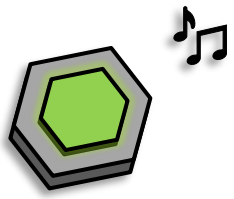
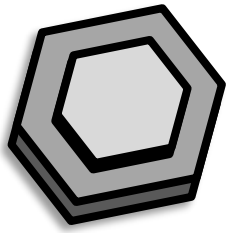
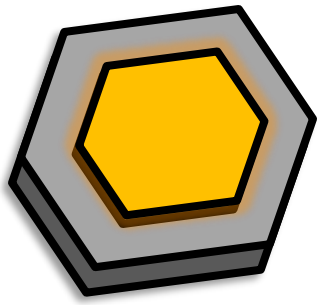
Increasing Children's Physical Activity Outdoors with Interactive Buttons through Co-Design

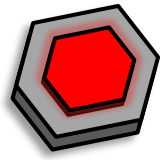






Bachelor Thesis

Michelle Gommers



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Abstract

Despite the importance of outdoor physical activity for a child's motor, physical, cognitive, and social development, there has been a decline in the amount of time children spend playing outside. Recent research has shown the potential of using technology to motivate outdoor movement in children. This project explores an approach of six co-design sessions with children aged 4 to 12 to investigate the use of interactive buttons in supporting movement-inducing play. In the first three sessions, the project goals were introduced, the interactive buttons were explored, and a mixing ideas technique was executed, resulting in 33 concepts for potential games. These sessions revealed many innovative design ideas, including Pet Store, Lego and Animal Gathering games, each featuring different methods of employing the technology and motivating physical activity. In the fourth session, the top six ideas were selected and further specified in the fifth session. The final two games, "Pizza Game" and "Escape Game", were realised, whereafter an evaluation took place in the final co-design session. This thesis presents the pitfalls and outcomes of the co-design process, the added value of the interactive buttons, and the insights gained from designing outdoor movement-inducing games for children.

Acknowledgements

I got a lot of help from many people during this bachelor's thesis. I want to especially thank my supervisor, dr. ir. Robby van Delden, and critical observer, dr. ir. Dennis Reidsma, for their feedback and guidance throughout the project. Despite some ups and downs, it was a very enjoyable experience and I have learned a lot.

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1. Introduction

Getting enough exercise is important to have a healthy upbringing. Overall, there is a decline in the amount of time that children play outside [1,2]. The Dutch Knowledge Centre for Sports and Movement [1] provides the guideline that adults should move around at a moderate intensity for 2.5 hours a week. The same institute indicates that children between the ages of 4 and 17 should move even more, moving around at a moderate intensity for 1 hour a day. In 2022, only 44.3% of Dutch people older than 4 years had adhered to these guidelines [3]. Movement is a crucial element in a child's upbringing, a lack thereof can cause problems in physical, motor, social and cognitive development [4,5,6]. Therefore, it is desired to stimulate children's movement to promote a healthy lifestyle. The aim of this Creative Technology bachelor thesis is to design a simple interactive technology implementation to increase children's physical activity.

Current technology has a lot of uses such as playing games, unfortunately, these activities are often inside and do not require a lot of physical movement. Playing outside might seem boring and less attractive to children in comparison [7]. Existing technology that motivates children to move inside includes games such as Just Dance or Wii-fit, there are also outside interactive playgrounds and playware but many of these are not affordable or accessible. Because of this, there is still a lot to gain in researching and designing new interactive technology that is motivating, adaptable, affordable, and can be used outside.

1.1 Research Question

The target audience is children aged 4 to 12, therefore, it is important to cater to their needs and design interactions that align with their interests. Furthermore, the goal of the interactive buttons is to motivate the target audience to move more. Thus, the designed interactions should focus on inducing some level of physical activity. This current project involves researching interactions and games that can be done with interactive buttons. These buttons can be programmed and networked to create different interactions when pressed, including sounds and LEDs. The buttons were created by another student in a previous project [8], and in this project, we investigate whether and how interactions for these buttons can be designed to motivate children to play more outdoors, such as in playgrounds or parks. This leads to the following research question:

"How can interactive buttons effectively be designed to entice children between the ages of 4-12 to move around more outdoors?"

1.2 Sub-Questions

This thesis explores a user-centred design method incorporating a co-design with the target group. In this co-design, children from after-school care help design and evaluate games that stimulate outdoor movement using interactive buttons. To support the main research question, four sub-questions were formulated considering the target audience, technology, and design:

1. *"What design elements can increase children's motivation for outdoor physical activity?"*
2. *"What interactions with an interactive set of buttons motivate the children to use it?"*
3. *"How can a co-design approach be utilised to design games for children with interactive buttons?"*
4. *"How to design movement-inducing games for children with the support of interactive buttons?"*
5. *"To what extent can adapting children's ideas result in a viable product that stimulates outdoor movement?"*

1.3 Thesis Structure

To address these research questions, this thesis is organised into 9 chapters, beginning with this introduction as Chapter 1. Chapter 2 discusses related background research as a foundation. Chapter 3 outlines the approach, methodology, and techniques. Chapters 4, 5, and 6 detail the design and implementation process, which is evaluated in Chapter 7. Chapter 8 then discusses the key findings and gives recommendations for future work. Lastly, the thesis is concluded in Chapter 9.

The main findings of this thesis project include key insights into co-design: the suitability of design techniques for this context, considerations for using focusing or divergent scaffolding, insights into balancing preferences, the adaptation of design elements such as competition, surroundings, and movement, a list of child-generated concepts, and various ways of using interactive buttons to support these games. These findings contribute to the theories of behaviour change, interactive buttons, children's movement-based games, and co-design with children. They are beneficial for designers aiming to stimulate outdoor movement in children and for those using co-design or interactive buttons to design play.

2. Background research

This chapter includes a literature review of techniques and design methods to help address the sub-research questions on the value of design elements (1) and technology (2). Additionally, this chapter features sections on co-design with children and a state-of-the-art on similar interventions to gain an overview of existing approaches and opportunities. This chapter also includes interviews with experts who frequently supervise children along with existing literature to build an understanding of the target audience. Finally, an analysis of the context and technology of the project follows to complete the background research.

2.1 Game or Behaviour Change Technique

This project aims to design a technological product that stimulates children to move around more outside. The base of this invention is phygital play, a combination of digital tools and physical elements that aims to enhance its effects [9]. In play, there are a lot of different technological possibilities that can guide, enhance or even replace traditional play. Another example is pervasive games where reality is mixed with a game or technology to improve the user experience [10]. Delden et al. [11] show the need to research the balance between physical and digital to improve play. It is important to create a balance that allows for fun play and the preferred change in behaviour.

Play can be grouped as self-directed and adult-directed play [12]. Self-directed play is a type of play that involves only the children's efforts. Adult-directed play is where the children are guided to partake in a certain play. This can be used in varying ways, such as adding a stimulating factor or shaping the play to be educational. Meijer et al [5] stated that the most optimal application of physical activity for children includes a combination of cognitively engaging activity and exercise. Multiple categorisations of play target changing or influencing behaviours. Gamification, exergames, nudging interventions and behavioural change techniques are activities with different balances between play and purpose [13,14,15]. In the context of this report, the purpose is to increase outdoor movement; in other contexts, this could also be changing habits or learning new knowledge.

Nudging interventions and behavioural change techniques are applicable when researching ways to get children to change their behaviour. These are methods that fit into the field of psychology. One prevalent theory is the COM-B Model. This model states that capability, opportunity and motivation should be targeted to shape behaviour. This theory is relevant in designing playful interactions for children, it notes that users should feel a sense of each

aspect to be able to change their behaviour per the purposes of the technology [16,17]. In the next section, this model is further discussed.

2.2 Design Methods (Literature Review)

This section is an edited version of the literature review conducted on design methods for the subject Academic Writing of Creative Technology module 11. The review consists of a comparison and analysis of sources found by looking up keywords relating to this project's goal and context, such as outdoor movement, children and playware. The findings provided a foundation of knowledge, which was used to support the approach and design process.

Design methods help create effective inventions and are a good foundation when designing something novel. In this review, design methods and key issues for technology that motivate children to increase their physical activity in the outdoors playfully from varying literature are gathered and evaluated. For this, the design heuristics are categorised into the main elements needed to design a simple playware that increases children's outdoor activity.

The models from the literature of varying design fields can be largely translated into three main categories of design methods. From an interaction design perspective, literature splits key issues into physical activities, game rules, and social interactions [18,19]. These two sources implement design methods to form a balance between traditional and digital play. Tetteroo et al. [18] add the limitless possible interactions from technology to further enhance the benefits of traditional playgrounds. Similarly, Soute et al. [19] do the opposite by adding traditional elements back into gaming to get children more active and away from screens. Bekker and Eggen [20] advocate another approach that involves embedding sensor and actuator technology in mobile games to enhance children's sports. This approach focuses on the interactions with technology, skill development, adaptive goals and feedback, drawing inspiration from computer games.

This graduation project has overlapping qualities with behavioural change methods, for this purpose, some psychological views are taken into consideration as well. One such theory is the COM-B model (Capability, Opportunity, Motivation and Behaviour). This design method states that these three aspects should be targeted for behaviour change. This model can also be used to categorise key issues and heuristics of interactive playgrounds [16,17]. The previously mentioned design categories also fit into the categories that target the user's needs. Since this literature review aims to find the best method to design playware that

motivates a behaviour change, the COM-B model is adopted, and the previous game categories are largely translated into this framework.

Aside from the play aspects directly influenced by the designed interactions and technology, there are also factors out of the designer's hands. Khalilollahi et al. [16,17] highlight the importance of the underlying factors of the design and context. These include the users, the play space and the manner of playing, an example is the safety of the play space. Sturm et al. [21] excluded these factors from their heuristics because they judged them to be outside their control when designing new technology. Depending on the extent of the research and design period these factors can be included in the thought process allowing for a more complete overview and fewer uncertainties.

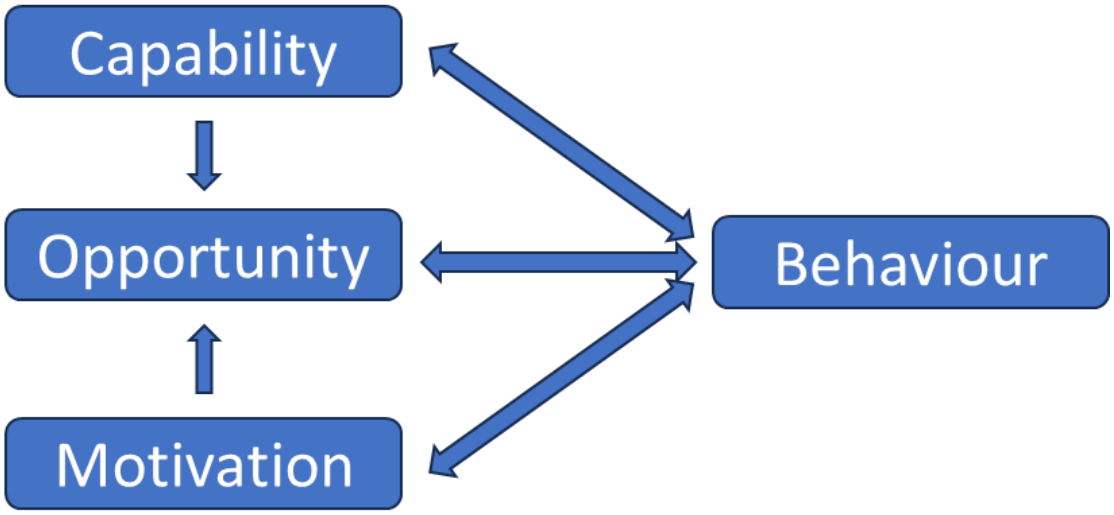

Figure 1: COM-B model

2.2.1 Capability

A few aspects regarding the user's capability are important to consider when designing an interaction for children. Children can often have a hard time understanding complicated rules, because of this it is important to keep the interactions simple [21]. Contrarily, Khalilollahi et al. [16] state that it is not very important to make the rules understandable but that it is more important to make them perceivable and inclusive. Despite the goal of the inventions targeting an increase in physical activity, Khalilollahi et al. [16] also state that the design should have a low level of physical effort and be easy to perceive to be inclusive for children with different abilities. Another aspect to consider is the comfort of the users by using traditional games and play they might be familiar with, this is also expected to aid with the understanding of the new interactions [17].

2.2.2 Opportunity

One key design issue that was mentioned throughout all of the sources. In the opportunity aspect of the COM-B model, the available choices of the user are included. Khalilollahi et al. [17] talk about the environment of the playware, whether it is safe, allows for social interaction or freedom of the users. Tetteroo et al. [18] use the concept ‘Gamespace’ to categorise activities one can do in an interactive playground, these are divided into fully external, partially contained and fully contained. On the one hand, when the playware allows for a lot of freedom in how to use it the play can become fully external, which means that the surroundings (and playware) are irrelevant to the play that is taking place. This does not mean that it is a disadvantage as long as the playware achieves its purpose by activating the children to start playing around, however, there is a higher risk since the technology is no longer influencing what is happening. Thus, there is a risk of children doing unintended actions such as resting or stopping outdoor physical activity prematurely. On the other hand, when there are a lot of rules, binding the users to the games (fully contained), there is a risk of limiting creativity and exploration which might demotivate children [18]. In this case, it is important to find a balance between the two issues, depending on the underlying factors of the users, such as age and interests, different balances will be more effective [17,22].

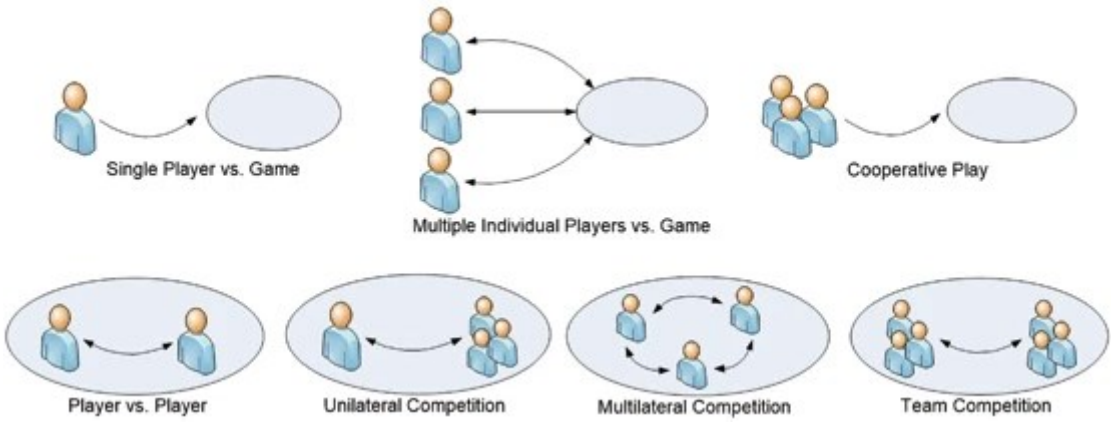

Figure 2: An adaptation made by Tetteroo et al. [18] of player interaction patterns from Fullerton et al. [23].

Another key design feature is the social interactions that the users can have with each other. Tetteroo et al. [18] mention seven ways games can be played alone or with other users. Soute et al. [19] elaborate on a part of this; the cooperation, competition and negotiation between users. The opportunity for social interaction allows children to design part of their own experience and can often help each other if there is a lack of capability. A social aspect can be used as part of a challenge and motivation to increase the weight of an accomplishment.

2.2.3 Motivation

Based on the sources, there are two main approaches to design for motivation. According to Khalilollahi et al. [17] and Cumbo et al. [22], motivation can be split into three aspects: physical, cognitive and social. Children are motivated to participate in the play by providing challenges of these aspects. Khalilollahi et al. [17] are also concerned that interacting with the same playware over and over might become boring and therefore highlight the importance of regularly updating the games and challenges. Cumbo et al. [22] support this concern by stating that play that allows for extensive exploration and games they designed themselves excite and motivate them better as this provides them with learning experiences and a sense of accomplishment and independence.

Furthermore, two forms of motivation are extrinsic motivation and intrinsic motivation. Cumbo et al. [22] claim that it is more important to focus on intrinsic motivation, as that is the main driving force behind using the playware. They suggest looking into users' preferences and adapting the interactions to fit them. The literature also shows examples of extrinsic motivation where the game asks the users to take certain actions through rewards, challenges or feedback from the technology. Torres et al. [24] assessed this type of movement-inducing playware to be 'forcing' physical activity by having this be a necessary action to continue progressing in the game. In these games, physical activity was used as an element that needed to be achieved to continue with the game. Other times it was used as a controller, which is also a forcing technique. In these cases, other game elements are used as a motivator and the interdependency between different game elements and tasks gets the children to move around more. Aside from forcing action regulations, there are inviting and guiding approaches. These were more often seen when stimulating the children to participate in different types of social interactions [24]. To complement the extrinsic motivation, literature advises the use of digital feedback to motivate children to achieve the game's goals [16,17,20,21].

2.2.4 Conclusion

The purpose of this literature review was to get an overview of design methods and find the best design practices that can be used in the graduation project on movement-inducing playware for children. In this review multiple heuristics were found from different fields in design, these have quite a few similarities but are worded differently. Some design models put more emphasis on certain parts but most of the literature mentions similar methods with different balances. There is no clear framework available to determine which heuristics are most effective in specific areas. However, based on the literature and completed projects,

some advice for different fields can be found. Depending on the purpose, scope and resources available for projects the amount and weight of each aspect is different.

2.3 The Co-Design Method

Cumbo et al. [22] and Fails et al. [25] mention that children want to play child-designed games and that it is difficult to match a child's interest as an adult designer. The literature review also concluded that open play and room for self-exploration of the children will lead to higher motivation and enjoyment. It is expected that having variety keeps the games exciting. Therefore, exploring the option of participatory design or co-design to design playware that stimulates children's physical activity with children is valuable. This would help adjust the interactions to a child's level of capability, fit their preferences, and provide opportunities for exploration and creativity. This section explores the field of co-design with children to create an overview of practices and techniques that can be used in this project.

2.3.1 Co-Design Roles

There are multiple roles adults and children can take in a co-design session [25,26,27,28]. Often experts from different fields are used in participatory design to design a product. Because it is difficult for an adult to clearly remember their childhood, co-designing with children, who are experts at being children, could be beneficial [25]. Additionally, nowadays' children are likely to have different preferences due to developments in technology and play. Designing with children can be done with active and passive roles. Active roles include informants, design partners, software engineers and protagonists who are the main agents of the design process, while more passive roles are users or testers.

This project explores a co-design where children take up active roles in the design process. The children assumed a variation of the protagonist role, where the research encouraged the children to take over the entire design process. Adult intervention was kept to a minimum, however, for the age group of 4-12 years old, steering is needed to get the desired results. Thus, the role was altered to be similar to an informant, design partner and tester where the children have control over the project's outcome with guidance from an adult design partner and software engineer. For this, guided activities and techniques were used along with explanations.

2.3.2 Considerations for Co-Designing with Children

This section delves into practices that are important when dealing with children. Especially during a co-design session with children, it is important to take the appropriate procedures to get the desired results. The overview of Fails et al. [25] provides us with several key considerations that need to be taken related to developmental differences, communication, and social structures.

Children need different scaffolding to accomplish a design activity than adults do [25]. Children have different capabilities than adults which should be considered when selecting design techniques. Children need simpler explanations and examples. They might also need more emotional support throughout the process. The co-design session should also fit the attention span of the children, going past their attention span can result in inadequate responses or a decrease in their emotional state. Therefore, the co-design should be split up into enough sessions that evenly distribute the design steps and workload. Each session should have limited goals and tasks to avoid overwhelming the children.

Children can also lack certain skills, such as reading and writing, or skills needed for discussion. They can get help from adults but also from peers or design techniques. A secure environment is needed for good communication. Therefore, the co-design should also be considerate of power dynamics [25,28]. The co-design aims to have adults and children design on equal grounds; thus, it is important to even the power gap. Creating an environment where all participants are equal, such as using first names, equal inclusion, and sitting at the same table can help.

2.3.1 Design Techniques

This section has a list of design techniques commonly used in co-design that are relevant to this project [25,26]. These techniques provide a foundation for the approach in Chapter 3.

Table 1: Table showing relevant design techniques and their explanations [25,26].

Design Technique	Explanation
Bags of stuff	A bag of art materials (paper, markers, props, etc) is made available during designing or brainstorming
Big paper	A big piece of paper will be put in the middle of the group that can be used to collaborate during brainstorming,

	individual design or other activities
Sticky noting	Sticky notes are used to write down advantages, disadvantages or notes to then stick on ideas.
Scenarios	Scenarios that could take place are walked through to gain insights and explore unexpected situations.
Act out the system	Acting out ideas with for example props can help gain an understanding of how the system would operate. This can help fill in gaps and find out what will or will not work.
Big props	Props related to the ideas can be used to act out ideas or to provide inspiration.
Storyboarding	Storyboarding involves drawing use scenarios in frames. This can be used to create visualisations.
Drawing-telling	This is a technique where drawings are made and then the participants explain what they have drawn.
Personas	Personas are similar to scenarios where
Discussion	Discussion can help look through different perspectives or work together to improve ideas.
Open/free interview	A type of interview that is not structured to allow for more flexibility and otherwise missed insights. Similar to a conversation with a goal.
Mixing ideas	In mixing ideas, multiple already created ideas are taken and then mixed to generate more ideas. This often results in novel concepts.
“Denken Delen Uitwisselen”	This is a teaching technique where children first think individually, exchange their thoughts in a group/pair and then share them as a group with the rest of the class [29].

2.4 Target Audience Analysis and Expert Interviews

This bachelor thesis uses a co-design with its target audience. Therefore, it is important to understand the needs, preferences, and characteristics of the target audience. We also researched the preferences during the co-design sessions themselves. A basic overview of the target audience is compiled from literature and interviews with child play experts. These experts are employees of the after-school care centre of the co-design's participants.

2.4.1 Target audience

The target audience is children between the ages of 4 and 12. This age group overlaps with the age of primary school students. At this age, children gain a lot of basic knowledge at school and develop their physical, social and cognitive skills. During the ages of 6 to 12, children undergo cognitive development where they develop the ability to think in concrete ways [30]. In the rest of their teenage years, they develop skills to think more abstractly. Each child undergoes a different development process, thus there will be differences in this per person. This target group may experience trouble doing abstract thinking or considering different perspectives.

The target audience for this project has a wide range, which causes a lot of variety in their developmental stages. Their age and other factors around their upbringing, such as gender or parents' ideas, can influence their interests. A group of 10 children is expected to have a wide variety of interests with a few overlapping subjects.

In the literature review (Chapter 2.2), heuristics were discussed based on children's general characteristics. For this, the COM-B model was used, which was also discussed in Chapter 2.1. The studies showed that children want to feel a sense of capability, want freedom to choose and need a form of motivation. This should be taken into consideration for the final product and during the co-designing process.

2.4.2 Context

Since the target group consists of primary school children, outside play likely includes parks and playgrounds that are close to their homes, friends' homes, or playgrounds of schools or after-school care facilities.

