beneficial will be to make the boards slide inwards so that you can for example place the box against the wall without trouble. However it does not need the sliding principle in order to be affixed to the box, only the locking mechanism will suffice where you simply place the board on top and it will click into place.

With both designs, magnets can also be used to affix the boards. In the integrated system, this could be to attach magnets furthest out on the box and the bottom of the board, it will then slide until it reaches the edge and affix itself at the end. For the separate subsystem solution, there can be more magnets along the top of the box and underneath each board in order to simply place the board on top of the box. By using magnets they need to be quite strong for them to sit in place when used. This will entail that it needs some force to take the boards away from the box, which is again a poor solution for younger children.
Another solution can be to use Velcro for the separate subsystem solution. Velcro will then be placed on top of the box and underneath the board so that you only have to place it on. The disadvantage of this is that Velcro is not a very durable

material and can be damaged rather quickly with much use. It will also require some force to take the board off the box.

Theoretically, the most practical solution for the use of the system will be to have a sliding principle or locking mechanism as this does not require much extra work. In addition, this can work for the third combined solution as well with the boards being able to work as an integrated part and a separate system.
If however this sliding principle gets broken at some point it will require more work with repairing it again as it is not something most people would be able to fix themselves. Magnets on the other hand can be placed on the system in a way that if they fall off or get damaged the user can purchase new ones and affix them easily themselves. Magnets will also be the cheapest solution for building the system. But if magnets are to be used, the strength of different magnets and easy ways of getting the boards out without the use of much force should be looked at and tested before implementation. In addition, it is important to note that loose magnets can be very dangerous around kids as they might swallow them. A solution to avoid loose magnets should also then be taken into consideration.

6.2 Display

A display is a key feature to implement for gamification and as a general way of making the system feel more modern with the use of technology. The intention is that the display and the rest of the box will work together in order to provide the user with information.
The information can as mentioned in section 3.2 be to track the progress of the user's training and give information about how well the user performs. This can then also be used as a sneaky way of testing, where someone else could see how the user did in the different tasks.
Information on the screen can also simply be feedback as to what the user does right or wrong or it can be used to give tasks to the user. For example, having different boards and levels opens up the possibility of performing different tasks on each board. In order for the system to be easy to use these tasks should be as intuitive as possible. But no matter how intuitive you make something you always have to account for there to be misinterpretations. So in order for the boards and levels to be used as intended there can be implemented a form for a guide on the screen that will show the user what to do with the different boards. There can for example be some animations that show the user what to do and how to "solve" the board. But further development of this should rather be looked at with future work with the system.

Going back to the implementation of the display this can be done in several different ways. One simple way is to have the screen on the front of the box as seen in Figure 6.4

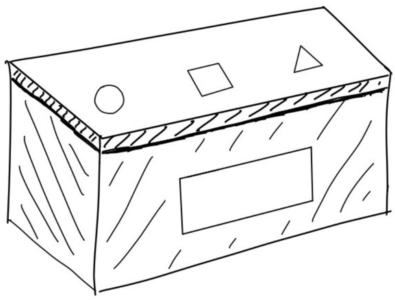


Figure 6.4: Display in front

By having it in the front the activity of putting the blocks into the holes will then be the main focus and as a consequence draw some attention away from the screen. You could have a sound play when new information is given to notify the user, but this will not support principle four of the 7 design principles for universal design [33] as the user would then be solely reliant on sound to catch the given information. Since it can be hard for the users to catch information given by the screen when their attention is on the top, it implies that the screen can not have a very large part in how the system will be used with this design. The screen is however very important to the intended system so this would not be an ideal solution.
This could however be solved with a slight tilting of the screen, as shown in Figure 6.5.

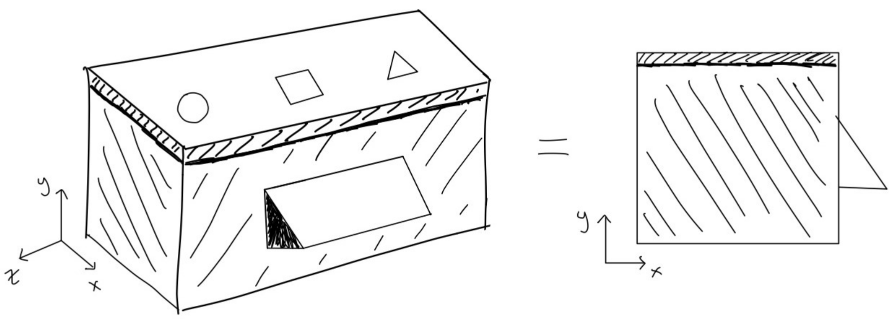
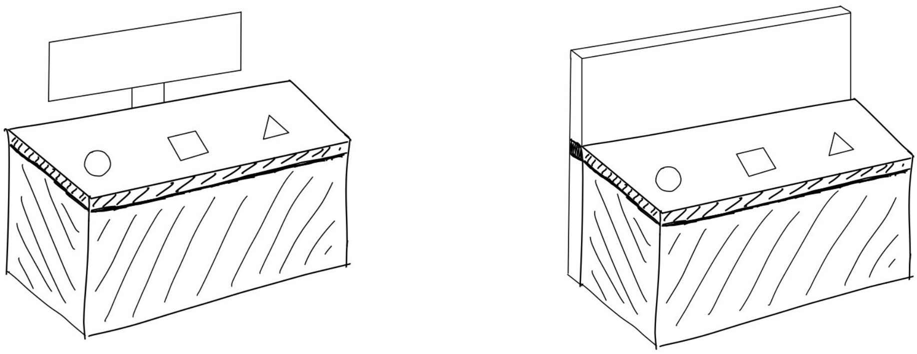


Figure 6.5: Display that sticks out in front

While the users' attention is also here mainly on the top of the box it will now be easier for the user to notice messages on the screen as they can simply look down and not have to bend down to see it. The display can however still be easily overlooked with the user itself blocking the view of it. With robustness in mind, it will in addition not be a great idea to have something small sticking out of the box as it is more prone to being broken by careless use.

By placing the display more in the eyesight of the user the information given is however more likely to be perceived. The user will then not have to check the display on their own initiative but rather be able to see the display change in the corner of their eye and therefore notice information. Two different ways of implementing the display on top of the box are shown in Figure 6.6



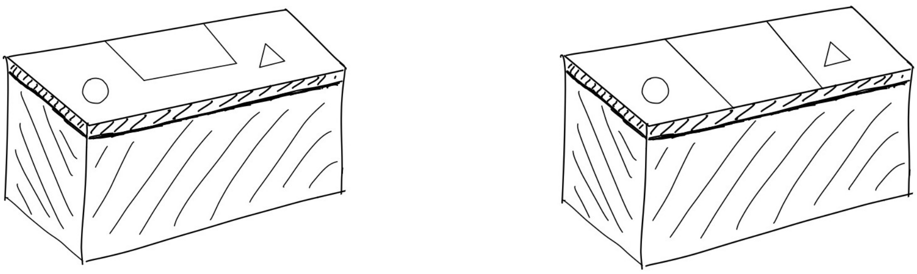
(a) One solution

(b) Another solution

Figure 6.6: Display above the box

Here the display will be very visible for the user while using the box and the information displayed will be hard to miss. The problem of having parts more prone to breaking will however also be evident here, as with Figure 6.5. Especially with the screen being placed on top [Figure 6.6a] which is very delicate and will not be favorable with rough use. The second solution is a little more robust where the screen is better mounted on the box. The space available for the display to use here is much larger than with the other designs allowing the screen to provide more information on the screen at once.
With this design, an idea is that it could function as a laptop where the screen can have an adjustable angle and work as a lid for the box. This solution however will be more prone to breaking as it has more parts and is more complex in its use. One way to avoid some of the complexity is to simply avoid having it work as a laptop and only have it still in place.

Another way of including the screen that will make the system more robust and keep the attention on the board is to implement it as shown in Figure 6.7.



(a) One solution

(b) Another solution

Figure 6.7: Display on top of the box

With this solution, the focus for both the activity of putting blocks in holes and the display will be on one surface. Solving the problem of having to be attentive in two different places simultaneously. With the display permanently placed into the box there are no parts that are more prone to breaking, thus also solving the issue with robustness from the earlier solutions in Figure 6.6 and 6.5.

By having the screen as part of the box the boards need to be modified in order for this solution to work. For the solution in Figure 6.7a the placement of the screen results in the board getting a "U" shape instead of being rectangular. Since the board is still intact as one piece nothing about the mechanisms for putting the boards on will change, only slightly modified to fit the other shaped boards. The new and more specific shape of the boards will mean that they will only fit on the box in one way as opposed to before where in theory it would be possible to place the board onto the box in two different ways. The only thing this will affect is that it limits the users' alternatives, but since the shape is very specific it will not require extra logical thinking to place the board in the right place as it is very intuitive.

For Figure 6.7b the display takes up a third of the box surface essentially splitting the board into two pieces. The mechanisms for putting the boards on will in principle still work the same with both the integrated and the subsystem solution, as they will only need some minor modifications. Having two boards instead of one will however affect the overall usage of the system.
One intention with the boards is that they can be used for different variations of skill levels, where each board is different depending on the users' skills. When having two boards that are separate from each other you can in theory be able to put one "simple" board on at the same time as a "hard" one. This will however not be favorable when it comes to progression and motivation throughout the system as you should practice at your own skill level in order to get a sense of accomplishment and be motivated by your own progression, as mentioned in section 2.2. This can be avoided however by labeling the different boards and

having the display let you know if you put two different boards on at the same time. In addition, one could implement a feature where if two different boards are put on the box the system will tell which other boards match with the ones the user has put on. This way the user will be guided in finding the right boards, but at the same time, it will require a good amount of logical thinking from the user. This would mean that small children or people who also struggle with their logical thinking will need much more help than originally thought.