The play environment plays a role in the opportunities and motivation the children can have. Good weather can have a positive influence on motivation to play outside, whereas rain can

demotivate. Similarly, the state of the environment can have varying effects. The amount of space also limits the opportunities for gameplay and movement.

2.4.3 After-School Care: Partou de Vlinder

To gather expert insights, we interviewed employees at the after-school care centre where the co-design took place. The semi-structured interview can be found in Appendix 1. Two employees who often work together were interviewed on how the after-school care centre operated, how the children usually played, and any considerations that might aid the design of this project. Findings from these interviews were used to create an understanding of the target audience, prepare for the co-design and get advice on game elements. This approach was approved by the ethical committee of Computer & Information Sciences (CIS) under research application number 240132.

The workers take care of the children the entire time they are there. Most days they have around 35 children and then there are 4 workers. The facility for school-age children consists of two big rooms and two backyards. Children older than 7 years old are allowed to go outside without supervision.

At the after-school care centre, they have a lot of activities, they are scheduled using a planning board. Weekly they have on average 5 activities that the children can participate in. There is a great variety of activities for example cooking, a type of parkour outside, or some paper crafts inside. Not all children want to join in these activities, and they are free to choose what they want to do. The after-school care centre does not try to actively stimulate the children into doing healthy behaviour such as going outside and moving around. The workers believe that the children usually go outside three times a day. Sometimes children did not want to go outside because they already played outside a lot during school. Their policy is to go outside every day, but nothing is mandatory. The stimulation they use is providing the activities that can be done and if the children want to move around, they need to do it outside. They can do anything outside if it is safe. In their policy, they do restrict certain things. The children cannot go outside during noon when it is too warm outside. And the after-school care also minimizes the use of technology and screens, which the parents also seemed to like. A lot of children indicated to the employees that they often play on screens at home and sometimes play outside.

The employees motivate children during activities by being enthusiastic as role models and actively participating in the games. They found that this helps get children to actively play

along as well. They also found that activities with challenges or competition were motivating to the children.

Depending on the age and gender of the target audience, their preference is quite varied. During the interview, it was said that boys often want to do physical activities, whereas girls prefer to do arts and crafts. When they do an activity with everyone, there is not much motivation at the start, but they end up enjoying it. If they go outside for a group activity everyone joins.

2.4.4 Reasons for a Decrease in Children's Outdoor Play

Loebach et al. [7] have found multiple reasons why children have decreased the time they play outside. One of the main reasons is the influence of the parents or other adults. Janssen et al. [31] found in their study that children's age and parents' perception and fear of the neighbourhood influenced independent outside mobility. Furthermore, after a long day of work, it is tiring for a parent to take their children outside and supervise them. Because of this, there were indications that parents found it easier to let children play indoors with for example an iPad than to let them go outside. Similarly, some parents allowed screen time when they were still sleeping. From the conducted interviews discussed in the previous section, the experts also suspected this to be the case. They speculated that parents would be tired after a long day of work and would want to rest while cooking dinner or doing other activities. This rest would exclude thorough supervision of their children.

Similarly, the after-school employees mentioned that existing alternatives to outside play are another key reason for a decrease in outdoor play. These alternatives could be easier, more approachable or more fun. With the development of technology also comes the increase in the appeal of indoor, screen-based activities.

2.5 State-of-the-Art

This section delves into the state of related research. Firstly, this current project is analysed and discussed with related work. Afterwards, the related works are discussed to get a view of how similar problems have been tackled with similar technology. The state-of-the-art highlights findings of existing research that can guide the design process and identify research opportunities.

2.5.1 Technology – Bee buttons

The technology used in this research is the bee buttons. These are buttons made by Max Pijnappel in a previous project [8]. During a discussion with Max Pijnappel and Rita Yousef, the capabilities and constraints of the buttons were discussed. Rita, a student working on a related project involving the buttons, provided valuable insights, including alternate applications.

The buttons can distinguish between 3 different types of inputs and have 3 different types of output. The buttons can be pressed for a short time, a long time, or twice in a row. These inputs can be programmed to create different types of gameplay. The output of the buttons is two different modalities: sound and light. The buttons can light up in the colours of the rainbow and have a rainbow effect. Furthermore, they have a blinking and circle effect. Different sounds and music can be stored on an SD card with each button. The speaker can play the sounds on different volumes that are audible from a few meters away outside.

Figure 3: Pictures taken of the bee buttons used in the project.

The buttons are called bee buttons because of their shape and how they can be connected. The buttons are in the shape of a hexagon and can be picked up with one hand. They are connected in a mesh, which allows them to communicate with each other and a dongle connected to a computer

2.5.1.1 Constraints

There are two initial constraints of the buttons. The buttons cannot be used in all weather conditions since they are not waterproof. Furthermore, since the buttons are networked together, they cannot be moved too far from each other. This does not immediately pose difficulties for the project but should be considered during the design.

2.5.2 Related Work

This section features a discussion of related work that was found to have problems, solutions, or commercial applications similar to those found in the project, followed by a synthesis of the related work, evaluated according to the characteristics of this project. The related work was found through searches in literature based on literature [32], personal experience and expert interviews.

2.5.2.1 Just Dance

Just Dance is an example of a game which elicits dancing, players score points by doing the correct dance moves with the correct timing. This is a game you usually do with other people; this competitiveness factor is usually added to increase motivation. Just Dance can be played on the Wii with a controller, this controller tracks your movements and gives you a score providing extrinsic motivation. Conversely, this game can also be played by watching an online video of the dance. In this case, the player's movements are not recorded, which takes away some of the game elements added for motivation but does make it more accessible. Just Dance is played in front of a screen, usually indoors, which therefore also slightly limits its user's movement. The gamification of dance is a good example of a balance between movement, play and technology that seems to be successful. Soares et al [33] found that this virtual dancing game is similar in perceived exertion to real dancing. The game has some variety through the songs they include and made an extra battle mode.

2.5.2.2 Wii Fit

Wii Fit is another indoor game played using the Wii, compared to Just Dance, it is a more serious game where you play sports. It has some gamified elements but the balance between technology, play and movement is different; Wii Fit focuses on sports using technology and play as a support. The target audience for this game includes older people as well. Wii Fit provides enjoyment as a leisure activity and gets its users to participate in low to medium-intensity physical activity [34]. For this game, users need a Wii and for some games, additional accessories are needed, such as a balance board.

2.5.2.3 Interactive Playground

Interactive playgrounds are a combination of traditional play with integrated technology. The main target group is children, who usually go to playgrounds. One variation of an interactive playground is an interactive floor or wall. These variations usually use projections and have a broader target group. There are varying purposes for adding technology, such as enhancing play, exercise, or even education. The integrated technology varies between buttons to

movement sensors. A lot of examples of different types of applications with different purposes can be found. Poppe et al [35] state that an interactive playground's design should consider context awareness, personalization and adaptiveness. Letting children have a certain level of open-ended play, where they can add their own rules and stories, is beneficial for their development [12].

Figure 4: Examples of interactive playgrounds. (a) Biba smart playground [36], (b) Yalp Memo [37], and (c) an interactive floor from Actifloor [38].

2.5.2.4 Yalp Interactive

Yalp Interactive is from the company Yalp which creates interactive play installations. Their motto is to create a new way to play [37]. These are often found inside playgrounds but can also be independently situated. Yalp makes play and sports solutions for a variety of environments, including schools, resorts and cities. The company finds it important that everybody can play, for this, they make it inclusive and accessible by placing it outside. Most of the installations are location-bound but freely accessible. Furthermore, they have also created playsets for the retail sector that can be used at home.

2.5.2.5 Traditional Play and Games

With the term traditional play, I describe play and games from the past that do not use any technology, typically played by children outside. This related work includes emergent gameplay, free play or guided play in the form of traditional games. There is a recent decrease in children's outdoor play [2]. This could suggest that traditional games are not motivating enough. Tetteroo et al. [39] found that creating an interactive play environment based on traditional play resulted in high motivation of the children, who preferred this over playing video games.

Figure 5: Examples of traditional games. (a) hide and seek, (b), hopscotch, (c) tag.

2.5.2.6 Head up games

An example of merging traditional and digital games is head up games [19]. Head up games avoid play where children need to look down at screens to increase social interaction. This type of pervasive game uses technology to support interactions and motivate children. The technology is used subtly to not attract attention but still aid the gameplay.

2.5.2.8 Augmented Reality

Another type of technology used in exercise-related games is augmented reality, which is often used in exergames to provide feedback. Pokémon Go [40] is an example that uses location-based augmented reality, it makes use of pervasive sensing to stimulate gameplay and movement [41].

2.5.2.7 Picoo

The last related work discussed in this project is Picoo [42], which was recommended by the after-school care employees during an interview. They have previously rented the Picoo system and believed it had similarities to this project. Picoo has educational and movement-related goals. They use interactive playware made of a type of controller that can interact with other controllers and output sounds, lights and vibrations. During the games, multiple modalities are used at the same time because it can be easy to miss if only one modality is used. Picoo also has a built-in scanner and cards that can be used to support the gameplay. Furthermore, the controllers are connected to a radio network which some of the locations can be derived from. Chapter 2.5.3 will delve further into this related work.

2.5.2.8 Synthesis

We analysed different aspects of the related work and compared them to the project goals and characteristics. Table 2 shows a synthesis of the discussed related work and 7 elements based on previous research on characteristics set for this project; the elicited movement, environment, type of technology, accessibility to users, screen use, the expected motivation

and the versatility they offer. This table does not judge the other inventions but relates in what ways they are similar to the project and how this can be helpful during the design. The related work has different goals and priorities which results in them having different standards.

Table 2: Characteristics of related work and project goal (Legend: V = yes; / = partly; X = no)

Characteristics:	Project Goal	Just Dance	Wii fit	Interactive Playground/floor	Traditional play and games	Head up games	Augmented reality	Picoo
Movement	V	V	V	V	V	/	V	V
Outdoors	V	X	X	V	V	V	X	V
Simple technology	V (Buttons)	V (TV (+ Wii or videos))	/ (TV + Wii)	X (Complicated Technology)	/ (No Technology)	/ (technology differs)	X (VR headset)	/ (Controller)
Accessible	V (need to have the buttons)	V	X (Buy Wii)	/ (Location bound)	V	/	X	/ (Schools can rent it)
No screen use	V	X	X	V	V	V	X	V
(Expected) Motivation	V	V	/ (less of a game)	V	X (Current situation)	V	V	V
Versatility	V	/	/	/	V	V	/	V

2.5.3 Expert Interview with Employee of Picoo

To gather more insights into related work and their design process, an interview with an employee of Picoo was conducted. Picoo is one of the related works that is very similar to the product this project aims to make. Therefore, it is interesting to get to know their story and some advice for this field. The interview was conducted similarly to the expert interview

with the after-school care employees and is part of the same approval request (240132). The interview questions can be found in Appendix 2.

The interviewee was interested in how you can get children to move more using interactive technology. In Picoo's market search, they found that parents preferred their children to play without supervision. This insight led them to aim for a product that required minimal explanation. Each game has an a5 instruction sheet with mostly icons and some bullet points. They keep it short, since from their experience few children read these. Furthermore, they want their product to be as easy to use and start up as getting a ball and playing football. Another feature that aids this is a random team picker, when you start up a game the teams or taggers are chosen by the technology minimizing discussions and preparation time. Another goal was that they wanted to avoid using screens in their product, this was to increase the social aspect of playing together instead of looking down at screens. This is based on the concept of head up games [19].

A dissimilarity between this project and Picoo is the use of an adult game development team to design and create the games. They are partnered with 15-20 schools and after-school care centres, with whom they do user testing as an evaluation step. The new ideas come from the game development team or existing clients (in contact with children), none of the ideas came directly from children. The interviewee mentioned that he would be interested in designing together with the children but suspects that they already have a lot of ideas without the capacity to make all of them. Additionally, they already have around 40 games and as a company first have to spend time and resources on going a different direction, such as going internationally.

The interviewee also advised on designing for different ages. The games should be kept short and straightforward when designing for very young children that are around 4 years old. Young children often enjoy playing the same simple game multiple times in a row. The older children do want more depth in a game, for instance, the addition of a levelling system. They also commented that older children also sometimes want to add something to the game themselves. Besides these, physical and cognitive abilities also play a role and should be considered. Furthermore, the employee mentioned that the location function of the controllers has a few errors where the wrong controller can be selected as the nearest controller. However, most children do not care and see it as an unexpected feature. The employee highlighted that most of the game happens inside of the children's heads and the technology is only there to support it.

When designing a game, the development team usually starts with a theme, such as pirates, and builds on that. Often for educational purposes, they started with the gameplay and then added a theme, which typically resulted in less open-ended play.

The team of Picoo purposefully made some games that do not require a lot of physical activity. This is also linked to the physical capabilities of different age groups, this way they can reach a broader target audience. Sometimes playing in teams can also help by sharing the physical burden between team members. Inclusivity is very important to Picoo and their recent research aims to improve their inclusivity even further. Similarly, Picoo has explored balancing capabilities through technology.

In the future Picoo is considering looking to establish their company internationally. Besides renting to schools they first looked at entering the consumer market, but it would be too expensive for households to buy both technology and games. From this, it could be expected that the bee buttons can face the same problem.

2.5.4 Conclusion

To conclude the state of the art, while similar technology exists, there are still many unexplored opportunities. Different types of technology, varied contexts, clearer goals, and alternative approaches could give interesting new results that could add to current research. The co-design approach explored in this project also has the potential to reveal valuable insights in this field.

3. Methods and Techniques

As a Creative Technology graduation project, this project employed the Creative Technology Design Process [43]. This is an iterative process split up into four phases: Ideation, Specification, Realisation and Evaluation. These phases are documented in chapters 4, 5, 6 and 7, respectively. We adapted this design method to build on its strengths and structure the co-design sessions. A user-centred approach was used with a co-design where the target audience directly participated in the design process. Because of this, the Creative Technology Design Process was altered to fit the timeline and division of design between the co-design and additional development that took place. The ideation phase was relatively bigger, and the specification and realisation phases were smaller.

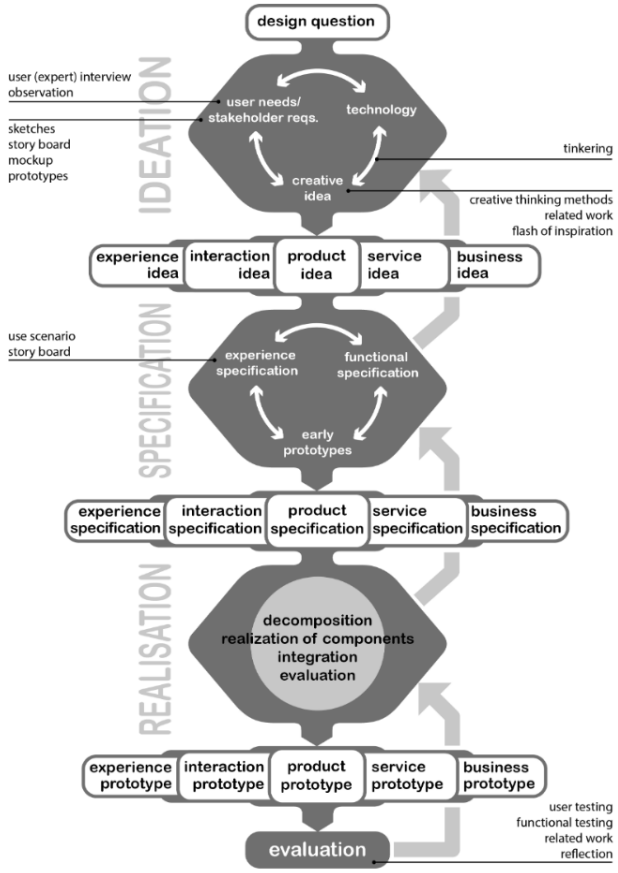

Figure 6: Creative technology design process by Mader and Eggink [43].

This project took a user-centred approach where co-design was implemented at most stages of the design process. The children assumed a variation of a protagonist role [27], becoming the main agents of the development under guidance and bound by a pre-determined structure and goals of the project. As children benefit from structure and scaffolding to focus on the design task, we divided the co-design sessions according to the four phases.

Table 3: Table showing an overview of co-design sessions per phase and the roles the target audience had in the participatory design process.

Phase	Co-Design session	Role
Ideation	Session 1: Introduction	Informant and Design Partner
	Session 2: Technology	Informant and Design Partner
	Session 3: Divergent	Design partner
	Session 4: Convergent	Design partner
Specification	Session 5: Specification	Design partner and Software engineer
Evaluation	Session 6: Evaluation	Tester

The co-design consists of 5 sessions in the ideation and specification phase, whereafter the top ideas according to the children's designer inputs were realised and then evaluated with them in the sixth session. The realisation phase was conducted without the target audience. Instead, it was done according to the previously decided upon ideas, only adding new elements when necessary.

The sessions took place once a week on Wednesday or Friday afternoons. Extra time was taken between session 5 and session 6 to allow time for the realisation of the games. The co-design took place at the after-school care centre on a big table close to the workers. The indirect supervision of the workers might allow for a safer environment for the participants. This also allowed other children at the after-school care to get a glimpse of what was happening. Each session had a different division of groups to elicit different responses and views.

In each session, design artefacts, observations, and feedback were collected. The parents were informed through an information brochure and letter and consented to their child(ren) participating in the research. This approach was approved by the ethical committee of Computer & Information Sciences (CIS) under research application number 240111.

This chapter details each phase of the design process and includes a list of the techniques used. The techniques are taken from Chapter 2.3.1, some of the techniques used are combinations of multiple techniques.

3.1 Ideation Phase

During the ideation phase, together with the children, we built a foundation of the target group's interests, introduced the project, explored the technology and generated ideas through divergent, and convergent brainstorming. The phase concluded with filtering and majority voting to assess the ideas and choose the ideas for the next specification phase.

Table 4: Table with an overview of design techniques that were used during the ideation phase [25,26,28].

Design Technique	Objective	When
Examples (+ related work)	To make design techniques and ideas more concrete and understandable.	Related work: during Co-Design session 1. Examples: every session.
Discussion	Get a lot of input on ideas and thoughts. Get multiple views.	Co-Design session 1, 2 and 4.
Drawings/sketches (+ storyboards)	Get visualisations on paper, and get creativity from drawing. Sketches can say more than words.	Every Co-Design session.
Inspiration cards	Give inspiration to build ideas, such as food, sports and superheroes.	Co-Design session 1, 2 and 3
Tinkering (prototypes)	Get to know the technology, get inspired and excited.	At the start of Co-Design sessions 2 and 3.
Mind maps and lists (word clouds)	Get an overview of a topic (in this case: what can the buttons do?)	Co-Design session 2
Working together	Share creativity and	Co-Design session 1 and 3.

	motivate each other.	
Mixing ideas	Divergent brainstorming, combines previous incomplete ideas to get novel ideas.	Co-Design session 3.
Templates/handouts	Structured idea designing. Give support to the technique to get complete ideas.	Co-Design session 3.
How-now-wow matrix variation (adapted from M3 instruction of the Creative Technology curriculum)	Filter ideas on Clarity, Feasibility, Technology, Movement and Originality	Between Co-Design sessions 3 and 4
Voting	Quick and easy way to find out preferences.	Co-Design session 4

Table

Figure 7: (a) Inspiration cards (designed by another student), (b) Mixing ideas booklets filled in during co-design based on sessions 1 and 2, and (c) Template to fill in ideas and make a complete concept.

3.1.1 Initial Ideation

Before the start of the co-design sessions, I prepared a groundwork consisting of a mind map of game elements organized according to the COM-B model, design techniques, design demonstrations to illustrate their application, and exploring the technology. I tinkered with the buttons to get an idea of what was possible and created a variation of an example game made by Max Pijnappel [44]. Finally, I established preliminary requirements aligned with goals to guide the remaining ideation phase.

3.1.2 Co-Design Session 1

The first session of the co-design served as an introduction, where participants shared basic information and their favourite activity at after-school care. It also aimed to familiarize the children with the concept of co-design and the project's goal, while gathering insights into their interests and generating a few initial ideas. This session discussed the project goal of motivating children to move more outdoors using technology, without involving the buttons. We went over relevant background information and related work to provide a foundational understanding. To aid the idea generation process, we used inspiration cards in the first two co-design sessions. These cards are from a previous project that shows things such as jobs, animals, and food. These prompts could make a base for thinking of themes and storylines.

3.1.3 Co-Design Session 2

The second session introduced the technology, and together with the children, we explored different aspects of the buttons. First, the children discussed what they wanted to do with the buttons. Then, during the exploration, they learned what the buttons could do (light, sounds, and effects) and played an example game [44]. Following this, the children designed some more games that fit the goal and the technology. In this session, they also made some drawings as storyboards and visualisations of their ideas.

3.1.4 Co-Design Session 3

In the third session, we used a mixing ideas technique to generate more games. Ideas and elements were taken from the previous session to make a little booklet for the children to create their own game. They used the booklet and their imagination together with a handout to write down the setting of the game and some rules. They did this while working alone and in pairs to first gather their ideas and then share them and add to each other's ideas.

3.1.5 Filtering Ideas

Before session 4, I used variation of the how-now-wow matrix (Appendix 3) to filter out ideas that did not fulfil the preliminary requirements made during the initial ideation. The matrix gave a score between 1-10 and ideas with a score lower than 6 were filtered out.

3.1.6 Co-Design Session 4

Session 4 served as the convergent part of ideation. We discussed the filtered ideas and then the children voted on them. The voting was done through majority voting for each game

on whether they would want to continue making this game and if they would like to play it. This session was done in one group, which allowed all participants to share their thoughts.

3.2 Specification Phase

During the specification phase, the children refined the top ideas from the ideation. Most of the specification was done in co-design session 5. I added extra details and worked out parts of the ideas outside of the co-design session to make realisation possible. Afterwards, the specifications were made into functional and non-functional requirements.

Table 5: Table with an overview of the design techniques used during Co-Design session 5 of the Specification phase [25,26,28].

Design Technique	Objective
Examples	To make design techniques more concrete and understandable.
Working together	Share creativity and motivate each other.
Flow chart	Visualise the flow of the game. Makes it easier to complete the idea.
Templates/handouts	Structured idea designing. Give support to the technique to get complete ideas.
Props/paper prototype (acting out)	Act out parts of the game to get a better understanding of it and its effect.
Scenarios	Think of scenarios of how the games can be played. Gain insight into what could happen.
Voting	Quick and easy way to find out preferences.

3.2.1 Co-Design Session 5

In this session, the children elaborated together on the top ideas using various techniques. Two groups each discussed and refined half of the top ideas selected in session 4. They were provided with a template with a title, a few characteristics and an open space to make a flow chart for each idea. The children were also provided with paper buttons to act out scenarios with.

3.3 Realisation Phase

The realisation took place between co-design session 5 and session 6 according to the ideas from the co-design sessions.

Table 6: Table with an overview of the Design Techniques used during the Realisation phase [23,45].

Design Technique	Objective
Tinkering	Tinker with the technology to get a better understanding of it and the possibilities.
Flow charts (more technical)	Visualise the flow of the game. Makes it easier to complete and code the idea.
Programming (pseudo code)	Use blocks and pseudo code to get an idea of what to program before programming.

First, I created technical flow charts as a foundation and derived pseudo-code from this. The bee buttons were programmed through Python and underwent an iterative process through tinkering and bug testing.

3.4 Evaluation

Lastly, co-design session 6 was a user evaluation. The evaluation took place at the after-school care centre with the co-design participants. The participants played the games and provided feedback through an interview. We observed their movement and interactions and gathered insights into the effects of the games concerning the project goals.

After one round of evaluation, changes were suggested through the interview, which could then be implemented in a new version of the game. One round of evaluation consisted of playing the game multiple times, with the option to directly add and test the suggestions.

The evaluation chapter also evaluates the functional and non-functional requirements made during the specification. They were evaluated based on the user evaluation and a separate evaluation of the buttons' performance. This evaluation tested their performance and whether the buttons were a suitable technology for this project.

4. Ideation

This chapter encompasses the ideation phase with an initial ideation and 4 ideation-related co-design sessions. The results of this phase are six design concepts and insights into the co-design approach.

4.1 Ideation process

The ideation phase consists of an individual ideation and an ideation together with the target group. Ten children between the ages of 6 and 9 from the after-school care participated in the co-design session. Most co-design sessions were done in two groups and the division of groups varied each session. Some participants were absent for some of the sessions. The children participated in a co-design study in which the first two sessions were for ideation and an introduction to the project. The third session involved divergent brainstorming based on the ideas from the previous sessions and the fourth session focused on convergent thinking. Each session lasted 30 to 50 minutes with a group of around 4-6 children and one adult as facilitator. Most sessions were held with two groups, allowing all present children to participate.

4.2 Initial Brainstorming

This section discusses my individual brainstorming on the buttons, design elements and design techniques. This brainstorming session was relevant in preparation for the co-design sessions to ensure relevant outcomes. Tinkering with the buttons created expertise that was used to explain and have a view of the idea’s feasibility. Background research, along with personal experience teaching at a secondary school, was used to arrange and adjust the design techniques in sessions to get the desired results.

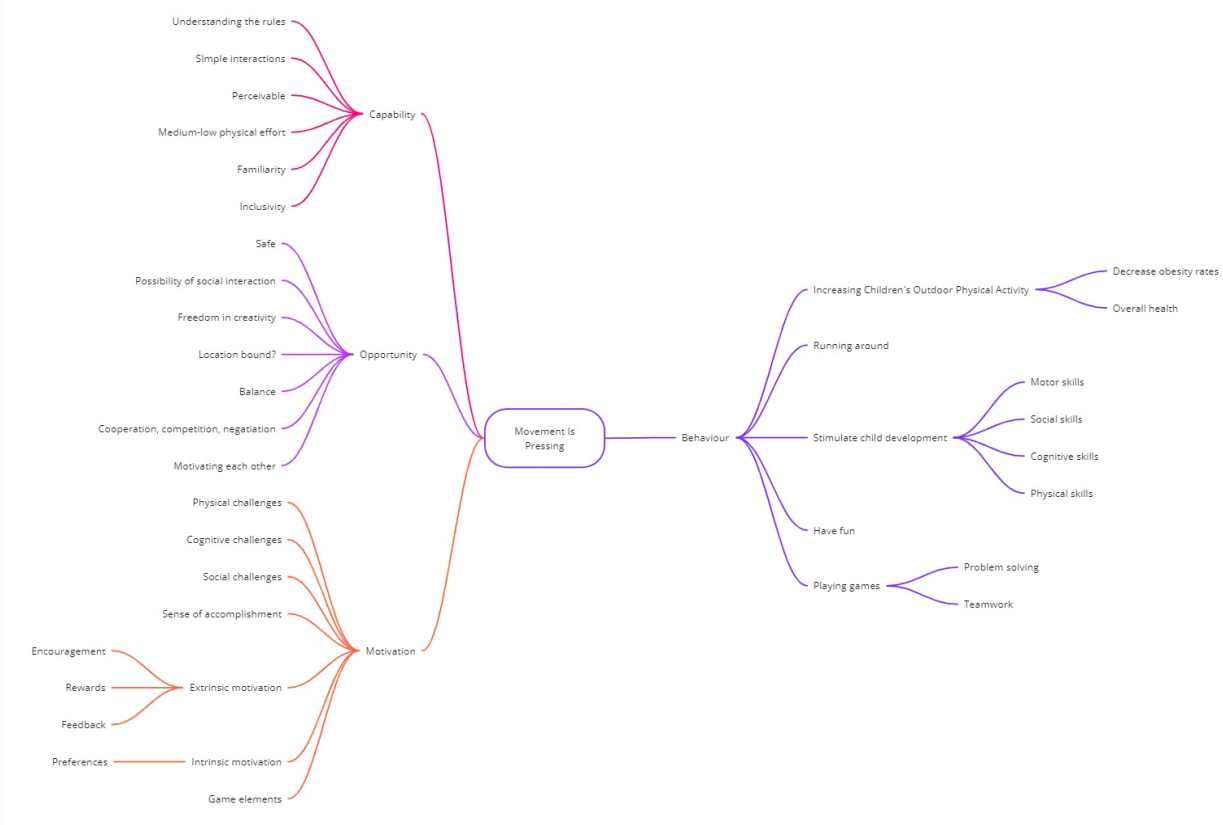

Figure 8: Mind map based on COM-B made during initial ideation.

Through tinkering, I created an overview of the button's modalities and opportunities to help steer the co-design sessions. Subsequently, the mind map (Figure 8) and tinkering results laid the groundwork for the ideas' preliminary requirements. These requirements influence the idea generation and are used to set the constraints of the project.

1. The ideas must keep the safety of the users in mind.
2. The ideas must make use of the bee buttons.
3. The ideas must include movement in the gameplay.
4. The ideas must be suitable for implementation in an outdoor setting.
5. The ideas should allow users to express their creativity.
6. The ideas should be stimulating.
7. The technology in the ideas should be used to support the gameplay.
8. The ideas should have novel elements.
9. The ideas should be designed by the target group with minimal help from adults.
10. The ideas could be based on traditional games.

4.3 Co-Design Results

In this section, the results from the co-design sessions are explored. The results are the concepts created during the brainstorming sessions as well as other points of interest relevant to the development of the games. In the following sections, we discuss some of the generated concepts, Appendix 4 shows the full list of concepts and descriptions.

4.3.1 Co-Design Session 1

The first co-design session provided introductory information on the participants and their preferences. A selection of the results will be discussed in this selection, all design artifacts can be found in Appendix 5.

The boys' favourite activities were playing football or with Legos, the girls liked drawing and playing outside. The activities described by the boys included more physical activity than the girls' activities. The participants usually played together in groups of the same gender. The initial ideas showed that the participants have interests in animals, mazes, parkour and Legos. A girl created an axolotl game and the boys designed two maze games. Conversely, one girl designed a parkour game, which falls out of line with the previously found division between interests.

Figure 9: Mind map with the 7 potential games from co-design session 1.

The children created seven ideas during this session. Discussing related work aided in explaining the project goals, which resulted in most ideas involving movement in the gameplay. Some ideas would not be feasible, this might be because the technology and constraints were not discussed. Familiar games were used as a base for some of these games, such as axolotl games, Lego building and gathering, mazes and Red Light Green Light. Furthermore, each participant thought of only one game. To stimulate more ideas and

creativity, additional design techniques and time restrictions were included in the next sessions.

Figure 10: Examples of design artefacts from session 1. (a) Favourite activity at after-school care, (b) designed zoo game, and (c) designed Legos game.

4.3.2 Co-Design Session 2

In this session, we discussed the interactive buttons. There were varying answers on what the participants wanted the buttons to do, with a lot of impossible answers, such as teleportation or candy rain. The mind maps had different feasible interactions and modalities; this was based on the exploration of the buttons. From the mind map, a preference towards animals, superpowers, rainbows and pizza can be seen. The exploration excited the participants, and they thought of some tinkering suggestions. Most ideas used the light modality of the buttons. However, a puzzle and hiding game was designed that employed the mobility of the buttons, which could allow for interesting and novel gameplay. All design artifacts of Co-design Session 2 can be found in Appendix 6.

Figure 11: Mind map with the 12 potential games from co-design session 2.

Twelve games were designed on interactions with the buttons. Simple, incomplete concepts, such as a limousine will appear if you press a red button, showed that some participants were unfamiliar with designing and found it difficult. For this reason, additional guidance should be used to create concrete ideas. Asking questions supported filling in the gaps but was not helpful for every participant or idea. With a bit of extra guidance, the children designed a game about a pizza journey, this idea seemed feasible to create.

Figure 12: Examples of design artefacts from session 2. (a) Mind map on the buttons, (b) sound word cloud, and (c) tinkering suggestion.

4.3.3 Co-Design Session 3

The main design technique in the third co-design session was mixing ideas. A mixing booklet had an overview of interactions, modalities, and game mechanics based on the ideas from sessions 1 and 2. The booklet consisted of lists of different categories that can be mixed to create a new game. The booklet can be found in Appendix 7. The template, a guideline to combine parts of ideas to make one concept, gave structure to idea generation resulting in higher feasibility and clarity. The filled-in templates and additional design artefacts can be found in Appendix 8.

Figure 13: Mind map with the 11 potential games from co-design session 3.

The children created eleven ideas using the template along with some storyboards to show visualisations of the ideas. Most sketches showed the base mechanics the gameplay was

based on. The visualisations were not feasible but supported the theme of the ideas, for example, a robot shooting lasers out of its eyes.

The participants often use their imagination and have difficulty making the games realistic. This could be seen as an advantage of the use of co-design where novel ideas are introduced that fit the preferences of the target group. These ideas provide a promising foundation for developing a new game. Some participants received more guidance during this process, which resulted in more feasible ideas. Asking questions and adult supervision proved to be helpful in the design process of children. Often, they forget to think about things or are unaware of possible actions to take.

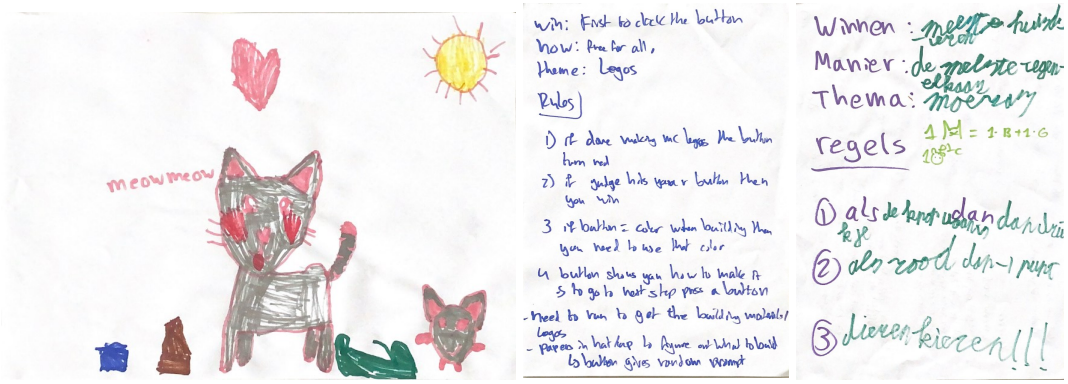

Figure 14: Examples of design artefacts from session 1. (a) Visualisation/storyboard of pet store game, (b) designed Lego game, and (c) designed swamp animal collecting game.

4.4 Top 6 ideas

After session 3, the children created 30 potential games. These can be found in Figure 15. Session 1 had 7 games, session 2 had 12 games, and session 3 had 11 games. Besides these games, the children thought of incomplete ideas and tinkering suggestions that were excluded from the mind maps.

At the end of the ideation phase, the children selected their favourite ideas to undergo further specification. As a first step of this process outside of the co-design, I filtered out partial ideas, mere suggestions, and ideas that did not reach the goals and preliminary requirements of this project. Afterwards, the children voted during co-design session 4 to select the final ideas.

Figure 15: Mind map with the total potential games from co-design sessions 1, 2 and 3.

4.4.1 How-Now-Wow matrix

This section describes the results of the first filtering process. I scored each idea between 1-10 on clarity, feasibility, use of technology, amount of movement, and originality, with the criteria derived from the preliminary requirements outlined in Section 4.2. I filtered out ideas with average scores below 6. This method eliminates misaligned ideas that are less likely to be properly aligned during specification within the project's timeline. For example, an idea that scored highly in all criteria except one could be turned into a solid idea during the specification by focusing on that aspect. Eight ideas had an overall score of 6 or higher.

Table 7: A variation of the how-now-wow matrix used to filter the generated ideas.

Idea:	Clarity	Feasibility	Buttons	Movement	Originality	(out of 10)
1	6	8	2	8	4	5.6
2	7	5	3	5	5	5
3	4	7	3	8	6	5.6
4	9	9	4	6	1	5.8
5	8	1	4	7	8	5.6
5b	8	8	8	7	8	7.8
6	4	8	6	8	6	6.4
7	5	7	3	4	4	4.6
8	3	3	4	6	7	4.6

9	1	3	4	5	5	3.6
10	3	6	5	8	6	5.6
11	1	3	5	4	4	3.4
12	6	7	3	8	5	5.8
13	5	7	4	3	4	4.6
14	6	7	7	4	7	6.2
15	7	7	7	3	4	5.6
16	6	7	6	4	1	4.8
17	4	7	5	3	9	5.6
18	7	8	4	7	7	6.6
19	5	5	5	5	7	5.4
20	6	7	4	2	7	5.2
21	8	7	6	2	6	5.8
22	1	4	5	6	2	3.6
23	8	7	7	6	7	7
24	6	7	7	6	6	6.4
25	5	3	6	6	6	5.2
26	4	6	7	6	8	6.2
27	2	2	6	4	5	3.8
28	5	7	7	7	7	6.6
29	6	4	4	4	4	4.4
30	3	6	6	7	7	5.8

Some ideas were close to an average of 6 but often had at least one aspect that they were lacking in. The originality criteria were used to boost scores of ideas that had a lot of potential but needed more thought on the other aspects. An example of this was a parkour game with Red Light Green Light elements, which scored low on clarity and technology use.

4.4.2 Voting: Co-Design Session 4

Eight ideas were taken to the fourth session, where the children voted for each idea whether they wanted to play it or not. During this session, three more ideas came up which were based on previous filtered-out or incomplete ideas. In total, the children voted on 11 ideas.

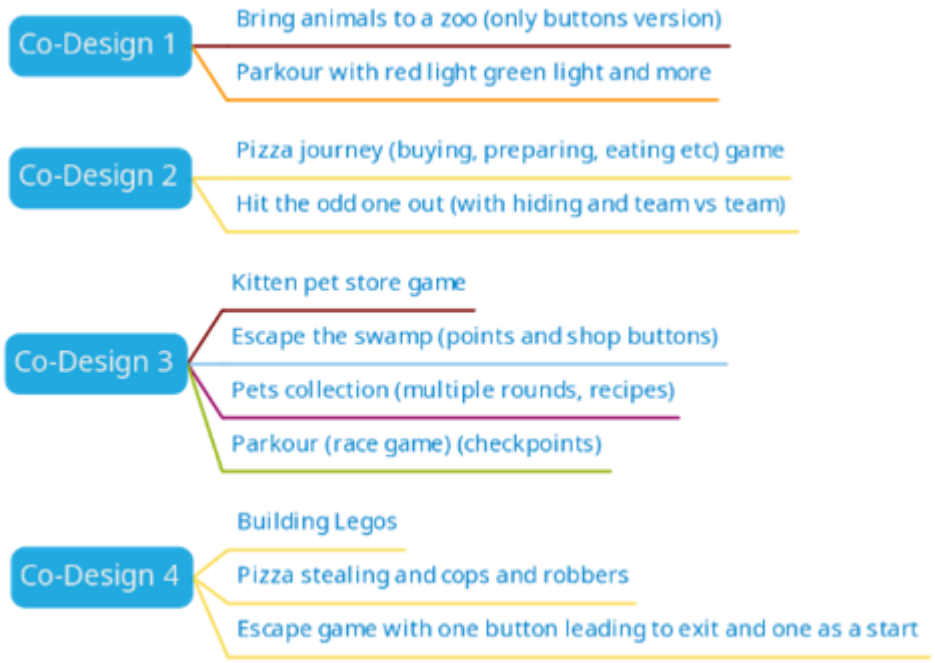

Figure 16: Overview of the 11 ideas discussed during session 4.

The three additional ideas, depicted in Figure 16, were later scored on the how-now-wow matrix variation and scored 6.2, 6.2 and 6.4, respectively. The pizza and escape games were based on games that passed the filtering, whereas the Lego idea was based on different parts that scored low on the use of buttons and movement. However, the discussed idea in this session had elements that seemed promising in these regards.

Table 8: An overview of the discussed games, number of votes and thoughts during co-design session 4.

Game	Votes	Thoughts
Bring animals to a zoo (only the buttons version)	5/8	All girls liked the game, but the boys did not. The boys would want a game with something like sports or Lego included.
Parkour with Red Light Green Light and more	0/8	It is almost the same as the Red Light Green Light game, it was not interesting enough.
Pizza journey (buying, preparing, eating etc) game	0/8	If money were part of the game or stealing it would be fun. They like stealing. Maybe also adding cops that chase you and that both teams could throw things at each other. (Thieves can throw anything, cops can throw bananas)

Hit the odd one out (with hiding and team vs team)	6/8	No specific thoughts came up during the discussion. They like the hiding element.
Kitten Pet Store game	7/8	If they could choose the type of pet and a money system is added they would want to play it.
Escape the swamp (points and shop buttons)	1/8	Escape games could be fun but not in this way. For example, you need to find the escape button or maybe there is a button that makes you stuck forever.
Pets collection (multiple rounds, recipes)	2/8	No specific thoughts came up during the discussion.
Parkour (race game) (checkpoints)	2/8	No specific thoughts came up during the discussion. Thought it was similar to Roblox.
Building Legos	8/8	Was brought up since they thought it was missed from the previous selection.
Pizza-stealing cops and robbers	8/8	Variation of the pizza journey game that came up during the discussion.
Escape game with one button leading to exit and one as a start	8/8	Variation of the swamp escape game that came up during discussion.

4.4.3 Overview of the ideas

In the end, 6 ideas had the majority of votes, 5 or more votes, and were taken to go to the specification step. The 6 ideas which will be elaborated in more detail in the next chapter are:

- Gathering at the zoo;
- Hidden odd one out;
- Pet store game;
- Building Legos;
- Pizza – cops and robbers; and
- Escape game.

5. Specification

This chapter reports on the specifications done during session 5 of the co-design, the final ideas that were realised, and their functional and non-functional requirements.

5.1 Specification per game

The specification was done in two different groups, each group elaborated on 3 ideas. Group A elaborated on ideas 3, 4 and 5. Group B elaborated on ideas 1, 2 and 6. This division aimed to prevent the original designers from specifying their ideas, thus gathering diverse input and fresh perspectives. All design artifacts of Co-design Session 5 can be found in Appendix 9. Before session 5, I investigated the ideas to come up with questions and identify gaps in the current concepts that should be addressed. During session 5, flowcharts, handouts, props and scenarios were used to visualise and act out the ideas. Explanations of the ideas before the specification can be found in Appendix 4.

5.1.1 Idea 1: Gathering at the zoo

The first idea is based on the idea of gathering animals to bring them to a zoo. This idea is a variation from a concept from session 1. The basic mechanics stayed the same, but the roles of the buttons were further specified. Buttons are spread outside prior to the start of the game. At the start of the game the players need to search around to find animals, you gather an animal by pressing on the button. Different types of animals give different points, these can be recognised through lights and sounds. To earn points, the animals need to be brought to the zoo, which is another button that can be recognized through its distinct colours.

5.1.1.1 Extension

An interesting mechanic added by the children is that the animals do not want to be captured, which mirrors real-life behaviour. After capturing an animal, the player needs to take it to the zoo within a certain time limit, or they will escape. They also discussed that animals can be sick. If this is the case the player needs to heal them, and only afterwards they can be gathered. This can provide a lot of interesting options for more complex gameplay. Some children brought up that they wanted the possibility of bringing healed animals to their owners instead of the zoo. This does not fit in this idea but might be interesting to look at. These extensions add complexity and a reflection of the real world that can engage the children.

5.1.2 Idea 2: Hidden odd one out

This game is based on a team vs team hiding game and an odd-one-out game. During the ideation, the mechanics of this idea were quite complex, with different possible odd-one-out patterns using lights, sounds and light effects. For example, three buttons could be imitating a dog, while the odd-one-out button imitates a cat. During the realization, the children of this group voiced a different opinion that they preferred a simple use of only colours to signify the button that needs to be pressed to score a point.

5.1.2.1 Reflection

Depending on the preferences of the designers two entirely different forms of the games can be made. The previous idea required more thinking, whereas this version is more straightforward where you must be fast. The specified idea increases the amount of movement in the game making it fast-paced but decreases the utilization of the buttons. Both ideas show a different balance between technology, movement and play.

5.1.3 Idea 3: Pet store game

The third idea is the pet store game, initially, this was about a kitten but during the selection process, participants voiced that they wanted to choose their pet. This is a change that allows the game to fit with more preferences. During the specification, a lot of time was spent on this selection process and the types of animals that can be chosen (Figure 17). A mechanic was designed where the animal is chosen through a puzzle, in this way the user cannot freely choose the pet they want. The puzzle is a variation of a Wheel of Fortune, where it is possible to get the desired pet at the correct time. The more often the game is played the more animals are unlocked, each animal having their colour.

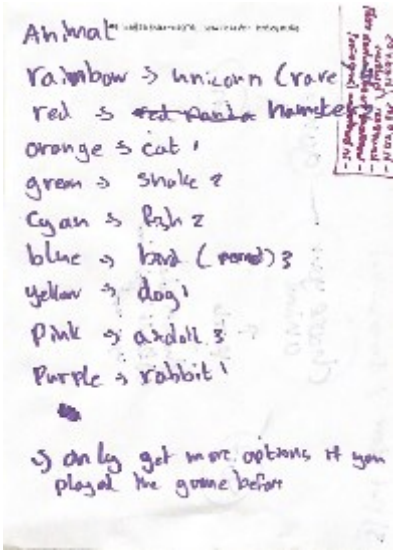

Figure 17: Picture of the design artefact showing the colour codes and animals.

After the pet selection, the main game starts. The original design included different coloured buttons to feed, rest, wash, and protect your pet. The children of this group retained these elements and added a mechanic where players carry one button to represent their pet.

5.1.3.1 Extension

Some participants also expressed their desire to mount the button on some wheels and attach a leash on it to take around outside. This would be a fun prop that can make the game more realistic. However, a downside is that this would not work in all outside environments. Rough terrains can increase the probability of the button or wheels getting damaged.

5.1.4 Idea 4: Building Legos

The Lego game only had the basic concept of using Legos as props along with the buttons. Multiple ideas were expressed on the winning condition; fastest time, number of creations, voting or a jury. In the end, the participants decided on a combination of several creations and a voting mechanism using the buttons. The game is played as a free-for-all or in multiple teams.