When it comes to implementing a display to the integrated solution of the boards and box [Figure 6.2] the most logical placement will be to have it as shown in Figure 6.8

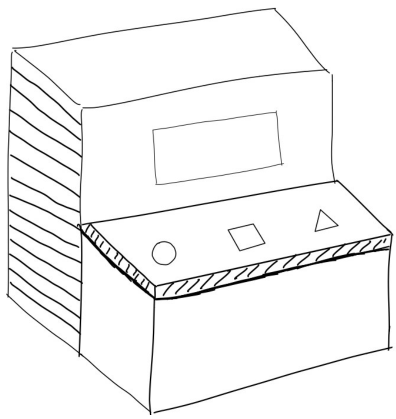


Figure 6.8: Display as part of the integrated solution

It is very similar to that of having a display over the box as shown in Figure 6.6b. This solution will however be more robust than Figure 6.6b in the sense that the display is now not a separate delicate part, but rather an integrated part of something that is already quite robust in itself. The placement of the display in this way is beneficial if the system is integrated, if you want to have the combined solution where the box is detachable, this is a rather poor design. For a detachable system, the best implementation will be to have the screen placed on the top surface of the box as illustrated in Figure 6.7a and 6.7b.

The generalization of these designs makes it possible for multiple solutions for the display. The designs presented above only show possible placements of the displays, not the specific solution. There exist for example many different screens compatible with Arduino and raspberry pi that can be implemented. These can then be easily programmed and will work well with the rest of the system. These screens are however quite expensive. Another more affordable solution for a display can be to only make a website or app that can interact with the rest of the system. The user is then able to use a phone or tablet as the display by placing it in its designated place. This solution will however be more complex in its making but will spare the system money.

6.3 Speakers

In line with universal design, feedback or other information from the system must not be solely dependent on the users' sight. Not only for people who are blind, but it can also be beneficial if the user is very focused on the task at hand and does not notice the screen for instance. The chance of this is however minimized by the design solution of having the display on top or over the box, but it is still a factor to be considered.
By including sound in the system it will be better suited to involve a larger audience and it will work better with the users as the chance of missing information will be even more minimized. If the system is to be used in a generally noisy environment, for example, a school, it can also be beneficial to implement a way that the user can listen with headphones. This can be done by having an AUX plug or with a Bluetooth solution.
When it comes to where the speakers will be placed in the system there are two things to be considered. Firstly the sound has to be close to the user so they will be able to hear better. Secondly, the placement should not be in the way of anything else.
The first place to rule out is the back of the system. Until now there have been no suggestions of implementation along the backside of the system, this is to give the users the possibility to store the system against a wall. The speakers should therefore not be implemented on the backside as the sound quality would be jeopardized if put up against a wall, in addition, the backside is the farthest away from where the user most likely will be. The two better and more realistic implementations will therefore be as shown in Figure 6.9

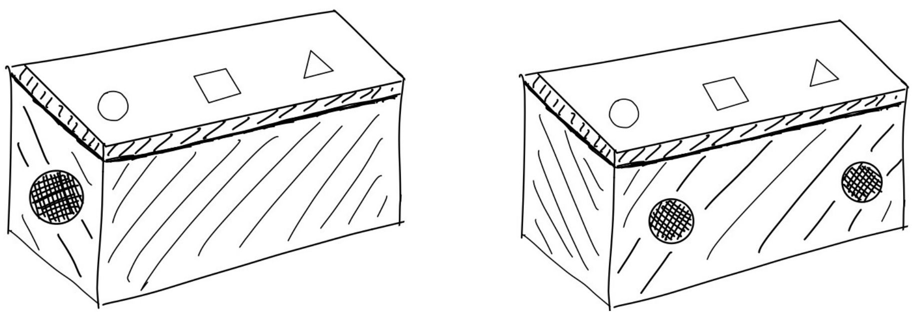


Figure 6.9: Speakers implemented into the box

Where the speaker is on the side it is assumed that there will be another on the other side to have balance in sound. With speakers in the front, it can be implemented just one speaker. Since the user will most likely be facing that surface it can suffice with only one source of the sound.