During the game, the buttons are used to decide what you must build and which colours to use. Similarly to idea 1, the buttons are hidden outside, and the player needs to find them. Each button has one colour or rainbow, this signifies the colour of the Legos used for building. Players can press a button to claim it, the button then instructs them what to make using sound. In every game, there is only one rainbow button, and each button can only be hit once. The next step in the game is to get the Legos and build. Each team or player needs to build 5 Lego creations fitting the instructions of the buttons. If players are done creating their assigned builds, they can make what they want. At the end of the game, voting takes place to decide the winner.

5.1.4.1 Extension

The children also came up with a possible addition to the use of the Legos. Every team or player has a box with some Legos that they receive at the start. If there are not enough Legos, players can search for them or the game ends. Furthermore, once a build was completed the used Legos could be used for another build.

5.1.4.2 Reflection

Since five builds need to be made, this game could take a relatively long time. Furthermore, the game does not require movement during the building, there is movement when searching for buttons and Legos. Compared to the other games the amount of movement is less but according to the interview with Picoo, this could provide a good balance to make it less physically taxing.

5.1.5 Idea 5: Pizza – cops and robbers

The pizza game is a variation of the traditional cops and robbers game. Two new roles are added to this traditional game: a pizza baker and a customer. This was done to create a pizza journey. During the discussion, the participants highlighted that they wanted different roles in the pizza-making process and the ability to steal. Because there are four roles, the gameplay is a bit more complex. Furthermore, there need to be four players playing the game to fulfil these roles.

Each role has its tasks to do to score points. Most tasks are completed by pressing certain buttons and interacting with the other roles. The participants were the most excited about the robber role, because of its stealing ability. The cop needs to stop the robber as well as eat doughnuts by pressing pink buttons. The pizza maker prepares pizza using dough and sauce, which they then sell to the customer. The customer earns money and uses it to buy pizzas. All participants enjoyed the concept of money.

5.1.5.1 Extension

Further suggestions are the addition of a bank, alternative ways to earn money, taking the pizzas home, a role picker and the option to buy plane tickets to get away with a stolen pizza. Out of these suggestions, the role picker and taking the pizzas home or escaping with them were added to the gameplay. The other ideas were briefly mentioned and not included in further discussion.

5.1.6 Idea 6: Escape game

Lastly, idea 6 is an escape game with a start, checkpoints and finish. The checkpoints were discussed to be based on progress and not actual distance. The escape is done through multiple rounds of puzzles. If a puzzle was completed correctly the door at the checkpoint would open and a new puzzle needed to be completed eventually leading to the exit.

During the discussion, different possible paths that could lead to the exit were discussed and acted out using props. A puzzle with a key and matching door was the only puzzle chosen during this specification. To complete this puzzle, the player first needs to find and press the yellow key, it then shows the colour of the exit and starts blinking yellow. Afterwards, the player can escape through the exit while the key is active, which is for 5 seconds. Each round, the colours, keys, and exits are changed through the technology. Before each game, the location of the buttons is changed.

5.1.6.1 Reflection

This results in a simple game that allows the players to connect their own story to it. The literature review revealed that children enjoy having creative freedom during games. Additionally, in the interview, Picoo advised that most of the game should go on in the heads of the players. This game aligns well with both insights.

5.2 Top 2 ideas

The children voted on the top two ideas within the separate groups. Group A voted on the three ideas (Ideas 3-5) they elaborated on, assigning the least votes to Idea 3 (Pet store), the middle number of votes to Idea 4 (Legos), and the most votes to Idea 5 (Pizza). Group B similarly voted on the other three ideas, they assigned the least votes to Idea 2 (odd-one-out), the middle number of votes to Idea 1 (zoo), and the most votes to Idea 6 (escape). Hence, ideas 5 and 6 were chosen as the top 2 ideas that would be realised.

Figure 18: Mind map showing the 6 specified ideas and the top two ideas are highlighted.

5.3 Requirements

This section discusses the requirements based on background research, interviews and the fourth co-design session. The requirements are divided into functional and non-functional

requirements to guide the realisation and for evaluation purposes. The requirements are listed according to 4 categories from the MoSCoW prioritisation.

5.3.1 Functional Requirements

Functional requirements are specific, measurable functions that the games perform for the product to fulfil its purpose.

5.3.1.1 Must Have

Table 9: Table with the must-have functional requirements and explanations.

Requirement	Explanation
1. The buttons must give auditory or visual feedback within 3 seconds after a correct interaction.	Feedback is needed for users to know they performed the correct action. No feedback can hinder the flow of the game.
2. The games must incorporate the sound feature of the buttons.	To fully explore how the bee buttons can be used, the sound feature of the buttons should be included in the games.
3. The games must use the LEDs of the buttons.	To fully explore how the bee buttons can be used, different colours and light effects should be included in the games.
4. The games must require players to move around for at least 6 minutes, partaking in physical activities that increase their breathing/heart rate.	If the games do not involve movement the goals of this project will not be met. Measures were based on a tenth of the Dutch guidelines on moderate-intensity activity per day [3].
5. The buttons must be operable by children aged 4 to 12.	The entire target age group must be able to perform the actions required in games and set-up.
6a. The buttons must be movable by hand up to 20 meters by children aged 4 to 12.	The entire target age group must be able to move the buttons for set-up and gameplay.
6b. The buttons must be easy to press for children aged 4 to 12 with minimal force.	The buttons must be easy to press for the children to be able to partake in the games.

5.3.1.2 Should Have

Table 10: Table with the should-have functional requirements and explanations.

Requirement	Explanation
7. The buttons should give multimodal feedback.	Using multiple modalities can help broaden the gameplay and decrease the chance of the user missing important feedback.
8. The buttons should give auditory or visual feedback within 3 seconds after an incorrect interaction.	No feedback when pressing the wrong button can cause frustration and misunderstandings.
9. The games should allow users to create and use house rules.	Customizability and flexibility can help games be more motivating and enjoyable.
10. The games should provide different gameplay in each iteration.	The games would not fulfil their purposes if they were only played once, different gameplay will increase players' motivation to play the games again.

5.3.1.3 Could Have

Table 11: Table with the could-have functional requirements and explanations.

Requirement	Explanation
11. The Pizza game could include a role-picking function.	A technological function could save time and discussion when picking roles.
12. The games could offer varying difficulty levels.	To accommodate different skill levels in the target age group, multiple difficulty levels could be added.
13. The buttons could give auditory or visual feedback within 3 seconds after an unexpected interaction.	A lack of feedback can cause frustration and a misunderstanding that the technology does not work.

5.3.1.4 Will Not Have

Table 12: Table with the will-not-have functional requirements and explanations.

Requirement	Explanation
14. The buttons will not include RFID or NFC technologies.	Due to the direction and time constraints of this project, the technology inside of the buttons will not be changed.
15. The buttons will not have location sensors.	Due to the direction and time constraints of this project, the technology inside of the buttons will not be changed.

5.3.2 Non-Functional Requirements

Non-functional requirements define the qualities that the product should have to fulfil its goals.

5.3.2.1 Must Have

Table 13: Table with the must-have non-functional requirements and explanations.

Requirement	Explanation
1. The LEDs on the buttons must be visible from a distance of up to 10 meters.	The LEDs must be bright enough to be noticed throughout the game, otherwise, parts of the gameplay can be overlooked.
2. The sound emitted from the buttons must be audible at a distance of 2 meters.	The sounds must be loud enough to be audible to at least the user who pressed the button, otherwise, parts of the gameplay and feedback can be overlooked.
3. The buttons must function in outdoor environments under dry weather conditions.	To increase outdoor physical activity, the technology must be suitable for outside use.
4. The games must be safe for children aged 4 to 12 to interact with.	It is very important to ensure the target audience’s safety.
5. The buttons must stay connected during gameplay, even when moved.	Disconnection can cause the games to malfunction or errors to show up, which

	disrupts the flow of the game.
6. The games must be understandable for children aged 4 to 12.	The entire target age group must understand the games to optimise their enjoyment.
7. The physical activities required in the games must be feasible for children aged 4 to 12.	Taxing physical activity can demotivate and exclude users.
8. The games must be enjoyable for children aged 4-12.	The games must be enjoyable to motivate the players and ensure continued play.

5.3.2.2 Should Have

Table 14: Table with the should-have non-functional requirements and explanations.

Requirement	Explanation
9. Each game should last between 5 and 30 minutes.	The games should take at least 5 minutes to have enough opportunities to move around. A round should be a maximum of 30 continuous minutes for users with different capabilities to comfortably participate.
10. The games should be adaptable to different environments.	The project goal is to play outside and not all users will have access to the same spots. The gameplay should be adaptable.
11. The games should accommodate a variety of group sizes.	Having a specific number of players that can play the game will limit the opportunities users have to play the game.
12. The sounds used in the games should be fitting.	The users should be able to recognize what the sounds represent to prevent misunderstandings.
13. Once started, the games should work without adult intervention.	It is important that the games can be played solely by the target audience. Adults should at most need to help with setting up and

	possibly supervising.

5.3.2.3 Could Have

Table 15: Table with the could-have non-functional requirements and explanations.

Requirement	Explanation
14. The games could include an A5-sized instruction manual.	A short instruction manual can make the product more complete to improve user testing.
15. There could be more than two realised games.	Different games can fit the varying preferences of the target group.
16. The games could use props to support game mechanics.	Props can be used to enhance the gameplay and excite the users.

5.3.2.4 Will Not Have

Table 16: Table with the will-not-have non-functional requirements and explanations.

Requirement	Explanation
17. There will not be more than 4 realised games.	Too many games will not fit with the time constraints.
18. The buttons will not function in all weather conditions.	Due to the direction and time constraints of this project, the technology inside of the buttons will not be changed.

6. Realisation

After getting all the input from the co-design, I realised the top two specified games. This section reports the tools and workflow used as well as the outcome of the realisations.

6.1 Tools and Workflow

The realisation consists of two games using the bee buttons. The games are programmed in Python. Tinkering was a helpful tool to get to know the buttons and different opportunities the technology has [45]. The tinkering was done with the requirements of the specialization in mind. Most of the idea was already specified, however, tinkering could be used to find creative ways to fill in the gaps. To support this process, flow charts were used. The flow charts served as the foundation for the program as well as a tool to figure out all interactions the game needs to have.

During the coding process, pseudo-code was used. Pseudo code is a piece of text that describes what certain parts of the code should look like. This was based on the different elements from the flow charts. Afterwards, the pseudo-code was turned into actual code part by part, creating the actual game. Throughout this process, functional testing was conducted to find any possible issues in the code. Through an iterative process, the coding was completed.

Lastly, the sounds were gathered from online sound libraries[46,47]. The sounds were chosen based on a few requirements, the sounds should be representative, simple, audible and cartoon or game-like. The sounds were gathered and handled according to their licence.

6.2 Game 1: Pizza game

The pizza game is realised according to the specification of idea 5 in chapter 5.1.5. The interactions are created with 4 players in mind, with each a role and task. Eight colours of the buttons were integrated into the game, as well as a total of 11 sounds. The pink colour was changed to purple for better visibility. A blinking effect was added when the pizza was stolen or bought. The sounds gave feedback after interactions and if a player won. An overview of all sounds used in this project can be found in Appendix 10. The game is played with at least four buttons, ideally, 8-10 buttons should be used to allow for simultaneous gameplay.

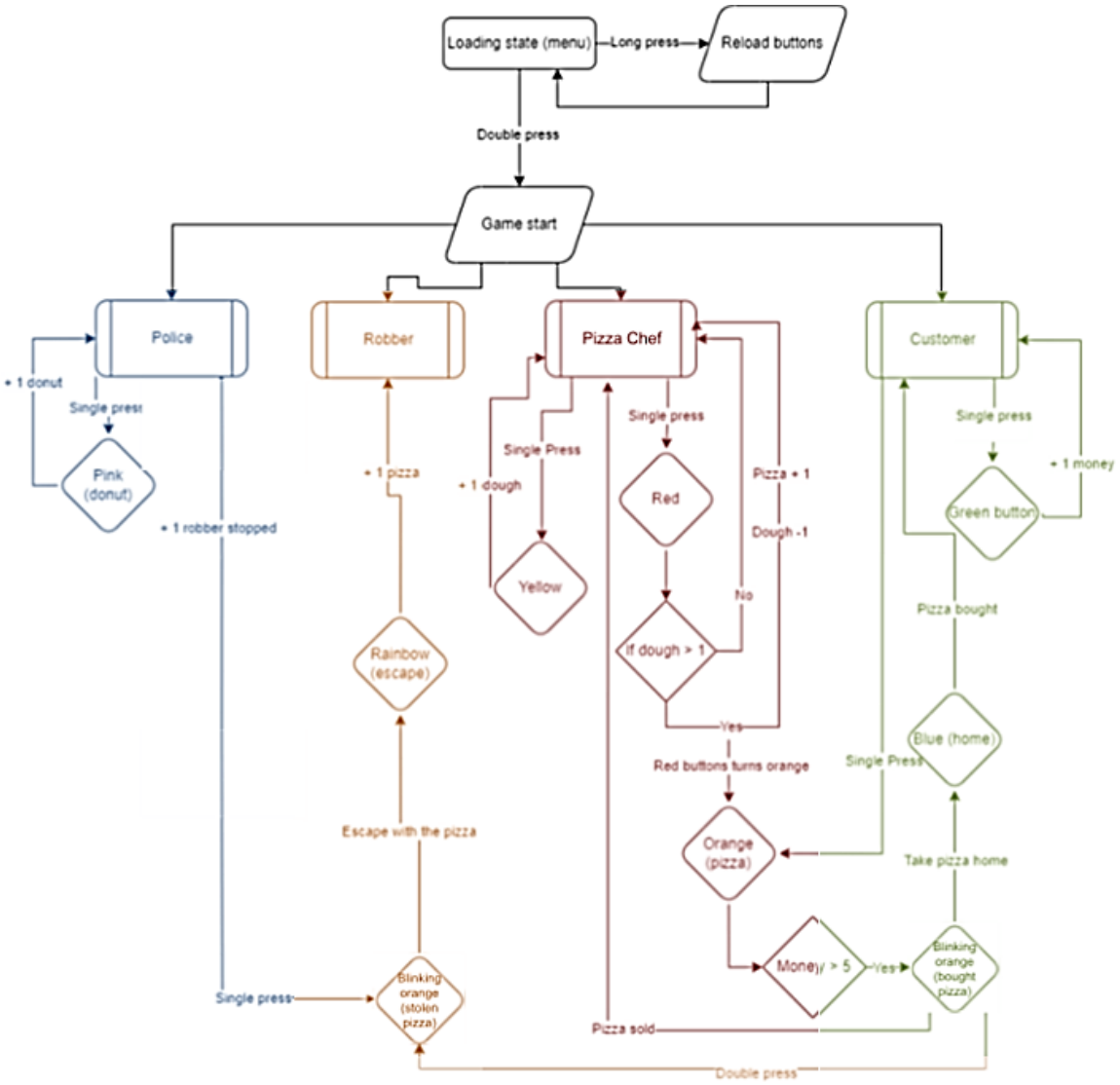

Figure 19: Flow chart showing the pizza game.

The game flow was realised using the flow chart made during the specification and was completed by adding more discussed elements. After, connections were made and variables were added to create Figure 19, which was later used as a programming foundation.

Table 17: Table showing the actions roles can take to gain points.

Role	Action	Points
Chef	Make a pizza	+ 2
	Sell pizza	+ 2
Customer	Get one money	+ 1
	Take bought pizza home	+ 5
Robber	Steal a pizza and escape	+ 5

Cop	Catch the robber	+ 5
	Eat a doughnut	+ 1

Each role scores points through their tasks and interactions with the buttons. During the realisation, the balance between roles was decided upon through iterative tinkering. The final win condition was set at 15 points, each task gave the player a few points, see Table 17. To fulfil a task, one or more actions need to be taken.

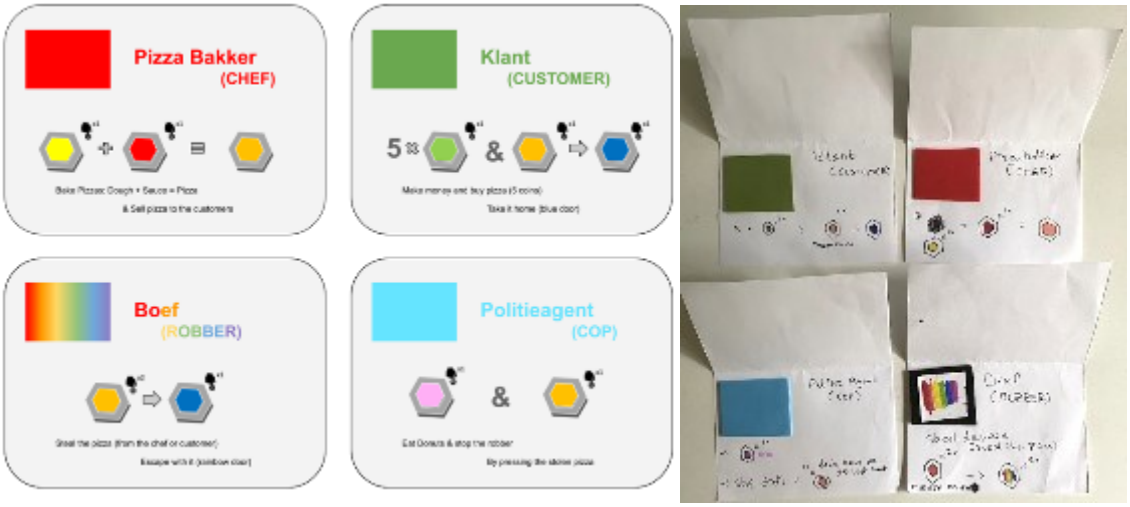

Figure 20: Role cards of the pizza game. (a) Hi-fi version, (b) Lo-fi version

During the specification, a role-picking function using the technology was discussed. The participants liked the idea of getting random roles. The flow chart showed that there are already quite a few intricate phases to this game and getting a role through a colour would be hard to memorize. Therefore, this was left out. Instead, role cards were made to serve as small instruction manuals and a role picker. These will be randomly handed out at the start of the game and provide a refresher on what each role does. These cards are used instead of an instruction manual and minimize the amount the players need to read. Figure 20 shows a lo-fi and hi-fi version of the role cards. These cards make use of bright colours representing the buttons' colours and symbols. Symbols were used to further decrease the amount of textual instruction and provide clarity.

During the specification, an addition of baking the pizza was explored. This was discussed during a co-design session on concept 14 (Appendix 4). This mechanic includes a timer sound effect where the chef needs to take the pizza out at the correct time. If the pizza was taken out too early or too late it would not be completed or result in a point reduction. In the end, this addition was not included in the final realisation because it might overcomplicate things and was not specifically decided on during the specification.

6.3 Game 2: Escape game

The second game, the escape game, is a realisation of idea 6, as discussed in 5.1.6. All colours and four sounds were used, the sound effects are described in Appendix 10. A yellow colour was used to represent the key, and the exit had a different colour each round. Four simple sounds were used to signify the key actions: obtaining a key, passing through an exit, pressing the wrong button, and escaping the game. At least three buttons are needed to play the game. The more buttons are used, the more movement is elicited, and more players can partake in seeking.

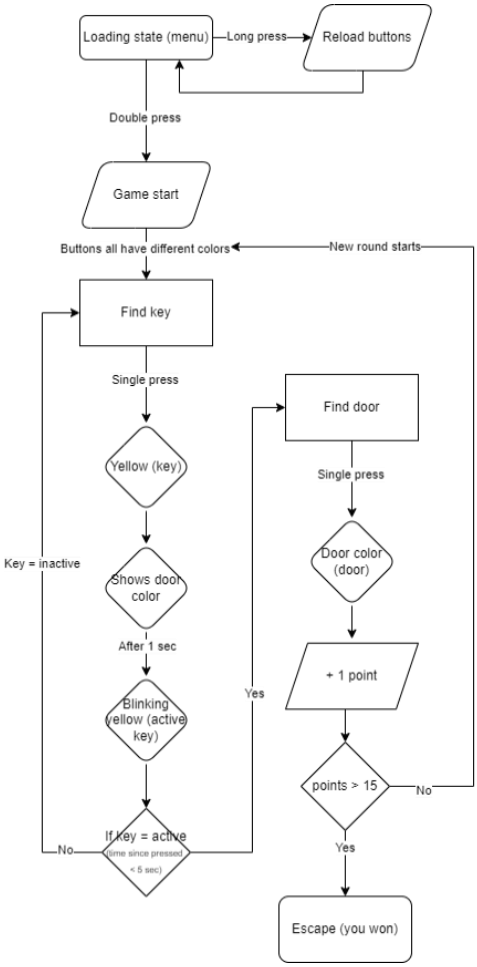

Figure 21: Flow chart showing the Escape game.

The escape game has a simpler game flow than the pizza game. Figure 21 shows the flow chart of this game. This game is played per round and has the same flow each time. The difference between each round is the colour of the buttons and the location of the key and exit. To complete a round, players must use a key to pass through an exit. The key becomes active after being pressed, first displaying the exit colour and then blinking, and remains active for 5 seconds. If the key becomes inactive, it needs to be pressed again. Once enough rounds are completed, the players escape the game and win.

7. Evaluation

After the ideation, specification, and realisation phases, this chapter entails the evaluation. A user evaluation was conducted on whether the realised games were successful, and the requirements set up in the specification chapter were assessed. Lastly, this chapter features a functional evaluation of the technology to assess the buttons in relation to the project goals and expectations.

7.1 User Evaluation

The user evaluation was the sixth session of the co-design. The evaluations were spread out over multiple sessions to get enough results. User evaluation is conducted to garner information on the amount of movement, interactions with the buttons, thoughts of the game, and the added value of the buttons. This can be used to further improve the games and suggest recommendations for future work on similar research.

7.1.1 Set-Up

Two games were evaluated and the evaluation for both games had a similar set-up. The only difference is the number of players that can play the game at the same time. Therefore, both games had the same pilot, participants, protocol, and measures.

7.1.1.1 Pilot

A simple pilot was held by the developer by running through possible situations that could occur. This was similar to the bug-testing and tinkering done during realisation but, in the pilot, it served as a check to ensure the evaluation could proceed as planned.

7.1.1.2 Participants

The evaluation was an extension of the co-design and used the same group of participants. Half of the participants elaborated on the pizza game during specification and the other half on the escape game. Therefore, some participants were familiar with the games beforehand and others only knew the concept from the ideation phase.

7.1.1.3 Protocol

The evaluation was done with children; therefore, the set-up was kept flexible. The following protocol was made, to sum up the actions taken;

1. Set up the equipment and game

2. Gather the participants in the evaluation area
3. Explain the evaluation process
    a. First play the game
    b. Then shortly answer some questions individually on what you thought of it
4. Explain the rules of the game
5. Make sure everything is understood and they can start
6. Additional game preparations (such as dividing up roles)
7. Game (play the game a few times to experience all elements of the game)
8. Thank the participants for playing and ask them to come for an interview one by one
9. Interview each participant individually
10. Thank the participants again and say goodbye

The instructions at each step differed based on the situation, participants present, and the game.