6.4 Extraction of blocks

Since the whole point of the system is to have a box where you take blocks and put them in holes in the box, there has to be a way of collecting them after use. As with the speakers the extraction of blocks needs to be easily available to the user. The extraction should therefore also be put either in the front or on the sides of the box. The implementation of this will be fairly easy as it only requires a path for the blocks to get from the box to an opening. This opening can be a little open space in the box where the blocks will come to when they are put into the box, similar to that of pool tables when striking down the white ball. This little opening can then also be a place to store the blocks when not in use.
Another solution for the hole is that it could be angled so that the blocks would roll out of the box and onto the floor. This solution can however work as a distraction for the user where the movement from the block can be seen while the user is trying to focus on something else. The user will then lose the focus they had because of this.

Another solution is to have the blocks be in the box, where the user then has to lift the board in order to get the blocks back. This can however cause unnecessary work for the user. For example, if the user puts in a block but wants to try the same block in another hole they have to first lift the board, pick up the block, put the board back down, and then they can try again.

6.5 Electronic components

Since this is a prestudy with a focus on design solutions and implementation, specific components will not be discussed much here. The most important ones will however be mentioned and their use and how they will benefit the system will be looked at.

As mentioned in earlier chapters it is the use of electronic components that will contribute to the gamification of the system. The display that has already been discussed is one of the main electronic components the system will use for this. Another component that also can be used a lot for this purpose is light-emitting diodes or LEDs [Figure 6.10] which are great for this type of use. These can be placed in various places to give more specific feedback, for example around the holes in the boards. There you can use the LEDs as an indication of whether the right block has been put in by lighting in a specific color. They can also for example be placed in the shelving system so that when you want to start a new level the right board will light up or blink so that you will see it.

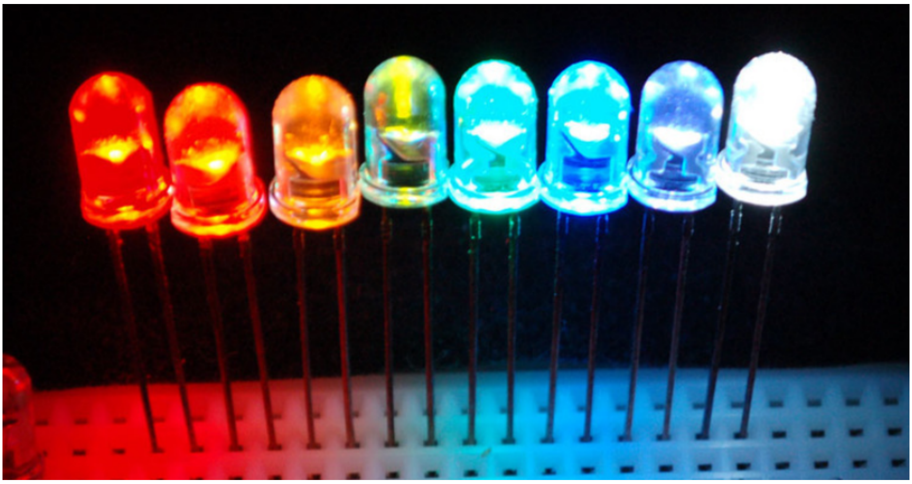


Figure 6.10: Some simple LED's with different colors [12].

In order for the system to work as intended there needs to be a lot of electronic components behind the scenes as well. As mentioned, microcontrollers along with several other chips need to be used in order for the different parts of the system to work together. These are especially important for ensuring communication between the box and the boards since they are supposed to be taken on and off. Different sensors will also be used for detection. For example, when putting a block into the hole, in order for the LEDs to signal what is correct sensors will be used to detect the block and decide based on given parameters if it is the right one for the hole or not.

6.6 Blocks

The blocks to be used in the system need to fulfill some requirements in order for the training of motor skills to be efficient and for being able to help the feedback systems as described in section 6.5. By taking the target user group and theory presented in the earlier chapters into consideration, a list of requirements for the blocks can be presented as such:

- **Customizable**

    - Since the system has a very specific intention of how and why it should be used, the blocks would benefit the system if they were able to be made specifically for the holes.

- **Light**
    - In order for the blocks to be easily picked up they need to be fairly light so as not to make the exercise unnecessarily hard.

- **Universal design**
    - One possible solution to the game is that the blocks can have different colors to indicate where the blocks should go. If the user is short of sight however this will not work very well. With the blocks being customizable it could easily be made some form of texture to the blocks so that one texture would correspond to a color for instance.

- **Not too small, not too large**
    - Size is an important thing to consider when training fine motor skills. The smaller they are more precise fine motor skill is needed in order to be able to pick them up and place them in the hole. If they are too big on the other hand it would be a struggle for those with small hands to pick them up at all, limiting their ability to even use the system as intended. Another important point to make here is that they should not be so small that a child would swallow them. If the blocks include electronics inside them this is especially important as it could be very dangerous.

The biggest point to take away from this list is the ability to customize the blocks as it would check most of the other requirements as well.

One way to be able to do that is with additive manufacturing or 3D printing as it is commonly known. As a phenomenon, it began already in the 80s and slowly evolved into becoming something more mainstream and popular in the early 2000s [34]. Since the technology of 3D printing has been available and evolved over many years it is now common to have easy access to 3D printers in some way as they can easily be bought online. It has also become a rather cheap, and fun solution to being able to make your own parts or designs for different purposes. In addition, 3D printing is fairly easy to learn as there exist several tutorials on different designs, uses, and printing online.
There exist however many different printers to satisfy different needs. One of the most common and cheapest 3D printers intended for private use is a so-called fused deposition modeling, or FDM printer [31]. They use either ABS or PLA plastics that are heated in a nozzle and extruded out layer by layer in order to make a solid model [31]. FDM printers are however not the best printers when

it comes to quality and should not be used if the parts being made needs to be 100% perfect.

Figure 6.11: Two common 3D printers [31].

For making blocks for this system an FDM printer will be more than adequate since quality is not the main concern with these blocks. By using a 3D printer to produce the blocks all of the requirements above can be satisfied. With the use of FDM printers, the material they are made of is fairly light, resulting in a rather light object as well. It will also be very easy to make texture on the blocks as this is a feature in every 3D modeling software when designing the objects. When it comes to size there is no problem with scaling a design to a specified size in this software as well.
The perks of using a 3D printer are many and not only will it satisfy the requirements pointed out here, but it will also have other benefits. In addition to being a rather cheap and easily available solution, the process of printing is not a very long procedure for rather small printing designs. With the blocks being prone to breaking as they are loose and small objects, 3D printing can therefore easily replace broken ones without much work.

Chapter 7

Levels

A large part of many games is the use of levels. As discussed in previous chapters, the implementation of levels and increasing difficulty will contribute to motivation and give the user a natural progression in training. In addition to being a device that trains fine motor skills, it can also work to train cognitive skills at the same time as these two skills are very closely tied to one another [20]. By increasing the difficulty in a physical and cognitive aspect level by level you are able to obtain a natural progression of training and learning in both skills.

When it comes to actually implementing levels in the system there are two main aspects to consider, the blocks and the boards. With the training of fine motor skills, grabbing the blocks is what mostly trains the muscular abilities in the hands. It is when mixing the blocks with the boards you are able to include training in both skills. For example, if the user is presented with several holes on the board and one block it requires logical thinking to figure out which hole it belongs to. In addition to feedback, the user will be able to learn from their mistakes further practicing cognitive skills.

For children, a progression with harder physical and logical challenges will be very useful for their general development as these two skills are very important to have later in life and can affect other skills, for example, math as mentioned in chapter 2. Older children or adults however may not benefit the same way with a progression of harder logical challenges as they might already have these abilities. It is however still important, no matter how old you are to regularly train to maintain your cognitive capabilities. So by for example including logical challenges the system can benefit most ages at the same time, but in different ways.

7.1 Blocks

As mentioned with the block requirements, size is important to consider when training fine motor skills. Smaller objects require more control and are used for people who already have some fine motor skills, while larger objects are more suited for less fine motor skills. One way to increase the difficulty can therefore be to downsize the blocks as you go along. This way you will not only show the user very clearly what level they are at in their training but also by having a minimum size of the blocks you are always able to see the goal which again will help with motivation.
Having several sets of blocks seems good in theory, as it is a good way to progress, but in reality, there should be a limit to the number of blocks included in the system, simplicity is key. If there are too many you only create new problems as to where to store all of the blocks and make it unnecessarily difficult to find the right ones to use. One solution however can be to include a minimum number of sizes in the system but provide other blocks to be bought separately by the users at a later point. This way the user themselves can decide if they want or need other types of blocks as well, and how many.
It is not however solely size that can affect the level of difficulty with grabbing the blocks. Another way is to increase the complexity of their shapes as it will require more precision when picking up for example a star than a cube.

7.2 Boards

The boards have in this report been the main focus for implementing different levels as they have a large potential with being customizable where only the imagination limits its possibilities. As previously discussed the main intention of the system is to use blocks and holes in order to train fine motor skills. By only including one task it will make the system more simple in its use and make it easier for the users to familiarize themselves with it.
But with the boards being so general it could be possible to make boards that have distinct tasks on them as well to train in different ways. This system is based on the box toy with holes [Figure 4.3] but the boards can just as easily be made to copy that of other toys, for example, the one in Figure 4.2. For the rest of this discussion, the focus will however be on that of the box with holes to make the explanation a bit simpler, in addition, many of the concepts with the blocks can be easily transferred, with some modifications, to that of another game.

The intuitive thought when implementing levels with the help of different boards is that each board will be a level. With a requirement being that the system should be as small as possible it is however not favorable to make too many boards.