7.1.1.4 Methods and Measures

The measures taken from the user evaluation consisted of observation and individual interviews. Observations were done during the play and focused on gameplay, technology and movement. A table was used to keep track of unexpected interactions, the performance of the technology during gameplay, and the level of perceived physical activity, divided into running, walking and intermediate movement. Interviews were conducted on their experience with the game, improvements and comparisons to other or no technology. An English version of the interview questions can be found in Appendix 11.

Movement was measured using the perceived physical activity through direct observation and verified with simple questions during the interview. It is difficult for young children to accurately recall their physical activity [48]. Therefore, the interview answers were used to assess to what extent the participants felt and perceived the game as physically active. Furthermore, the use of measuring devices was not included due to working with the personal information of young participants. The layout of the buttons and gameplay elicit short, sporadic movements, resulting in children mostly moving in bursts, which is consistent with findings on typical child behaviour [48,49]. Therefore, the observation focuses on measuring the frequency of movement across three intensity levels. A scoring sheet can be found in Appendix 12.

7.1.2 Encountered problems

A problem that was encountered during the evaluation was the malfunctioning of the buttons. The pilot test was half successful due to connection issues with the technology. During the pilot, which was held a week before the first round of evaluations, the technology seemed to work sufficiently inside a room. Later tests showed that the technology seemed to show some more faulty input and output causing problems. During the first test, it took a very long time to set up the technology and after the first play, the technology started malfunctioning more. For the second test, preparations were made to test the escape game without technology. In the second round of testing the technology worked long enough to show the idea of what it would look like, after which a paper version needed to be used instead to conduct the evaluation.

During the evaluations, the buttons needed to be placed in the shade for the lights to be visible. Furthermore, to minimize the chance for the buttons to disconnect and thus disrupt the gameplay, they were spread around in a circle with around 50 centimetres between each button. In an ideal evaluation, the buttons would be spread around further apart to encourage more movement.

Another problem that was encountered was the number of participants and rounds of evaluation. In total, there were 10 participants in the co-design. Toward the end of the co-design, participants left the after-school care centre and were no longer able to participate in the remaining research. This meant there were fewer participants during the evaluations. During the first round, 4 participants were available and afterwards, there were only 2 left who could participate in the evaluation. Due to time constraints and the after-school care having fewer children, it was not possible to gather more participants to fill in.

7.1.3 Results

The results are split into two evaluation sessions. During the first session, there was one group of 4 participants evaluating the pizza game. In the second session, one participant evaluated the Escape game first, followed by a group evaluation with two participants.

7.1.3.1 The Pizza Game

The first round of evaluation was held on the Pizza game. The results are split up into observations and interview responses. Firstly, the observations are discussed on the interactions, unexpected gameplay, and level of physical activity.

As discussed in Chapter 7.1.2, the buttons malfunctioned throughout the evaluation causing the interactions to be doubled or misunderstood. After the testers pressed a correct button, the sounds were not always audible causing the users to press it multiple times. This seemed to both confuse and slightly frustrate the testers. If a button is pressed multiple times, it registers as a double press instead of a single press, which results in the game thinking a different action has been taken. This shows the importance of having feedback throughout the game. Another time, the button was pressed for a longer time, causing a long press to register. This might be due to a lack of instruction on the type of presses and the faulty technology.

Besides the unexpected errors and button inputs, some gameplay elements flowed differently than expected. Every tester took on one of the roles by getting a random card. According to the expectations, their role would have been kept a secret to allow for more intricate play. This, however, was not done. After receiving their role cards, they immediately began showing them to their friends in excitement. This was different than expected but resulted in fun discussions before the game. Moreover, this also resulted in the main part of the game itself becoming a bit more straightforward, which would fit with younger participants. Another unexpected gameplay was regarding the carrying of buttons. In the game, there is a mechanic to carry and steal pizzas. Besides the pizzas, some other buttons were carried around as well. If this were done with a lot of buttons, an unbalanced layout could be created diminishing the gameplay and movement. The buttons should be within reach for all players to be able to play out their roles. Lastly, the stealing of pizzas was more held back than expected. To steal a pizza the button needs to be pressed. Prior to the game, a safety warning was given, this might have caused the robber roles to less actively steal the pizza button in fear of hurting the other players.

The final observation was on the perceived physical activity throughout the game. The testers were not moving when pressing a button, when the buttons malfunctioned or when they were uncertain what to do. Besides these occasions, the users were mostly moving around. This was often walking or running when they had a specific target in mind. When the buttons were close to each other the speed was less, if further away the speed would increase to be there before other players are in your way. During the evaluation, the testers were quite enthusiastic and therefore ran around a lot. Each participant ran short distances at least ten times during one round of the game. The robber even seemed to be more active and showed signs of slight physical exhaustion such as taking a break after running. Finally, some more movements such as jumping and bending down were observed.

Table 18: Table showing answers from the interviews (in key phrases and translated into English) of the first round of evaluations.

Group:	A	A	A	A	A
Participant:	1 (chef)	2 (cop)	3 (customer)	4 (robber)	Synthesis
Game:	Pizza	Pizza	Pizza	Pizza	Pizza
Experience:	Fun	Fun	Fun	Pretty fun (didn't really like Robber)	Fun (1 didn't like playing lone robber)
As expected:	Yes (everything)	No, but is better	No, slight differences (would have preferred it with those differences)	It's better than what was expected	Ranged from yes (1), it's better (2) and partly less than expected (1)
Again?	Yes, often	Yes, to try out all the roles	Yes, 2-3 times a week	Yes, every day if they could	Yes, multiple times
Where?	Free at school, at home in the backyard. Inside is also possible	Outside, big space with a lot of grass. Or in the backyard.	Outside (BSO), or if there is enough space outside. Would also play at school or home	Outside (BSO)	Outside, 2 mentioned inside, some other places
With who? / Recommend	Recommend it to their best friend, who likes running.	Would not recommend it to friends from school but play with friends from BSO (they are more fun)	Play with friends from BSO, recommend to best friend	With friends from BSO (also participants (not in this group))	Ranges between everything, mostly with friends from BSO
Pros:	A lot of roles, Likes robber or chef the most, that it is outside	I don't know	Everyone has something fun to do, eg stealing/baking, eating doughnuts, buying pizza	Different characters, how the buttons were in a circle, how the pizzas could be hidden, couldn't just find a pizza → needed to be made.	A lot of roles, outside, fun tasks, spread out buttons, hiding pizza, making pizza (not find)
Cons:	Nothing	You can't choose your role	The robber can't take the pizza out of someone's hands	That there was only one robber (it feels like 1 vs 3)	Not choose the role, not easily steal, only one robber
Changes:	Nothing	Possibility to choose your role	Robber can steal by touching the person	Have 2 robbers and choose who to play with	Choose your role, steal by tag, 2 robbers, the robber also needs to do 4 jumping jacks to escape
Movement:	Moving with friends is fun, more than normal play	Not a lot of movement, some other things (?) have more movement	Moves around more than usual, you can press buttons, run and jump. Amount is good	The robber moved a lot, running away and walking around. Would even want more by spreading the buttons further apart or making yellow become orange.	More than what they normally do (3), less movement than some other activities (1)
Technology:	With paper would be less fun	Less fun without buttons, difficult to play everything	Would prefer real pizzas and doughnuts (plastic) and paper money. A combination could be nice	Don't know how to make it without buttons or other technology, maybe part is the robber surviving for 1 min. No preference as long as it works.	Buttons are better than without technology (2), would like plastic/paper elements (1), no preference as long as it works (1)

Picoo:	Buttons are more fun, especially for this game. For other games, Picoo can be more fun	Picoo is more fun because then you always have something in your hand which can interact with others. However, this game is more fun with buttons	Controller (Picoo) is more fun, but both are fun.	Prefer the buttons, they fit the game better.	More fun: Buttons (1), Picoo (2), Both (1); More fun for this game: Buttons (3), Picoo (1)
Extra:			Before the robber can escape, he should do 4 jumping jacks (since the robber is the one that needs to move less than the other roles	It was really fun	Extra movement for Robber (also added to synthesis for changes)

The interviews were conducted after the game was played with each participant individually. Table 18 presents an overview of the interview responses and a synthesis of these findings. From these findings, it could be concluded that all participants found this game to be fun. All participants liked that there were a lot of roles with each of their objectives. One tester did not fully enjoy the robber role that they had played on this topic, they suggested a change where there are two robbers instead of one. Since the robber is a role that is against all other roles, it felt like it was one player against three players. Having a team of two robbers would even it out and might make it a more fun role. The remaining gameplay for the role would stay the same. The amount of movement for the shared role would be similar to the other roles because the robber is a role that was found to have the most physical activity. Another suggestion on the role division is that one tester wants to be able to pick out their role.

When asked about whether the game fits the expectations they had when designing, one participant said it was exactly as their expectations, two claimed it to be better, and the last one mentioned that it was slightly worse than what they thought it would be like. The last person said they would prefer some changes to be added to this game. They want the robber to be able to steal from the other roles more actively. The suggested method was similar to playing tag, when the robber touches someone holding a pizza, they can steal it. This is similar to the original concept of the idea before evaluation.

In line with the observations regarding physical activity; three of the testers mentioned during the interview that they participated in more physical activity than their usual activities. One participant found that other activities had more movement. One of the participants suggested spreading the buttons further apart to increase the amount of movement as well as changing the pizza mechanic to let the chef run back and forth. Another participant also suggested that the robber needs to do four jumping jacks to complete their escape.

Lastly, the buttons were compared to having no technology and the controllers from Picoo. Overall, the participants preferred the use of buttons over no technology because they thought the game could not be properly played without them. For similar reasons, three of the participants preferred the use of buttons over Picoo. When asked for their preference for technology for games in general the answers were mixed. One participant would like to have an added element of non-technological props. They thought physical pizzas, doughnuts, and money would make the gameplay more enjoyable and wanted to play with a combination of tangible props and technology.

7.1.3.2 The Escape Game

The second round of testing was on the Escape game. This evaluation was done in two iterations, the first iteration was done with one tester and the second iteration was done with two testers and a variation of the game. This variation had some storytelling mechanics added to the gameplay. Both variations were first shown using the technology and then played with a paper version of the game. This was because of problems with the technology. Due to weather conditions, the evaluation took place inside an open, uncrowded room. First, the observations and interview responses of the first iteration are discussed, afterwards, the revised prototype and second iteration are explored.

Contrary to the first round of observations, the technology was not involved in this evaluation. Therefore, only the unexpected gameplay and level of physical activity were observed. The first key point is that this test was done inside and with coloured paper instead of buttons. This caused there to be a lot of time in between the games to reshuffle the hiding spots and colours. If the game was played by two players, one player would hide every round and the other player would search, this can also be alternated. This results in the hider walking around the entire space until all buttons are hidden. In the observations, the hider sometimes ran shortly to not let the other player wait or to quickly change two buttons. The seeker, on the other hand, walks, runs and stands around. The seeker was observed to walk when there was no time pressure, run when the target was found or they were in a hurry, and stand still when they could not find it for long. The perceived level of physical activity is higher for the seeker, but the players swapped roles making it more balanced. Compared to the Pizza game, this was less intense due to the amount of breaks between each round and during the switching of the roles. The level of physical activity can differ for both games depending on the competitiveness between the players.

Table 19: Table showing answers from the interviews (in key phrases and translated into English) of the second round of evaluations.

Group:	B (Scenarios: version 1)	C (Physical: version 2)	C (Physical: version 2	B&C
Participant:	5	5	6	Synthesis
Game:	Escape	Escape	Escape	Escape
Experience:	Fun that you need to find them, like hide and seek. Fun that you need to find both the key and door	Fun, nice that you can play with multiple people. Fun that one searches one colour and the other another colour, or both the same. Then both have a chance	Veery fun, would be very fun with buttons as well	Fun, especially hide and seek part
As expected:	Kind of, did not help with developing the game	More as expected than version 1.	Better than expected, could not quite remember designing it (or at least not in this way)	Not as expected, better (1)
Again?	Yes	Yes often (is taking a physical version home)	Yes	Yes
Where?			Would want to play it outside, with nice weather. This would also make it more difficult	Outside (inside also possible)
With who? / Recommend	Would be fun to play with friends or family, but parents would not want to run around a lot (only watch TV)	With their little sibling and parents if they want to run	Best friend of father (who often plays with)	Friends and family
Pros:	It's good that you can play alone or with others, finding the buttons is really fun	Multiple people, each have something to do (was only in version 2)	You need to find colours	Find the buttons, multiple players
Cons:	It is easy, they prefer difficult games. Wouldn't change it, but just play another game	-	Nothing	Too easy (1: version 1)
Changes:	Add a story/narrative to it, and choose a category such as animals pizza or Lego. Or about places, sound shows where you are.	-	Nothing	Add story (1: version 1) → version 2 was created accordingly
Movement:	Not now, but if she would play it yes. You need to hide the buttons, you move more with fewer people. Max 2-3 and then you move enough and not too much	You don't have to run a lot, but you do need to move a lot. If two people want to get the same key you need to be faster than the other one. Ran, bent over, jumped, walked. Nice amount of movement	Run, jump, walk. Mostly running. It was fun, more would be nice. If played outside you can move more	Not intense but a lot of movement, different types. Depends on factors. Move more with 2-3 people playing and both needing to find something
Technology:	Without technology would also be fun, but the buttons would be more fun	Buttons would also be fun, but with paper, it is easier because everyone could do it then. They are equally fun	Buttons would be more fun, the size would be better for doing it outside and other things would also be easier	Button more fun (2), paper would be easier/accessible (1)
Picoo:	Can't play with pico, you can't hide them, so this is more fun. (With NFC chips): could be fun in that way, but not more fun than the buttons	Cannot play it with Picoo	Picoo is also fun, you also hide those. Not sure which one is more fun, would be the same way as buttons	Cannot do it with Picoo (2), Picoo may be more fun (1) (used exactly the same way as buttons). Using NFC chips could be fun
Extra:	About the pizza game: would also like 2 robbers, the new cards are nice and good to use. Would also be interested in keeping your roles secret. Thinks others would agree	Prefers that there are a lot of variations. Liked the pizza game more	Fun to create different games with, would want to make more	Variety is fun. Liked the pizza game more. Like changes suggested to the pizza game

During the interview, the tester claimed that 2 or 3 players would be the ideal amount to maintain a good level of physical activity. Having more than one player adds competition to encourage each other, whereas having more than three players would minimize the distance they would have to travel to find a key or exit. Furthermore, the tester liked that the buttons

were hidden and needed to be found. The tester was not present during the specification of the game and wanted to add to it. They would prefer the game to be more difficult by adding memorization and location themes.

A variation of the game was made accordingly to be tested in the second iteration of this evaluation round. The new version of the game had five different locations with each their coloured key, the colours needed to be memorized. During the game through hints via sound, the players could find out where they are and then know which key to find. If played in multiplayer, multiple locations can be in the same round, which means that two different keys and exits need to be found to escape. This adds another sense of difficulty and a different type of competitiveness.

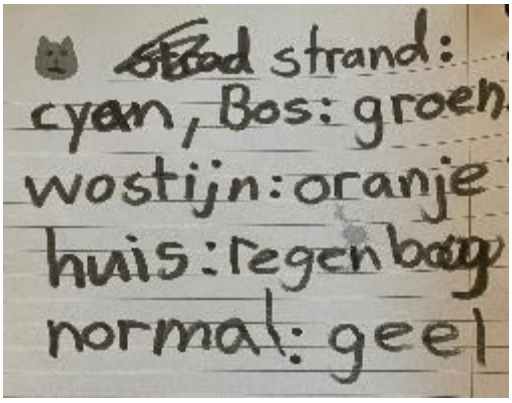

Figure 22: Design Artefact: The locations and colours used for the revision of the game.

The second iteration of the evaluation was done according to the new version of the game with the locations from Figure 22. The memorization element was used straightforwardly without buttons by saying the name of the location. It was possible to make small changes during the game because paper buttons were used. The participants were expected to work together; however, they made it a competition. Hence, the observed movement was higher with two participants seeking at the same time. There were times when they found the same key but only one player could press it to use for the exit. Therefore, the testers were inclined to run to be the first instead of working together. The perceived movement consisted mostly of running and sometimes walking or standing still after not finding their target for a while.

In Table 19, the interview responses show that the participants enjoyed the game and would want to play it again. Both participants also took a paper prototype version home to play with their families later. This version was tested without the buttons and inside but both participants stated that they think it would be fun to play with the buttons outside. Playing outside would make it easier to run and the buttons are more visible than the paper. One of

the participants found the paper to be more accessible to use and thus had no preference between the two. Afterwards, the participants were asked to envision using Picoo controllers for this game. One participant said to use the controllers in the same way the buttons would be used, but this seems to be less appropriate. The other participant did not see a way to use the controllers. After being asked about using Picoo and NFC cards, they could envision it but still prefer it with buttons. When asked about the amount of movement, both participants said they moved around a lot. However, one noted that running was not necessary, making it more accessible to a wider audience, including their parents.

7.2 Evaluation of Functional Requirements

Some requirements regarding the performance of the buttons were not met due to connectivity issues. These requirements are about the input, output, and connectivity of the buttons, Chapter 7.4 explores the functionality of the technology. This section discusses the requirements that were not (fully) met and some of them that were met. A full list of the functional requirements can be found in Chapter 5.3.1.

The must-have and should-have requirements were met, disregarding the effect the errors of the technology had. Requirement 4 (movement) was observed to be fulfilled in both games. The amount of movement was relative to the time the games were played, however, both games showed that the players were engaging in physical activities throughout the game. Requirement 9 (house rules) was also met for both games. During the evaluation, the children made suggestions that could be implemented as house rules, for example, the revision of the escape game that was also tested. Furthermore, requirement 10 (different gameplay in each iteration) was met by including multiple roles, automated randomization of the buttons' colours, and human activity, where children hide the buttons at different locations.

Contrarily, all could-have requirements were not (fully) met. Firstly, requirement 11 was to have a role picker or generator. This is a feature Picoo has but is complicated with the buttons because they are not player-bound. It might make the phases of the game too complicated for young children. Instead of this function, small role cards were used for the pizza game, partly overlapping non-functional requirements 14 (instruction manual) and 16 (props). Secondly, requirement 12 (varying difficulties) is partly met through the escape game revision. This revision offers an extra difficulty level through adding memorization. Lastly, requirement 13 (feedback after unexpected action) was purposefully not met during the realisation because providing feedback after unexpected interactions could come across

as the interactions being incorrect. This could in turn provide more confusion than leaving out the feedback.

7.3 Evaluation of Non-Functional Requirements

The non-functional requirements were evaluated using the results of the user evaluation and some findings from tinkering. A full list of non-functional requirements can be found in Chapter 5.3.2. Similarly to the functional requirements, some of the requirements on input, output, and connectivity of the buttons were not met, this is discussed in the next section.

From the must-requirements, requirement 1 (visibility of LEDs) and requirement 5 (connectivity when moving) were not met because the buttons did not function correctly. Requirement 11 (varying group sizes) of the should-category was partially met; the games can be played with different group sizes but there is a small range. The pizza game is designed for 4-5 players, whereas the escape game can be played with any group size but is recommended for 2-3 players. From the could category, requirement 14 (instruction manual) and requirement 16 (props) were met through the role cards in the pizza game. Similarly, the revision of the swamp game has a reference sheet as an instruction manual (requirement 14). The realisations did not include an actual instruction manual since it was expected that the children would not want to read them (interview with an employee of Picoo). Furthermore, no additional props (requirement 16) and extra realised games (requirement 15) were made due to time constraints.

7.4 Usability of the Buttons

This section evaluates the performance of the buttons through short tests with simple interactions. The main modalities and range of the buttons were tested in indoor and outdoor settings. Four buttons were used in this evaluation. First, the visibility and audibility were tested using simple noises and lights. Next, the registered input was tested to get an idea of the range and possible incorrect registrations. Lastly, throughout the evaluation errors and unexpected scenarios are registered to give an idea of its usability in real situations.

Figure 23: Picture of the buttons under partial shade. The top two buttons are green, and the bottom two buttons have no colour.

The buttons were designed to be usable in an outside environment, with the disclaimer that they cannot be used when it is raining. Besides not being capable of withstanding rain, this test found that the visibility of the lights could only be distinguished in full shade. The tested brightness setting was set at the maximum value. Different colours were tested in sunlight, partial shade and full shade. In sunlight, the buttons looked white as if there were no colours and in partial shade a slight difference between the colours could be seen, see Figure 23. During gameplay, this would not be visible enough when moving around and different colours must be distinguished.

The audibility of the sounds was also tested in indoor and outdoor environments. The buttons can have a volume between 1 and 21. Inside, the audible volume is from 5. This was tested in a quiet environment with the requirement that the sound should be fully heard from a 2-meter distance. Similarly, a volume level of 10 was tested to be audible outside. During gameplay, there will be more noises, such as children talking and screaming. The volume can go up to 21, with which the included audio is audible in most outside environments with children playing. However, the audio could be difficult to hear for children with hearing impairments or in very loud environments, such as those with construction noises.

The registration of inputs was measured along different ranges inside and outside. An example game was used where a sound and colour were connected to all three different types of input: short press, double press and long press. Additionally, the double press broadcasted the colour and sound, meaning that all connected buttons showed the output. The first test was with a range of 0 meters, where all buttons were at the dongle. It took a few seconds to connect and start the game. Both inside and outside, most interactions were registered correctly. An exception indicative of the difference between expected and actual

behaviour was the long press, which needs to be held for at least one second. A few times, the duration of the action of pressing the button was too short, and thus a short press was registered. In this case, feedback for an unexpected action could be beneficial.

Furthermore, there is a delay after pressing a button. The output shows usually between 1 second to 4 seconds after pressing a button. During a broadcasted instruction, the delays are more noticeable. The sound and light of the different buttons light up at different types altering the audio that is played. If text or similar audio is broadcasted, the delay might render it inaudible

The second range was tested by moving one button away from the dongle, each test was done with a 1.5-meter gap. Inside the button stayed connected at 4.5 meters but stopped responding at 6 meters. After moving the button closer again, the delayed input and output were played at the same time. The outside test had similar results. The further the button was away, the more errors could be detected.

The third range was tested by making a chain of two buttons away from the dongle. The connection was lost inside after the furthest button exceeded 6 meters when the middle button was placed at 3 meters. Another test was performed with the middle button at 4.5 meters, this time the second button could go a total of 7.5 meters away from the dongle. These tests show that the third button disconnects after exceeding 3 meters from the middle button. A chain could not be made during the outside test because one of the buttons lost connection within 20 seconds of starting. This was repeated three more times, after which the outdoor test was stopped.

Lastly, a chain using all four buttons was tested. This test was only done in an indoor setting due to repeated connectivity issues occurring during the outside evaluation. Each button was laid out 3 meters apart. The first button disconnected before all buttons were laid out, causing the test to be restarted. During the second try, the furthest button did not register any inputs. The other buttons did work. From these two tries, the buttons cannot be expected to function stably during real games.

Overall, there were quite a few connection issues during the evaluation. Some might have been due to low battery; some buttons showed a certain effect that indicated this. The first set of four buttons had percentages between 24 and 46, after which a set between 34 and 60 was used. The new set had similar problems. Furthermore, some disconnection occurred that seemed to be separate from the battery. There was no plausible reason found during the

evaluation. This happened outside more often than inside. Additionally, there seemed to be a correlation between the duration of use and the amount of connection losses. Since the outside test was conducted after the inside tests, the number of issues might have been partly influenced by the duration it was used for. The temperature of the dongle was also seen to influence its performance. There were also instances where the input was not registered at all. This could be due to poor connection or the hardware of the button.