Therefore it is important when designing the different boards to make them as general as possible so that they can be used in more than one way. An example of doing this can be to implement several levels in just one board. One board will then for example be level 1 to 3, the next 4 to 6, and so on.
As discussed there are two ways of increasing the difficulty here, physical and cognitive. When it comes to physical progression, one way can be to reduce the size of the blocks as described earlier. This would mean that each time a board is switched the physical challenges with fine motor skills is more challenging for each board. Another way will be to introduce more complex shapes with each board. An example of three different boards with this in mind can be seen in Figure 7.1, 7.2 and 7.3

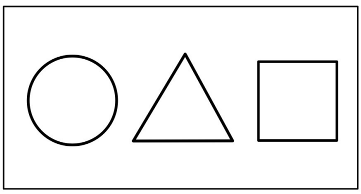


Figure 7.1: Board 1

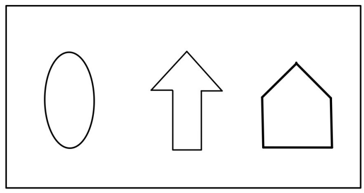


Figure 7.2: Board 2

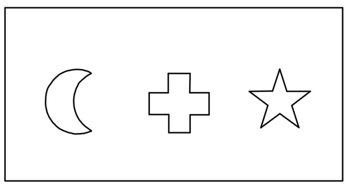


Figure 7.3: Board 3

As can be seen in the figures the sizes decrease and the complexity of shapes increases from board 1 to board 3.
The sizes and number of shapes are here only used to illustrate the points mentioned above. In reality, there could be implemented more shapes and the largest size might be smaller than illustrated here for example.
Another important point to make here is that the size of the shapes in the figures represents the size of the blocks and not necessarily the holes on the boards. Let us assume that the shapes presented here are the shapes of all of the blocks and each block in one shape has three different sizes. For example with board 1, there will exist three different balls, one small, one medium, and one large that fit in

the circle hole.
If the holes on the board are in the largest size you are then able to fit the other two sizes into the hole as well. Grabbing the smallest block will be more complicated, but the hole is then bigger so the probability of getting the block into the hole will be bigger. Opposite for the larger blocks, so all in all the difficulty of each board will therefore stay the same in that sense. It will however increase the generality of the system in the sense of how the board can be used with it being more solutions to a problem.
However, if the holes on the board are big, it may cause several of the other smaller blocks to fit into holes of a different shape. This will in itself increase the difficulty as there now will be more options for each hole and finding the right block will be more difficult. This may not be a negative thing on the other hand as it can increase both training with fine motor and cognitive skills. With more options it will require the user to having to think more before trying a solution, making the user grasp more blocks in trying different solutions. But with the added difficulty the general difficulty of the task may have to be scaled down on the boards to not make each level more complex and difficult than it already is.

In order for the system to have more functionality while having as few boards as necessary, other different ways of increasing the difficulty can also be implemented in each board. Some examples of this can be the use of color, LEDs, or sound to create different games on each board.

7.2.1 Color

As mentioned earlier there are many ways of customizing the blocks with the use of 3D printing, an example can be color. The task could for example be to put a blue ball in a blue circle-shaped hole, and another to put a green ball into a green circle hole. Using LEDs around the hole could eliminate the need for two different holes in this case with the LEDs being able to change color.
By using color the user has to observe and match both colors and shapes which will increase the difficulty on the board. For users who are short of sight instructions can be read from the speaker system where the user has to for example match texture on blocks with the same texture being placed around some holes.

7.2.2 Light

The LEDs can not only be of use with color matching, but they can serve as a way of guiding the user as to how to play the board making a level easier or harder. As mentioned in section 6.2 the display can be used as a guide in itself to show the player what to do as a way of making the task clear. An example of a task can for instance be that the player is supposed to put in blocks in a specific order. By only showing the instructions on the display once the user has to memorize the task and then perform it. This will be more difficult and require more cognitive skills from the user. LEDs around each hole can then be used to make this a simpler task by lighting around the hole that is supposed to be used next. For those that are short of sight, this would again be replaced by an audio solution.

Chapter 8

Discussion

In the making of a new system, certain requirements and limitations will be considered in order for the system to work. When it comes to design on the other hand there are many solutions as to what can work while still within the scope of the requirements. For this system, as stated in the previous chapters there are certain solutions for the physical aspect, but when it comes to the design of levels the possibilities seem endless.

Throughout these chapters, there have been several suggestions of different solutions for each requirement and the advantages and disadvantages have been compared. It is important to come up with more than one solution to different designs in case something goes wrong in developing the system. An example of this could be that a presented solution works very well in theory but in physical installment, it meets unexpected problems not looked at in this report. This could, for instance, be that the electronic components working inside the box have to take up a certain amount of space at a certain location making it impossible to, for example, have speakers on the side of the box as shown in Figure 6.9. Having already presented several ways of different solutions in this report these kinds of problems can be quickly resolved by then trying another option.
The different design suggestions are also made as general as possible to eliminate most of these types of problems. However, problems that can arise in the making of the system have not been properly looked into as the objective of this report was to look at design solutions rather than the implications of implementation.

Since the designing of levels and the ways in which the system can be used does not depend on the physical implementation of the system in the same way that for instance the speakers do, there are more possibilities when designing them. How the user puts a block into a hole is not dependent on for example how the board is affixed to the box, or where the speakers are placed. It will however be very dependent on how big the boards and blocks are going to be as this will limit the number of holes which again will limit the possibilities of how many different ways one board can be played. It would therefore not make much sense to only give one solution at this point as it could change very quickly when developing the system with how big the smallest size blocks can be, as well as with the size of the boards. The solutions with the levels presented here give instead guidelines for how it can be done so that the process of implementing the different levels and solutions will be quick and painless.

With these points in mind, one way how the system can look when finished can be seen in Figure 8.1 and 8.2

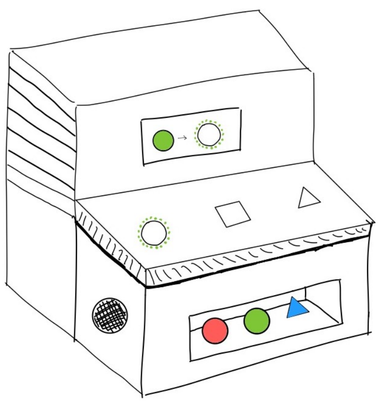


Figure 8.1: Solution with easy level

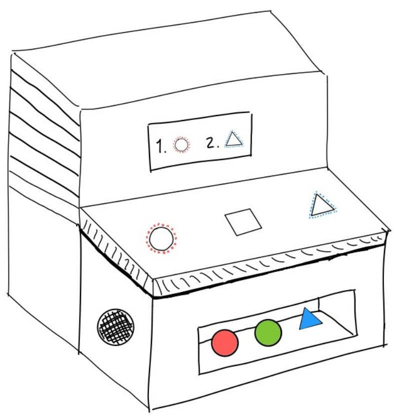


Figure 8.2: Solution with harder level

With the argumentation made for the display in section 6.2 it was concluded that the best placement for the display would be in the direct eyesight of the user. With placing the display on the box as illustrated in Figure 6.7 the boards will be affected where there will be less space for holes, limiting their potential. For avoiding this the best solution would therefore be to use the integrated solution presented in Figure 6.2 as this would maximize the board's potential and make the display more on display. The extraction of blocks is placed in the front so that the user could easily grab them, and the solution with having a hole in the board is chosen as this would be the simplest and tidiest solution as described in section 6.4. With the extraction being in front the speakers would then have to be on the sides.
Also shown in Figure 8.1 and 8.2 two different ways of playing on the same board can be seen. In figure Figure 8.1 an easy task is illustrated where the user has to put the green ball in the green hole in order to finish the task. In Figure 8.2 a

harder task can be seen, where the user has to first place the red ball in the red hole, then the blue triangle in the blue triangular hole. If the user then manages to do this in the correct order the task is completed.
This design will utilize the advantages of the different parts, as discussed in chapter 6, and will all in all give the most benefits to the system as a whole.

One of the main requirements presented for this system was that it should be simple and intuitive to use. Even though the system presented above has a lot of complex concepts and functionality, it is made as simple as it can be whilst incorporating the concepts sought after in the report. It is however far more complex than that of the original box toy, but added complexity is only natural with added functionality.
This will however affect the use of the system. One requirement was that it should not feel like a test, and as discussed in section 2.1 this could be done by removing the need for a second party. With the system being more complex however, some level of help is unavoidable. Even though the boards and the system as a whole will be made relatively small, it would almost be impossible for a very young child to lift these boards themselves and put them back in place. The same goes for people who have little to no fine motor skills, lifting these boards will be problematic for them and may require some help related to this.
As discussed in section 2.1 it is, on the other hand, mostly the assistance needed when performing the activity that should be avoided in order for the system to not feel like a test, and with the simplicity in the levels and its use, this has been avoided. In addition, other measures have been taken in order to also make the system mainly fun, such as being able to use it at home and implementing it with games.

Chapter 9

Conclusion

9.1 Reflection

Looking at the work that has been put into this report there are several points to highlight. With the main intention that this report was to be a prestudy the work had to reflect this.