The connectivity issues caused some buttons to be disconnected, this happened around 6 times during the evaluation. After a disconnection, the buttons needed to be reconnected by refreshing through the dongle and restarting the code. This lasted between 4 seconds to half a minute. Before this evaluation, even longer times were encountered when more buttons were used.

8. Discussion and Recommendations

This project investigates the design implications when creating a play that encourages children's outdoor activity using interactive buttons and explores a co-design approach with the target group. This chapter discusses the insights gained throughout the entire process, the background research, design phases, and testing. The insights are categorized into the approach, technology and design, aligning with the sub-research questions. At the end, recommendations for future work are discussed.

8.1 Co-Design

This project explored Co-Design with the target audience as an approach to making playware for children. This approach aimed to let the participants control most of the design. Adults guided the project by establishing constraints, planning the co-design sessions, supporting the participants, and realising the chosen ideas. In this section the third and fifth sub-research questions are discussed:

3. *"How can a co-design approach be utilised to design games for children with interactive buttons"*

5. *"To what extent can adapting children's ideas result in a viable product that stimulates outdoor movement?"*

According to the background research (Chapter 2.2), the games should fit the target group's physical and cognitive capabilities; they should be simple to understand and require low physical effort. Basing new games off traditional games can help make them easier to understand, Tetteroo et al. [39] also explored designing based on traditional games. Furthermore, Chapter 2.3 illustrated the benefit of using co-design to fit the target group's preferences, which is expected to trigger novel ideas and increase the games' motivation. The background research provided a toolbox of techniques and potential pitfalls for participatory design with children, including plentiful scaffolding, power dynamics, concrete examples, and flexibility.

8.1.1 Pitfalls

During the co-design sessions, a few pitfalls were encountered. Firstly, doing a co-design with multiple children with different genders, ages, preferences and capabilities led to diverse ideas. Sometimes also contradictions and not all co-design sessions or groups were as

productive in delivering elaborated ideas or brainstorming. Some groups or individuals had more difficulty joining the design process. Sometimes it was too difficult, or the design techniques required too much creativity or skills the participants did not have.

Secondly, the sessions should be kept relatively short and filled with activities to keep their attention span. However, it should also be flexible, because when working with children, unexpected situations often arise. A time limit should be set for ideation to allow for a higher number of ideas to be generated. In the first session, no set time was used, resulting in every participant thinking of only one idea. Nevertheless, the co-design created novel games that the children were excited to play.

Furthermore, due to the capabilities of the participants, adult guidance and intervention are needed throughout the entire design process to create feasible games. Quite a bit of steering was needed to make sure the ideas fit the goals, were clear enough and could be implemented. Adult intervention was needed to give examples of the design techniques, lead brainstorming by asking questions and during the convergent part of the ideation to filter ideas.

During the specification phase, the participants often preferred to go over things quickly. They often did not fully complete the games or execute the scenarios and already moved on to the next game. Perhaps playing versions of the game on the technology could be helpful to excite them. A lot of variations to the ideas were added during the discussion, but they sometimes collided with the current idea. Furthermore, some participants were focused on solely their version of the game and did not want to listen to other ideas. From experience, this is something that adults also find difficult and might be even harder for children.

Lastly, during the realisation phase, the completed ideas from the specification were implemented. Unfortunately, the ideas were not complete yet. Some gaps needed to be filled and some decisions needed to be made on what elements to include or exclude to create a viable game. Next to the balancing of points in the pizza game, some links were needed to connect different elements of the games. The children enjoy thinking of new ideas and additions but often fail to make a coherent story. Furthermore, to create a viable product, the filtering process during the ideation was crucial. 22 ideas were filtered out, of which 11 ideas were unclear, and 7 were not feasible. Some of these ideas could fit the children’s preferences, causing them to get majority votes. However, because they are not feasible they would not be turned into products that fit the project goals. Therefore, it is important to have adult filtering to keep the ideas on track.

8.1.2 Outcomes

The co-design resulted in 33 concepts of which the majority have the potential to be turned into actual games. Each session provided new insights and developments to the design. The stepwise approach also helped familiarize the participants with this project and the design process. The generated ideas include novel concepts that fit the children's preferences and have novel ways of using interactive buttons to stimulate outdoor physical activity. The pizza game uses intricate asymmetric gameplay based on the traditional game Cops and Robbers. This is a novel variation centred around the simple theme of pizza that excites the players with different roles and tasks and provides different gameplay in every iteration. Similarly, the zoo game uses the option of unlocking new pets to provide different gameplay in every iteration and motivate the players to play again. Furthermore, the Lego game uses Legos as props and resource gathering. Cato [50] is a concept that also uses resource-gathering, which seemed to be the most fun to play and had the best social interaction between the players. This type of resource-gathering encourages the players to interact with each other, think fast, and move around. During the last co-design session, which was the evaluation, a variation of the escape game was thought up as house rules adding a theme to the game. The background research showed that open-ended play as well as children thinking of their own stories is beneficial to their cognitive development.

Next to the generated concepts, the co-design shed light on the preferences of the children. Each session featured a different combination of participants, which also resulted in different interests and discussions among the groups. Especially boys and girls, as found in background research and interviews, were said to have different interests. This was also confirmed through the generated ideas and discussions during the co-design. Through the voting process, two ideas were chosen where the preferences overlap.

8.2 Technology

In terms of technology, this project evaluated using interactive buttons to support gameplay. Throughout the co-design, the generated ideas used the buttons in a lot of different ways. This section discusses the added value of using the bee buttons and whether this technology is suitable for this project. Additionally, the answers to sub-research questions 2 and 4 are discussed:

2. *"How to design movement-inducing games for children with the support of interactive buttons?"*

4. *“What interactions with an interactive set of buttons motivate the children to use it?”*

8.2.1 Added Value of Simple Interactive Technology

Background research and related work suggest that adding interactive technology can help motivate users. However, research, such as head up games [19], mentioned that screen use should be avoided to allow social interaction. Furthermore, parents also seemed to dislike their children playing with too much technology, the interviews with after-school care employees supported this. Using simple technology, therefore, seems to be a good solution.

Compared to Picoo [42], which also uses simple technology, this project uses buttons that are most of the time not held in the user’s hands. This allows for different types of gameplay. In both products, the technology takes on a supporting role in the game. Picoo also incorporates a haptic modality, that strengthens the feedback given to the user. This is especially useful for accessibility and noticeability, which are a potential shortcoming of the buttons on the one hand, but, on the other hand, the buttons offer more opportunities when it comes to placement. The children usually used the location of the buttons as a key mechanic to build the games around, especially for getting the players to move around. For instance, in the Lego game, the buttons are found outside and need to be gathered or in the escape game, where the players need to run around to find the buttons. In addition to this, the buttons are also moveable. This was used in for example the pizza game, where the buttons were bought or stolen or in the pet store game, where players had one button representing their pet. The buttons can be used similarly to Picoo but have their own benefits triggering novel ideas and gameplay.

The modality of the buttons that were used the most in the child-designed concepts was light. This might have been seen as the easiest and most noticeable aspect. Furthermore, the different colours, and especially the rainbow effect, excited most of the participants. In the same way, during tinkering, the participants were very excited to have the buttons ‘meow’ or ‘woof’. Sound effects added to the themes and narration of the games. An example of this is the buttons giving instructions on what needs to be built during the Lego game. Colours have a more indirect effect on the narration, where meaning is given through connotations or previously decided-upon meanings.

During the first co-design session, the type of technology in this project was not yet discussed. This resulted in ideas with many ways of using technology, some of which were not feasible, such as a maze. One participant came up with the zoo idea (Chapter 5.1.1) with

the use of augmented reality. This is like Pokémon Go [40], where the user needs to walk around with their phone or tablet to find animals/Pokémon through their camera. The other ideas were based on Picoo, lights, or mobile interfaces. The use of lights and Picoo are examples of using simple interactive technology, whereas the mazes are not feasible and the mobile interfaces decrease the social interaction [19].

During the evaluation, playing the games without the use of technology was considered and tested as well. Overall, the testers mentioned that the games would be more fun with the technology because some of the mechanics could not be executed without the buttons. A paper version of the escape game was tested, but turned out to be like a Wizard of Oz technique where the technology parts were acted out, which is like a game with role-playing and imaginative aspects. The testers liked the accessibility of the paper version because it was something they could take along easily and play more often. However, the paper version would be more difficult to play outside and made the game more slow-paced. This takes away from the aim to stimulate outdoor physical activity. All in all, it could be concluded that according to the children, the main added value of the technology is that it can support their games as they have been designed.

The buttons also have the added value of automated randomization of the gameplay (functional requirement 10). In each round of the games, for example in the escape game, the placement of the keys and doors can be changed without moving the buttons. This can save time and reduce the amount of tasks the users have. Furthermore, the interactive buttons also allow for automated scorekeeping, similar tasks, or ensuring the game rules are followed. In the pizza game, the scores for all four roles are kept track of, this would be difficult to do for the children, especially because each action has different points. Furthermore, in the games designed by the children, the buttons are also used for keeping track of time (pizza baking/parkour/race games), giving instructions (Lego/football/maze games), voting (guess who/Lego games), tracking lives (pet store game), and managing the economy (escape the swamp/pizza games).

8.2.2 Suitability of the Bee Buttons

The bee buttons had quite a few constraints that interfered with the project goals. One of the main aims is to use the buttons outside, this is not possible under all weather conditions. The buttons cannot be used when raining, however, it is unlikely that children would want to play outside under those conditions. Furthermore, the buttons cannot be used under all dry weather conditions either. This does pose some problems with the number of opportunities to

play the games and indirectly the motivation. The buttons are not visible in sunlight or partial shade; complete shade, for example, in a forested environment or adding a small parasol structure, is needed. In the backyard of the after-school care centre, there was a small space with a lot of trees, allowing the buttons to be properly utilized. However, a similar environment is likely not available for all potential users.

During the evaluation, the possibility of using a different technology, the controllers from Picoo, was discussed with the testers. There was no clear preference for either the buttons of this project or the controllers from Picoo. However, the testers stated that they wanted a technology the game could be played with. For some of the created games, the children thought they could not be fully transformed into a version using controllers.

To summarize, the current version of the technology has errors, connectivity issues, long setup time, and reduced visibility in daylight, which hampers the games from being played properly and achieving their goals. Therefore, these bee buttons do not seem to be suitable for the project. However, if these aspects were improved upon, the buttons would be a desirable technology to support the realised games.

8.3 Designing for Movement-Inducing Play

This section discusses insights gained through background research, the designed concepts and evaluation results on designing for play that encourages physical activity. This subchapter relates to sub-research question 1:

1. *“What design elements can increase children’s motivation for outdoor physical activity?”*

The COM-B model can be used to change behaviour, Chapter 2.2 features an overview of heuristics to get children to partake in physical activity using interactive technology based on this model. According to the background research, the environment and game settings should allow for opportunities for physical activity, free play, and social interaction. The games should have enough rules to encourage movement but should be open enough to allow the children to express their creativity and explore, which was suggested to improve their motivation. Furthermore, different types of social interaction can be used as motivation, the employees from the after-school care centre believed that competition was especially motivating for the target group. Additionally, challenges, varieties in gameplay, and smart use of game mechanics can motivate the players to move around.

Most potential games were made in a manner that required physical activity to play them. The technology allows for a variety of ways to implement forms of exercise. One straightforward example is needing to consecutively press buttons that are far away from each other. Depending on the different factors in the gameplay, including competition, teamwork, and time limits, they would either walk, run or jump, which overlap with activities the target group often partake in. During the co-design, the children also showed interest in using exercises as punishments or required actions to achieve a task. For example, doing three jumping jacks to escape as a robber in the pizza game or gathering buttons spread out outside for the Lego game. Additionally, in the Lego game, the buttons give instructions on what to build, the players need to gather Lego bricks to create their instructed creation to achieve a task.

Compared to different technology, the buttons had different ways to illicit movement. For instance, Picoo's controllers are player-bound, which allows for gameplay such as a game of tag to be designed. In contrast, the buttons are laid on the ground, which can easily be used to let the players move or run distances to press them. This in and of itself elicits movement from the users.

8.4 Limitations

This section discusses the evident limitations of this project. Firstly, in this explorative study, there was a limit to the diversity of the participants which causes certain minorities to be less represented in this research. A longer study with more diverse participants, including children with disabilities, would be preferred to get a complete result, however, this is not feasible for the time and materials of this graduation project. Secondly, the design process was executed together with children from after-school care. There were times when children did not show up, there was a vacation or other circumstances at the after-school care centre causing the co-design sessions to be interrupted and there to be a small number of participants left during the evaluation process. The evaluation gives useful insights but slightly lacks credibility due to the small test group, this should be taken into consideration. Furthermore, during the evaluation, it was not possible to measure physical activity using sensors within the scope of this project due to concerns about handling personal information. Functional requirement 4 states that the games must require players to move around for at least 6 minutes, partaking in physical activities that increase their breathing/heart rate. However, since the children's breathing and heart rate could not be measured, the movement level was estimated based on the perceived physical activity.

8.5 Future Work

Throughout this thesis, opportunities for future work were encountered. There were quite a few directions that would have been interesting to explore but were not possible due to the constraints of this thesis. This project found that simple interactive technology could be useful but only tested the buttons. Therefore, it would be interesting to use a similar approach with a different technology. This would lead to entirely different ideas and possible gameplay.

Similarly, it would be valuable to hold the co-design with a different group of participants. Even within this small group, a lot of different, and sometimes conflicting, preferences could be seen. It would be valuable to also look at different age groups. This project aimed to design for ages 4 to 12 but the participants ranged between 6 and 9. Furthermore, the two 6-year-olds had difficulty following the co-design and thus contributed less to the ideas, so it might be interesting to focus more on the kind of games they would make. It would be interesting to explore how to scaffold participatory design to both also more prominently activate these younger children while also keeping the input of older children.

Due to constraints, this project did not focus on the accessibility of the games. There are a lot of children that have for example visual or mobility-related impairments. Therefore, it would be interesting how these buttons, or other technologies, can be made accessible. Picoo has also researched this, but it could be interesting to use a co-design approach similar to this project.

Lastly, this project investigates how co-design can be used to create these games. A research opportunity would be to have two different design teams, one adult team and one child team, and then compare the outcomes during an evaluation.

9. Conclusion

The aim of this Bachelor Thesis was to find an answer to the following research question:

“How can interactive buttons effectively be designed to entice children between the ages of 4-12 to move around more outdoors?”

This question was investigated through a participatory approach with the target group. This approach was chosen to provide insights into the advantages of including children in the design process. Background research suggested that this approach would be beneficial in designing games that fit the target audience’s preferences as well as their capabilities. Through multiple co-design sessions, the children created 33 ideas, from which 22 filtered-out ideas, 5 potential games that were voted out, 6 full-fledged ideas, and ultimately, two games implemented using interactive buttons. Despite a limited evaluation, due to the holiday period only six players participated, and the technology regularly malfunctioned meaning one game was tested through Wizard of Oz, during these tests, the games were found to already effectively motivate the involved children and stimulate the players to move around outdoors, mainly walking and running.

In the 33 ideas, the children showed novel ways to use the technology, gameplay or encourage movement. For instance, a multi-role economy-based game extending cops and robbers with pizza bakers and customer roles, a Lego game with resource gathering and instructions, and even a pet store game addressing variation through a mechanic that unlocks new animals each play-through. All games were designed to fit their creator’s preferences and were thus motivating for them to use. The testers gave positive answers on wanting to play the two realised games often. They also stated that the games elicited moderately intense physical activity, which aligned with the observations of them playing.

This project identified pitfalls and benefits of using co-design with children, evaluated the added value of interactive buttons according to the target group and how the bee buttons can be used for this project. Additionally, we explored and supplemented strategies to stimulate movement. These findings inform the design of movement-based games for children using interactive buttons and the benefits of a participatory approach.

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Appendix

Appendix 1 – Interview Questions After-School Care Centre

The interview was held in Dutch, below the approach and questions in Dutch can be found.

De interview vragen zitten opgesplitst in een paar thema's; Algemeen, Beleid BSO, Ervaring en Eigen mening. Deze thema's zijn om een beter beeld te krijgen van de omgeving waarin de co-design zal plaatsvinden, over de target group en andere dingen die van belang kunnen zijn bij mijn GP-onderwerp. De thema's worden niet specifiek uitgelegd, maar gebruikt om duidelijkheid voor mij te maken en ervoor te zorgen dat ik deze vlakken benader.

De werkers die ik ga interviewen hebben vooraf al een kleine verbale introductie gehad over het project en krijgen een informatiebrief en consent form waar aanvullende informatie op staat voor het interview.

Algemeen:

1. Wat voor werk doet u?
    1. Voor hoe lang heeft u dit al gedaan?
    2. Met welke leeftijden kinderen werkt u? (eventueel doorvragen)
    3. Voor hoe lang bent u met de kinderen bezig op een dag?
2. Wat voor activiteiten doen jullie normaal gesproken?
    1. Hoe ziet een dag / dagdeel op de BSO er uit?
    2. Hoe veel van deze activiteiten zijn binnen of buiten?
    3. Hoe veel van deze activiteiten gebruiken fysieke inspanningen?
    4. Hoe vaak zijn de kinderen met technologie bezig? (spelletjes etc)
    5. Hoe verschilt dit per seizoen?
    6. Hoe spelen kinderen samen tijdens deze activiteiten? En heeft dit een effect op de voorgaande vragen?

Beleid BSO:

1. Wat voor beleid volgen jullie over de activiteiten?
    1. Hebben jullie een streven naar een balans tussen verschillende soorten activiteiten? (creatief, knutselen, buiten, relaxen, spelletjes, etc)
        1. Wat is dit balans?
    2. In hoeverre hebben de kinderen de vrijheid om zelf de dag in te delen?

2. Wat doen jullie als BSO met bewegen?
    1. Wat doet u om bewegen aan te moedigen?
    2. Wat zijn dingen die u doet om bewegen te ontmoedigen? (waarom/wanneer?)
3. In hoeverre speelt de omgeving van de BSO een rol bij het bewegen?

Ervaring:

1. Uit uw ervaring: wat vinden kinderen leuk om binnen te doen?
2. Wat vinden kinderen leuk om buiten te doen?
3. Wat is over het algemeen de voorkeur voor binnen of buiten zijn van de kinderen?
    1. Is dit verandert in de loop van tijd?
    2. Zit hier een verschil in per leeftijd of kind / groep?
4. Wat doen kinderen wanneer ze zelf vrije tijd hebben? (binnen / buiten de bso)
    1. (voor buiten BSO, waar baseren ze het antwoord op?)
5. Waarom denkt u dat kinderen steeds minder vaak buiten spelen?
6. Wat zijn leuke of succesvolle activiteiten geweest die de kinderen lieten bewegen?
7. Wat zijn uitdagingen die u heeft meegemaakt bij het aanmoedigen van bewegen?

Eigen mening:

1. Hoe ziet u het belang van bewegen in relatie met de ontwikkeling van kinderen?
2. Hoe ziet u de rol van een BSO-medewerker met betrekking tot het stimuleren van beweging bij kinderen?
3. Wat zouden ouders kunnen doen om het bewegen van de kinderen aan te moedigen?
4. Wat zou u willen dat ouders / BSOs / etc zouden doen om kinderen meer te motiveren buiten te spelen?
    1. Wat voor motivatie zou kunnen werken?

Appendix 2 – Interview Questions Employee of Picoo

These are the Dutch questions used during the interview, the interview was done together with another student with a similar project. Some of the questions were guided towards their project and are less relevant to this project.

- Algemene introductie
- Hoe is het begonnen?
    - Hoe is het getest?
    - Is het samen met de kinderen gemaakt?
        - Tips en tricks
        - Wat heeft het meest geholpen in de ontwikkeling van Picoo?
        - (Co-design)
    - Hoe anders is het nu vergeleken met het begin?
        - wat is er veranderd? en waarom? (in welk deel van het proces)
- Wat is het verschil tussen een speeltuintje, de BSO, en de schoolomgeving?
    - Zouden jullie willen uitbreiden naar andere plekken?
    - Wat is jullie zicht op de toegankelijkheid van Picoo?
- Hoe kiezen jullie de spellen uit?
    - co-design, based on traditional play, etc
- Focussen jullie ook wel op oudere kinderen? 8-12? En zien jullie hierin veel verschil?
    - Hoe zorg je dat kinderen van verschillende leeftijden goed samen kunnen spelen?
- Hoe bevorderen jullie autonomie?
    - hoe zorg je dat er weinig instructies nodig zijn?
- Beweging
    - Wat hebben jullie ondernomen om beweging te bevorderen in Picoo?
    - Wat zijn de gevonden effecten van Picoo op de kinderen?
        - Beweging
        - Maar ook motivatie voor buitenspelen over binnenspelen
    - Hebben jullie ook eerder gekeken naar beweging stimuleren van ouderen?
- Technologie
    - Hoe heeft jullie technologie geholpen in de doelen van Picoo?
        - Meer beweging
        - Inclusive play
        - Geen schermen
        - Motivatie

        - Welke modaliteiten hadden de grootste effecten op de kinderen?
            - Zit daar verschil in per leeftijd?’
- Hoeveel vrijheid is er om zelf spellen aan te passen of eigen regels te bedenken?
- Toekomst:
    - Welke mogelijkheden zie je in dit onderzoeksgebied?
    - Wat zijn elementen die nog missen of verbeterd zouden kunnen worden in Picoo?
    - Wat zijn dingen die je had willen doen maar niet gelukt waren?
        - Bijvoorbeeld iets wat je zou willen toevoegen maar niet in de context van Picoo past
    - Wat zijn volgende stappen / uitbreidingen / richtingen die jullie interessant vinden?
    - Zijn er nog tips die je hebt voor ons die een soortgelijke richting opgaan?

Appendix 3 – How-Now-Wow Matrix Variation

A variation of the How-Now-Wow Matrix (as shown above) that uses scores and more than two characteristics. The characteristics are Clarity, Feasibility, Buttons, Movement and Originality. The variation was used in Excel where each characteristic was given a score between 0 and 10. The Wow ideas overlap with the outcomes that scored high on all aspects. In the end, the chosen ideas are the ideas with an average score of 6 or higher. These scores are found to have enough potential to score become Wow ideas after specification.

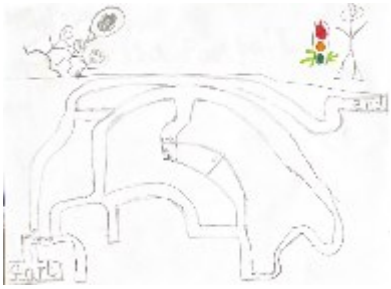
Idea:	**Clarity**	**Feasibility**	**Buttons**	**Movement**	**Originality**	**(out of 10)**
#	7-10	7-10	2-4	5-6	0-1	Avg()

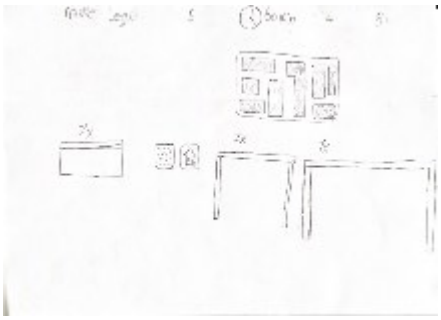
(The above numbers show which colour represents which scores.)

Appendix 4 – Generated Concepts

(Design artefacts are added when it can aid in the description with visuals. A complete overview of the design artifacts of these ideas can be found in Appendix 5, 6, and 8.)

#	Title	Description
Session 1		
1	Cat and Mouse and Dog	Variation of cat and mouse where you play a type of tag but there is also a dog role. It was inspired by Picoo. 
2	Axolotl minigames	A game where you take care of an axolotl, it is played on an tablet. You can also play a variety of minigames (not specified). 
3	Maze	A maze where there are different paths you go through, buttons can be pressed to open new pathways and puzzles can be done in the maze. At the end there is a boss battle. 

4	Red Light Green Light	A version of Red Light Green Light where you dance and there is a maze for which you need to press a button to open a wall. 
5a	Bring animals to a zoo (+ AR)	An AR game where you can fine animals through your phone camera, which you then need to collect and bring to the zoo. You win when you brought 10 animals to the zoo.  Variation: you can choose where you want to be, for example on the moon.
5b	Bring animals to a zoo (only buttons version)	Variation made based on concept 5 with the buttons as technology (outside of co-design). Buttons are spread around, through sound you can hear what type of animal there is. Press the button to collect the animal and then bring it to a zoo (use colours for this).
6	Parkour with Red Light Green Light and more	There is a parkour outside, you need to step on things, jump and more. However, there is also a Red Light Green Light element, that you cannot always move,

		and if you move when there is a red light you need to start again.
7	Lego building and gathering	There is a table with Lego bricks and on the other side a table where you can build. You need to gather the Lego bricks and bring them to your table to build something. 
Session 2		
8	Red panda game	Unclear. If you press on a red button you will see a panda. The panda can shoot lasers from its eyes and you do not want to get hit by it. You lose a heart if you get hit 
9	Bird and cat game	Unclear, similar to cops and robbers where there is a game with birds and cats.
10	A game of knackwurst tag	A variation of “knakworst tikkertje”: there are taggers, if you get tagged you freeze with your arms up. Other players (not yet

		tagged) can put one of your arms down and say “KNAK”, if both your arms are down you are back in the game. If you press a blue button you get the ability to fly.
11	Limousine game	If you press the red button a limousine appears. If you press another button you can find out how to make one.
12	Football game	If you press on a button it will say something you have to do (football related), for example take a penalty.
13	Pizza eating game	The buttons are pizzas and pizza slices. The goal is to eat pizza, you do this by pressing on the correct buttons. (A lama and red panda are eating the pizza together)
14	Pizza journey (buying, preparing, eating etc) game	In this game the buttons are pizzas and appliances. You will go through different stages of making pizza. You will buy them, prepare it (bake in the oven and take out at the correct time) and then eat it. Other variations and steps can be added such as selling and delivering the pizza.
15	Hit the green snake button	The buttons light up similar to a moving snake. There can be different coloured snakes and you need to hit the green snake.
16	Wack a mole	The buttons represent the holes and depending on how it lights up you need to hit it and score points.
17	Guess who had the green button (hiding	Everyone gets a button and the button

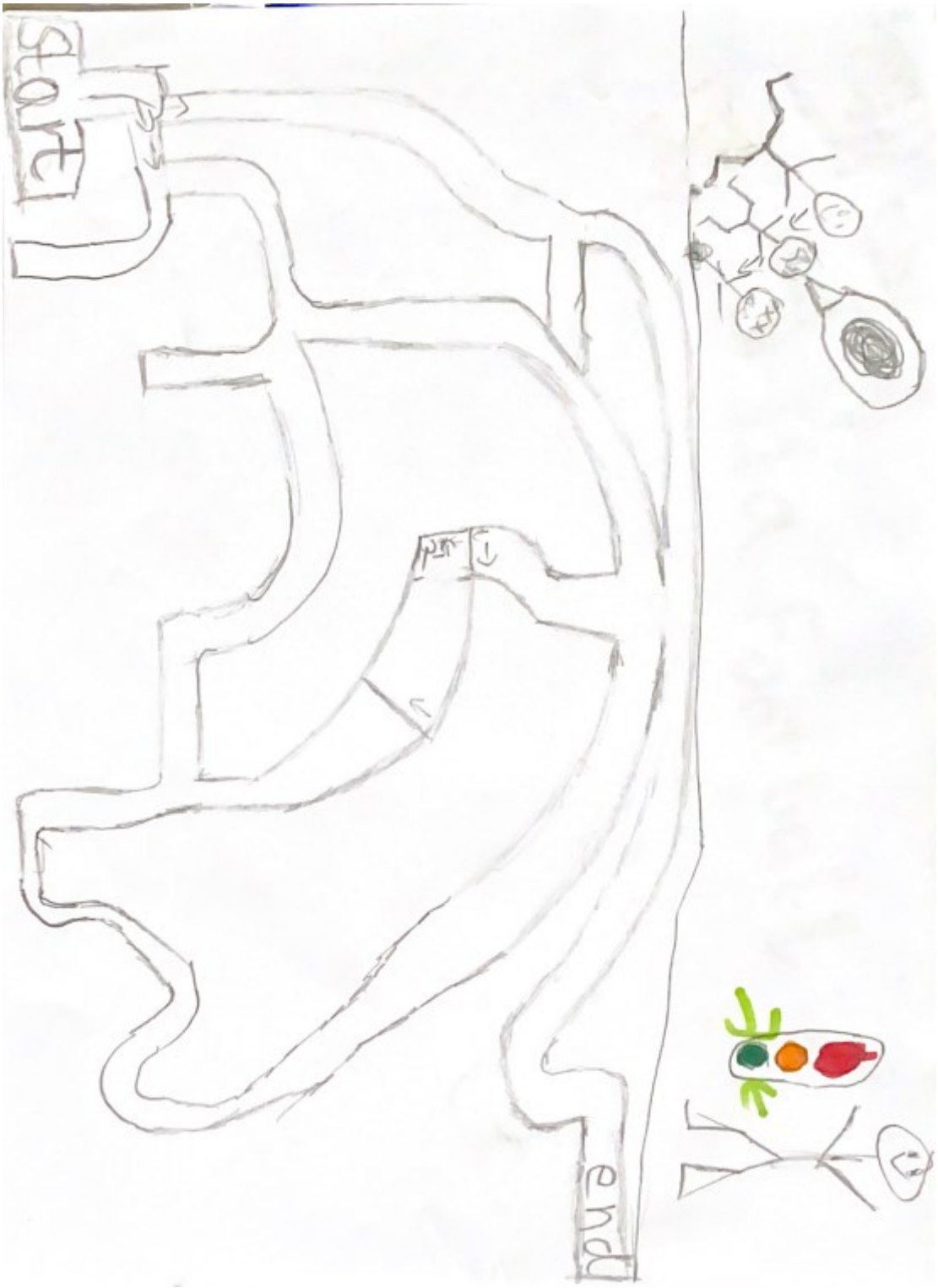
	+ Voting)	lights up in red or green. Only you know which colour you had. At the end you vote to guess who had the green button.
18	Hit the odd one out (with hiding and team vs team)	Two teams play this, you hide the buttons of the other team outside. Once all buttons are hidden a version of hit the odd one out will start. The team's buttons can be recognized by the casing's colour. The odd ones out can be found through the colour it lights up. Addition: sound can also be used for odd one out.
19	Puzzle (buttons are puzzle pieces)	You need to make a puzzle using the buttons. You need to find the buttons and put them in the correct order to make an image or pattern. The buttons give feedback when they are correctly placed or not.
Session 3		
20	Listening and repeating game	The buttons can make sounds are say words/sentences, you have to find the button and correctly repeat what it said.
21	Fast rainbow press (everyone has a button)	Variation of the game used during tinkering: everyone has their own button that can show purple or rainbow.
22	Red panda - Red Light Green Light variation	Variation of Red Light Green Light from squid game. A red panda tells you when to move or stand still, if it catches you moving when you cannot you will get shot by their laser eyes and lose.

		
23	Kitten pet store game	You are at a pet store and 
24	Escape the swamp (points and shop buttons)	You need to escape from the swamp. Two types of buttons (differentiated by the casings), one type are for points and the other is a shop. You need to get points and buy things at the shop to be able to escape the swamp.
25	Escape the maze (with puzzles in between)	You need to escape a maze. During the maze you need to open doors and solve puzzles with the buttons.
26	Pets collection (multiple rounds, recipes)	In this game you collect different types of pets.
27	Make all buttons green (etc, unclear)	The goal is to make all of the buttons green, you do this by pressing buttons.
28	Parkour (race game) (checkpoints)	There is a parkour, you hit the start button and a timer goes, you need to follow the parkour and hit the checkpoint buttons on you way. When you hit the final button your time stops. Pressing the blue button brings you to the second level.
29	Building Legos competition/game	There is a big box of Legos, the button

		tells you which colour you can use through light and what you need to make through sound. This is a competition which ends through voting or a jury.
30	Control the other player (parkour/maze)	You can control another player by using buttons, there is a button for forward, right, left, backwards and jump. Using these buttons you navigate the other player through a parkour or maze.
Session 4		
31	Building Legos	Combination of the previously mentioned Lego games. You need to gather Legos and build them. The buttons give instructions and what and how.
32	Pizza stealing and cops and robbers	A version of cops and robbers and variation of the pizza journey game. There are different roles in the pizza making process and you have the ability to steal the pizza.
33	Escape game with one button leading to exit and one as a start	A variation to the other escape games, but instead there is one button that leads to the exit that you need to find and one that is the start.

Asides from these concepts there were also requests for tinkering. These were mostly variations of the first example game [44]. That game had multiple buttons where one was yellow, and all others were purple. You need to press the yellow button and then it will move to another button, you do this for multiple rounds and then win. If you press correctly, you hear a “ting” and if pressed wrongly a “Beep”. If you win, music is played.

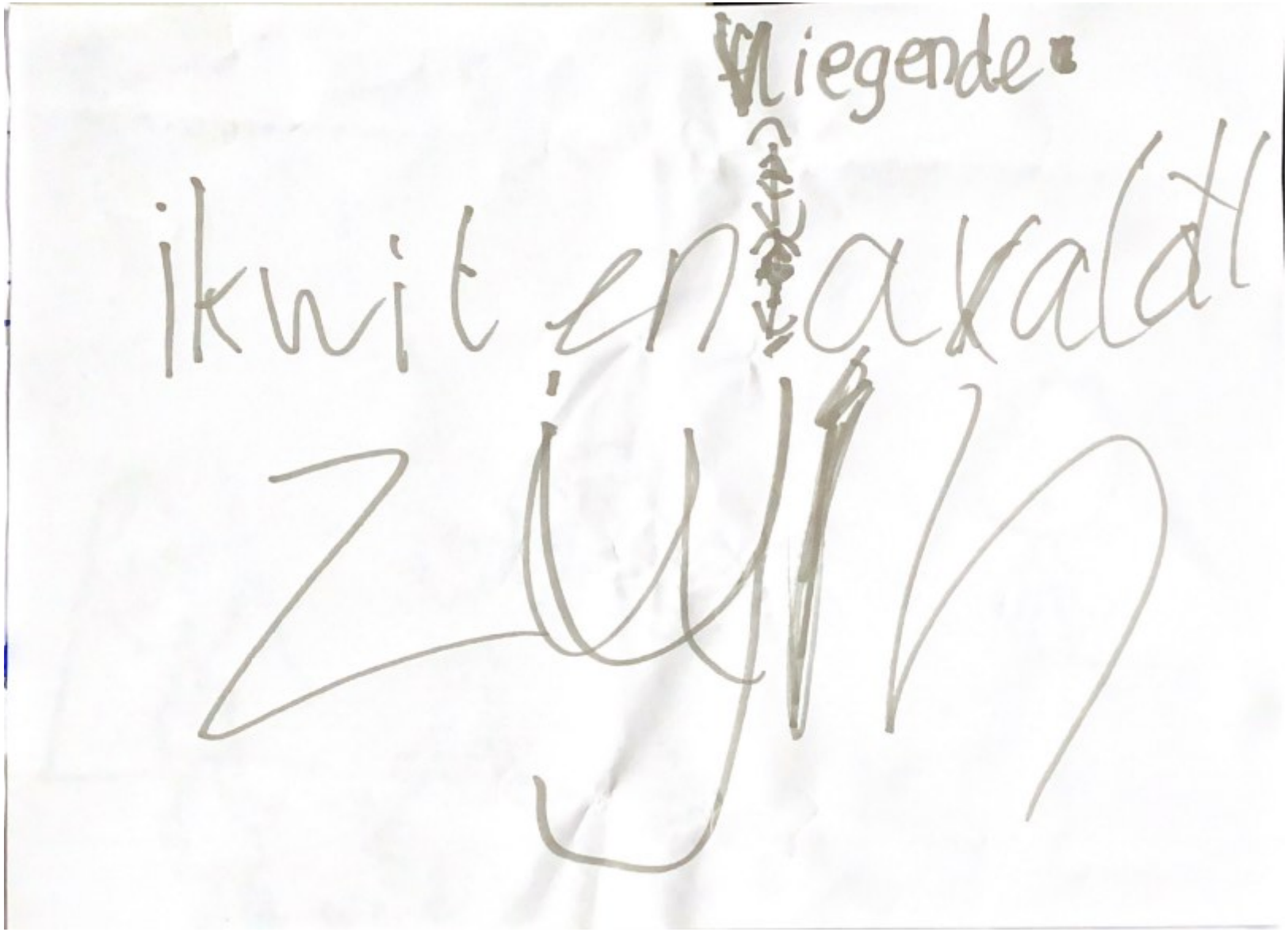
Appendix 5 – Design Artefacts Session 1

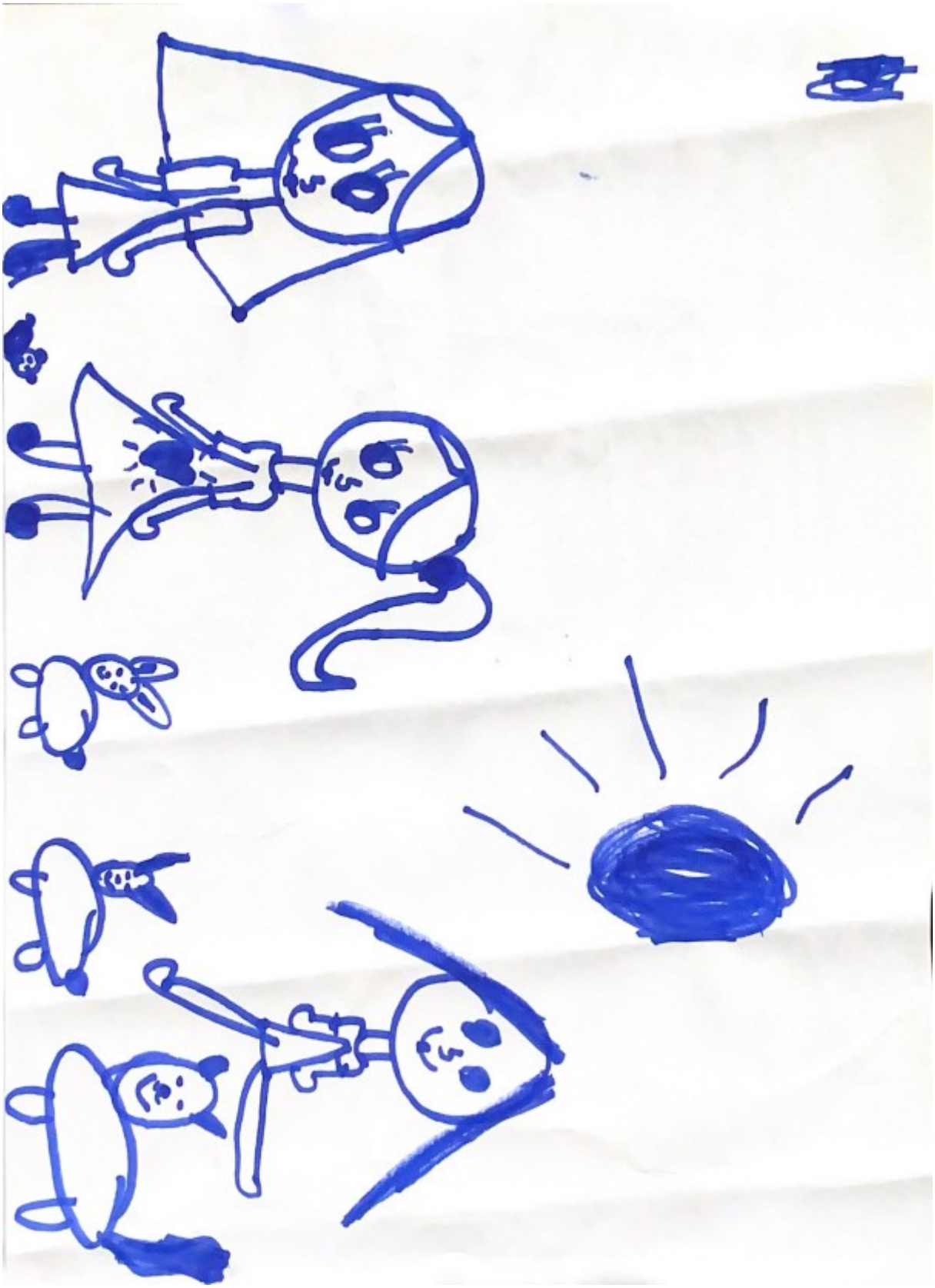


R&Q - Pla

B-Pla Football

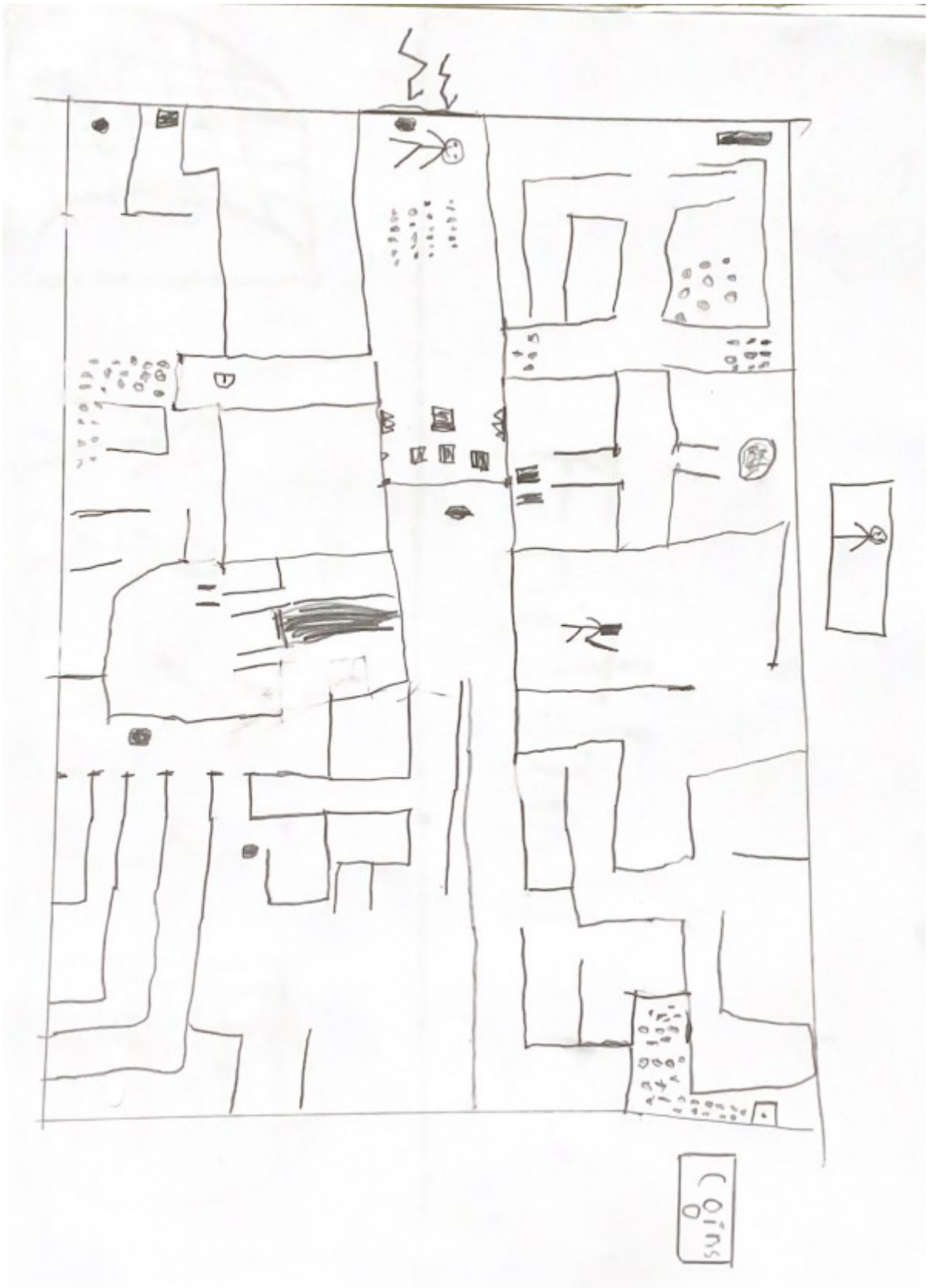

axsalotl
mihl
gams
+7
run!!!


liegende
ikwit en axalatl




KIK

boss battle
coins
100




Footfball

-LEGO
-climb
-fun

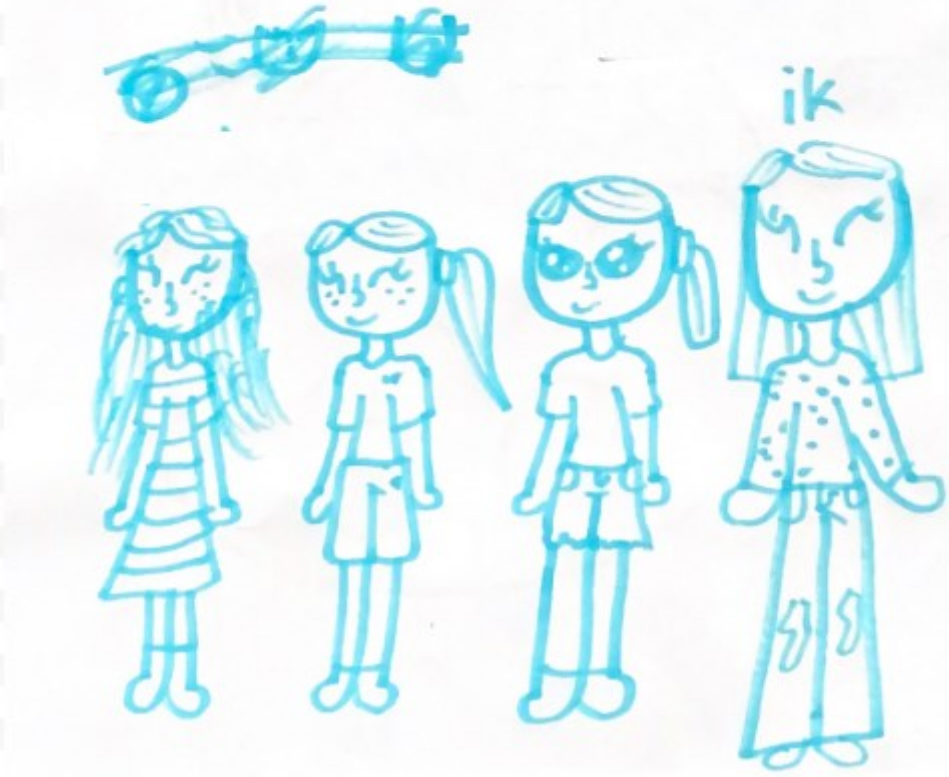
Spel op je telefoon | naam: Zoek de dieren

Je zoekt allemaal dieren buiten.