The work connected with this report has had a time limit as to when it needed to be finished, because of this its limitations had to be defined in advance to make the report and its work feasible in the time available. As mentioned in the preface the wish with the entire project was to be able to create something new with a mix of physical objects and technology. By following an engineer design process the natural steps to take in order to accomplish this would therefore be to do a background study, lay out the requirements, brainstorm possible solutions, choose a design and lastly develop and test the solution. In this process, there are a lot of different steps and each step also requires a certain amount of time to complete. The steps are also equally important on their own in order to achieve a developed system. If you, for example, spend too little time on the background study it can come back to haunt you later, and as a worst-case scenario lead to the developed system being unsuccessful as you will not have any reason or arguments to support your choices for the design. The work with this report landed therefore on dividing the engineering process so that the work in this report was to focus on research and everything that would pave the way for developing and testing at a later point.
By dividing it this way the objectives of the report and its structure would also be more organized as the work would mostly be a literature study in preparation for prototyping. It would also entail that it would be easy for anyone to continue with the prototyping as all the groundwork is presented in one report.

The scope of the report can again be divided into two parts. The first is a literature

study of gamification, user group, and existing products, and the second is the designing of different solutions to the system. Since a literature study is very important and facilitates further development of the prototype it was important to use some time with this. With also not having much previous knowledge of rehabilitation and the needs of people who have a disability the literature study was a necessity for having a solid foundation with the designs.
However, with having a technical background and not having done many literature studies previously, the designing process was more fun and interesting than reading up on concepts. This resulted in a bit unorganized work process which again made it harder to start writing the report as there was so much to write at the same time. In hindsight, it would have been beneficial to not jump the gun with the design and use more time, in the beginning, to research to make the work process a bit smoother and organized resulting in a better workflow through the semester. In addition, it could have been a good idea to reach out and be able to interview some experts in the fields of psychology and rehabilitation to get a better viewpoint of the intentions of the system. But with much research available online and as mentioned by having an unorganized work process as well as there being limited time to complete the report this was not prioritized early enough in the work process to have time for it.

9.2 Further work

Everything done in this report is as mentioned made with the intention of the system being developed at a later stage. The next logical step to take here would therefore be to progress to the next step in the engineering design process. This means that further work will be to consider more concrete solutions to the different design suggestions presented here in form of testing. A first logical step could for example be to look into the use of magnets as a mechanism for affixing the boards to the box or if it should be implemented a sliding mechanism instead. The making of the blocks using 3D printers, or deciding how and what the display should show as the system is being used are also good things to start with. In addition, it needs to be decided what types of electronic components should be used and how to connect it all with I/O devices and network communication.
After this, prototyping and testing of its functionality to see if going back to the drawing board and tweaking the designs are needed. If that happens the hope is that this report will still work as the foundation for design choices where you can base choices solely on the theory presented here without the need for another literature study.

9.3 Conclusion

The system presented in this report is one of many available systems that are made with the intention of aiding fine motor skills. The group of people that has trouble with this however are many and diverse, and it can be hard to make a product that will satisfy the needs of all of them. Luckily the training of fine motor skills can be done simply by using objects that are easily available to most people like scissors or pencils. In addition, there have been developed a lot of different toys, games, and systems able to train fine motor skills in order for the training to be very specific. For example, the Amadeo [Figure 4.6] is a system made for the exact purpose of training the fine motor skills in the hands.

The need for the system presented here may therefore not look very meaningful as it already exists many ways in which people can develop and train their skills. The benefits of physical activities and digital solutions to train fine motor skills on their own are many, but by mixing them together, elegantly and smartly you are able to get the benefits from both into one system. The solutions available today that utilize this principle are however not very commonly seen on the market. They are either very expensive and require assistance, such as the Amadeo, or are cheap and small but do not satisfy a broader group of people. A system that is a combination of this is therefore a product that has demand since it will be unique in both its design and use. In addition, this system aims to implement gamification as a way of making training fine motor skills fun but also as a way for it to train and develop the users' cognitive skills as an added bonus. With doing that the system has more function and purpose which again will give it some edge and make it stand out in a market of other training solutions.

Even though it sounds very complicated to build a system that will do all of this, the entire report is written with the intention that it is going to be developed at a later point. Meaning that all requirements and technical aspects are based on existing technology and solutions to make it more feasible.
All of the design solutions are also made with feasibility in mind. Different aspects of how the system can be used form the basis of different designs. For example, by not implementing any features on the backside of the box it can easily be placed against the wall by not having any functionality on one surface. With the system being used by several different people it is however not realistic to consider all the possibilities of use when designing. But by designing with generality and the 7 principles of universal design [33] in mind the system is made in a way that it can be very flexible and adaptable to different needs.

Based on the work done with the literature study and the design process, as well as the discussions in this report, it can be concluded that the proposed mechatronic system is a feasible and promising solution for individuals with fine motor skill impairments. Not only does it introduce new, innovative elements, but it also builds upon proven techniques that have been shown to provide physical and cognitive benefits. Overall, the system is believed to have a strong potential to effectively aid its intended users by providing them with a fun new way of improving various skills.

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