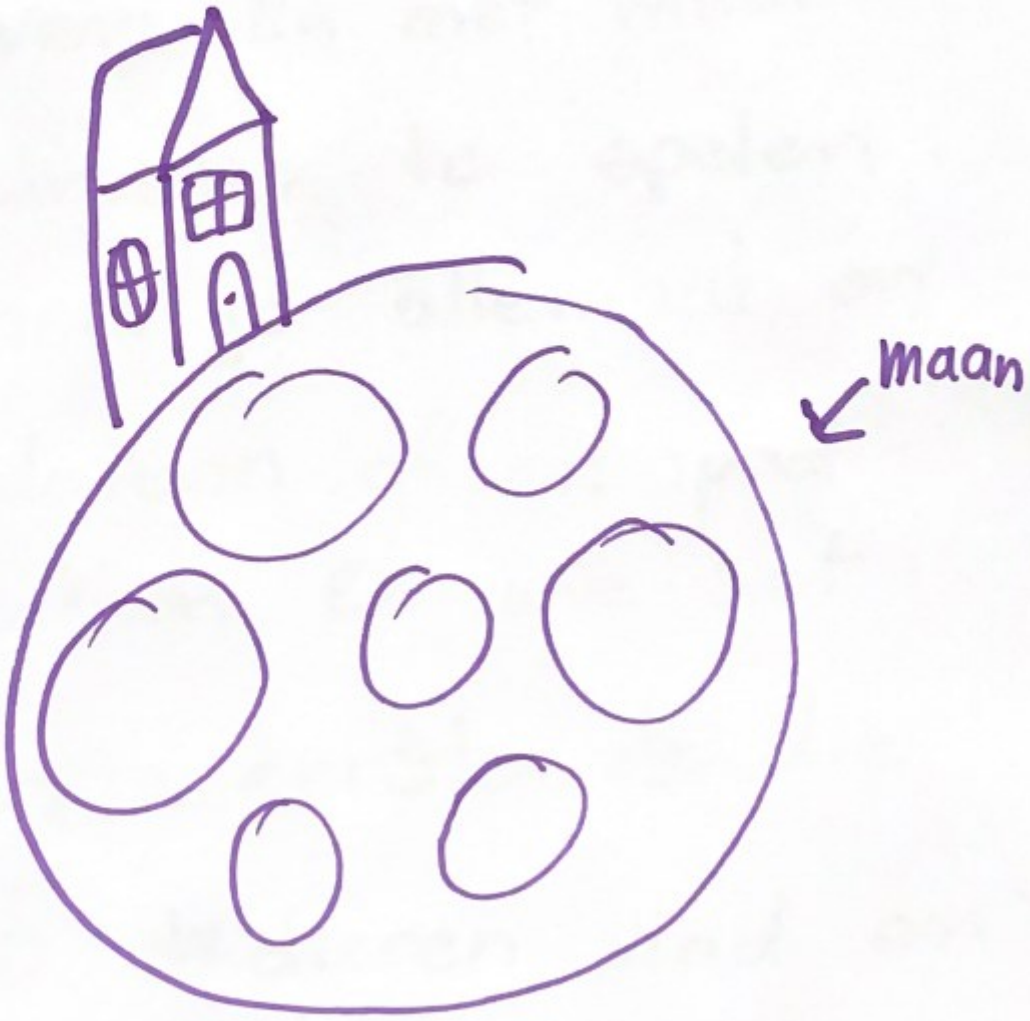
En je moet weer weten waar de dierentuin is.

En brent ze naar de Dierentuin.

I like to play with
en .
I Love drawing.
I have 4 pets 1 cat, 2
bunnys and 1 hamster.



En je kan kiezen waar je heen wilt!



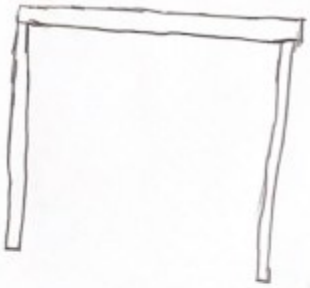
dier
Als je de vind, kan je
ze eten ~~geven~~ geven.
geven. En met meer
mensen te spelen
moet je allemaal een
telefoon of een ipad
pakken, en wie het
~~eerste~~ eerste die
10 dieren vind en
naar de dieren tuin
brenkt wint!

Een mens dat dieren vind en ze naar de dierentuin brengen.

name Lego 5 60 min 4 8+

7x

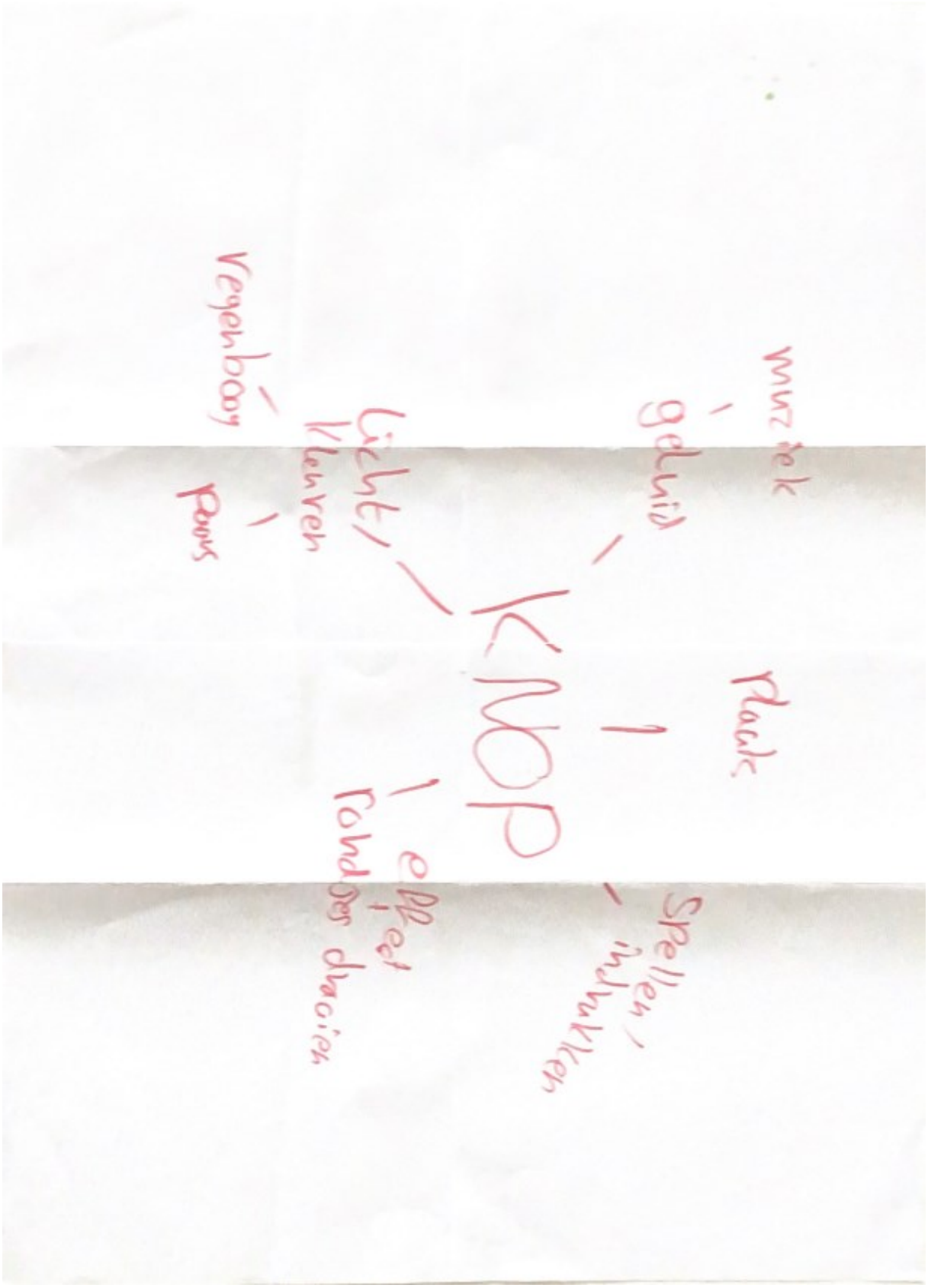
7x



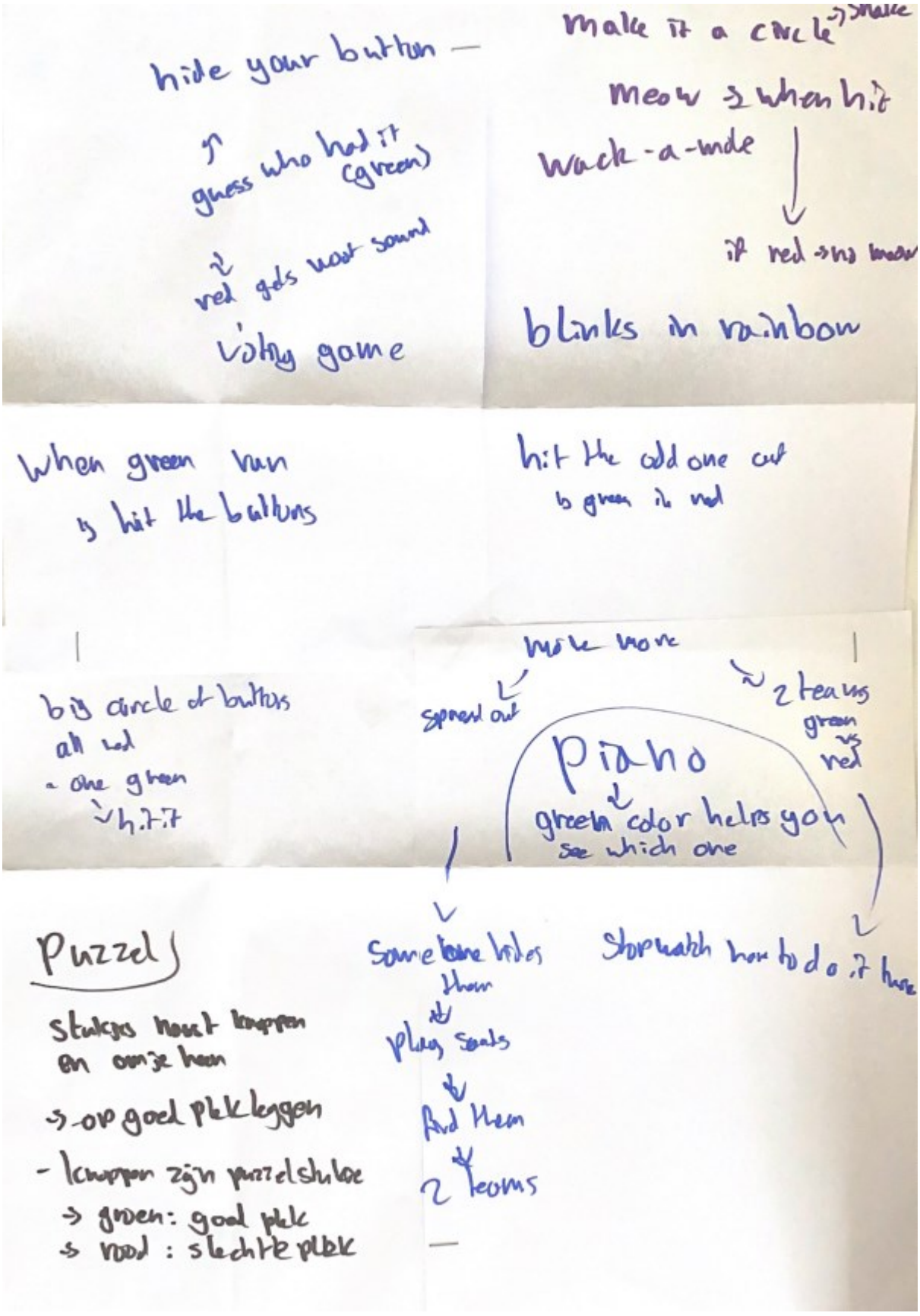
1x

- petcat
- majical creacher
- fofest at end of game
- you are strong in th game
- robots

Appendix 6 – Design Artefacts Session 2



bubbles
effects
Shake
Color

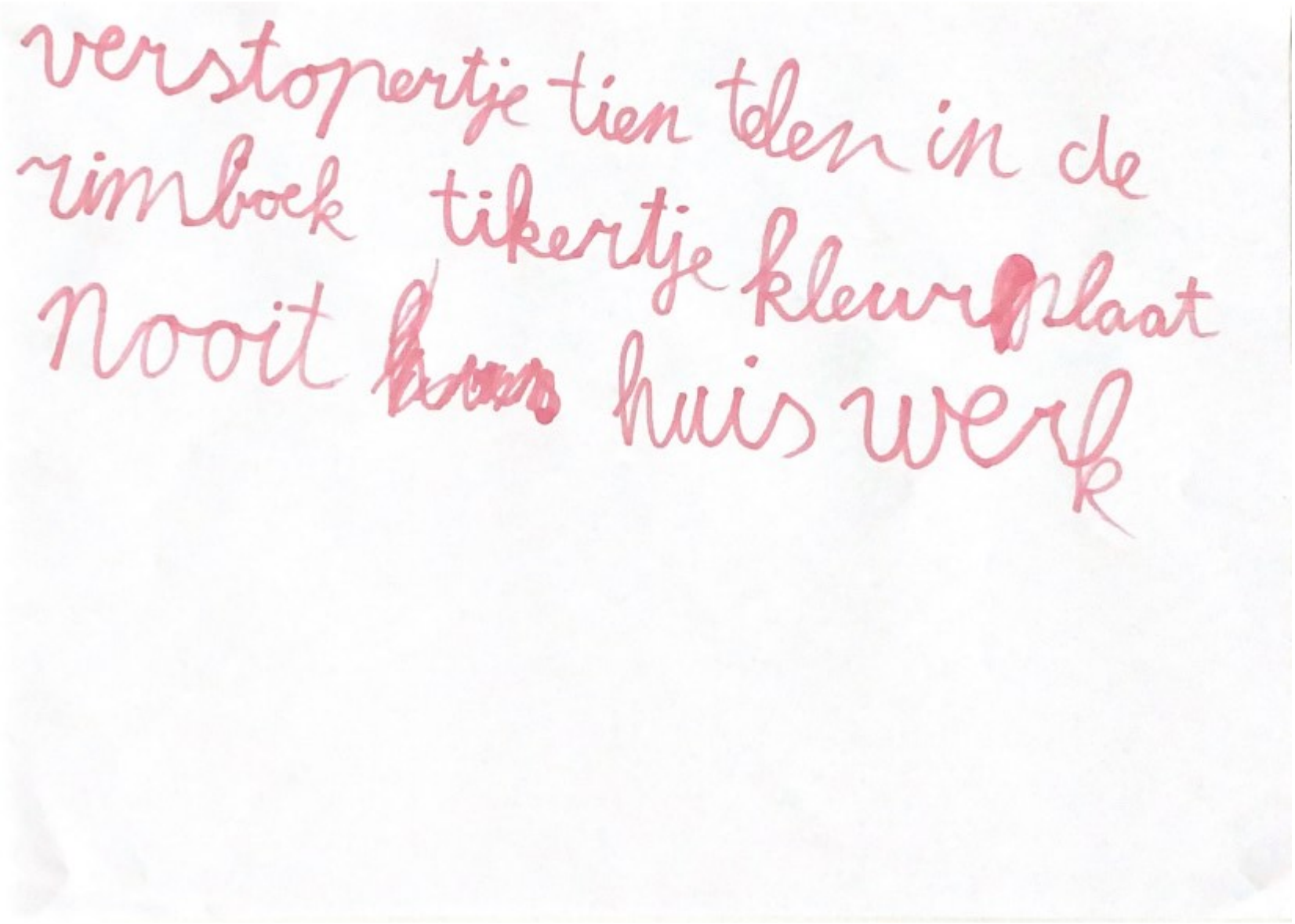

hide your button —
guess who had it (green)
red gets most sound
Volley game
make it a circle
meow → when hit
wack-a-mole
if red → no meow
blinks in rainbow
when green run
& hit the buttons
hit the odd one out
& green is red
big circle of buttons
all red
- one green
hit it
make more
spread out
2 teams
green
vs
red
piano
green color helps you
see which one
Puzzel
Stukjes mogt knippen
en omzet kan
→ op goed plek leggen
- knoppen zijn puzzelstukje
→ groen: goed plek
→ rood: slechte plek
Someone hides them
plays sounds
find them
2 teams
Stopwatch how to do it here


alls je in de knop drukt
dan krij je alle grachten
en dat je wilt
dat je wilt
ik
ik heb alle
Vliegen

Ik zou willen dat ik dan
maar eenvoudig zou zijn.
Jan


Als je op de rode knop drukt
dan zie je een rode panda.
1 jaar later

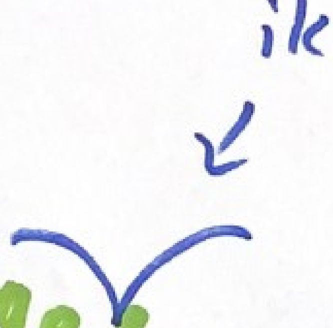
tikertje
sneep regen
niet naar school

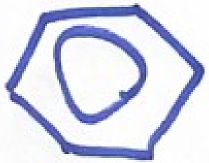

verstopertje tien teden in de
zimbock tikertje kleurplaat
nooit huiswerk

op de lijnen

blijfen en snœp reegen

een spel met
een poes en vogel





KNAKWORSTTJE
ALS IK KAN de knop druk
kan fliegen

alls je de blauwe
knap in drukt
dan kan je vliegen

als ik de knop in drak
dan kan je kijken hoe je en lu mozine moet maken

DE ROD E KNOP
KOM TEEN
LU MOZ INE

voetbal
als je erd op drcakt
dat je een penelty
~~moo~~ moet nemen

Licht

regenboog

paars

roze

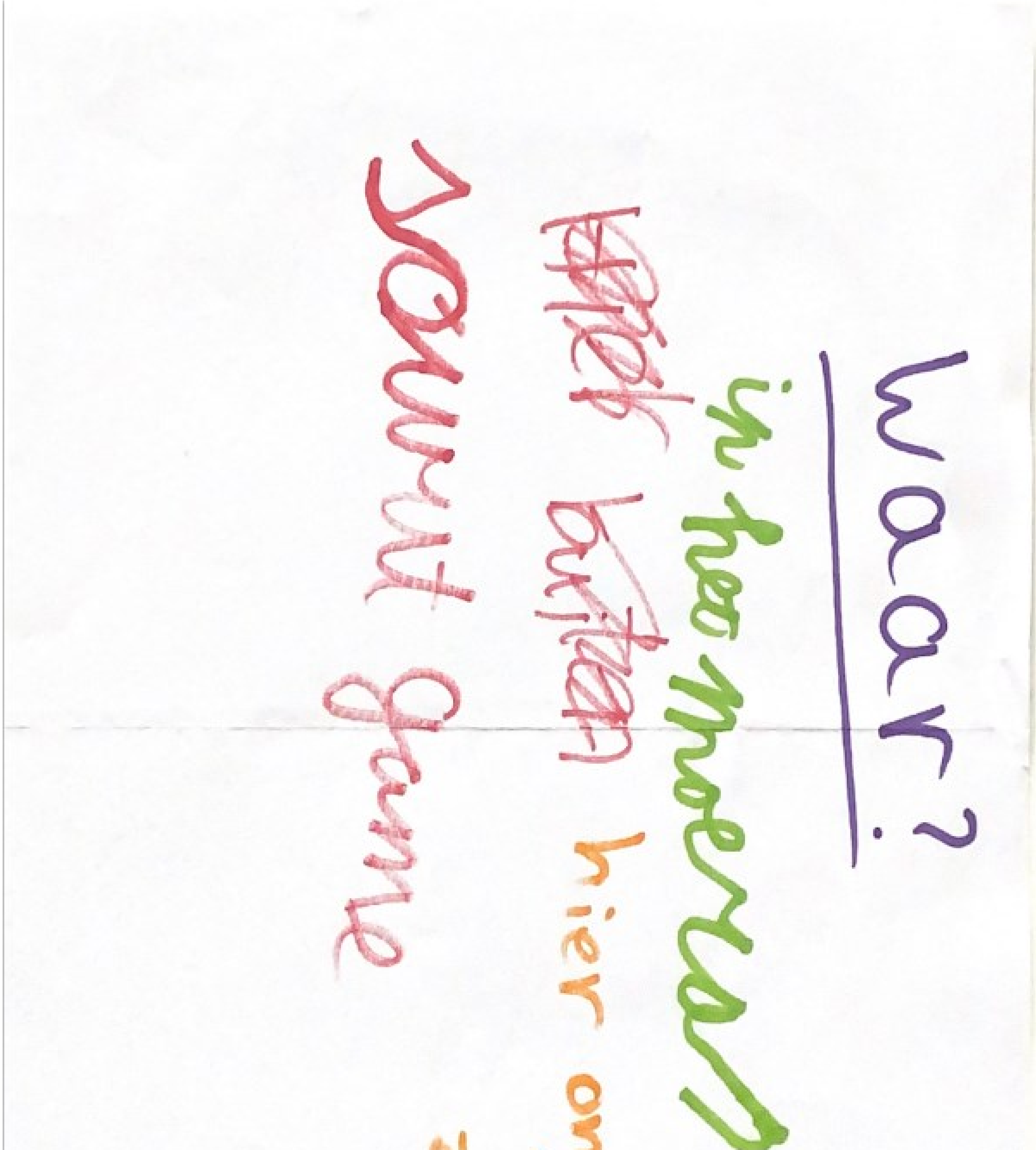
rood en regenboog

cyaan

mint groen

turkwaaz


Geluid?
mouw
kat
ror
tijger
Linnding ding
RODE
PANDA
Geluidwaarteen
woef
regen
Zeemeermin
unicorn
tijger, Leeuw


waar?
buiten
hier onderwater
zeemeermin
Game


wat gebeurt er
Superkrachten
krijger
er
komt
un
dode
panda
tijger
kat
leeuw

Doel 1 & 2

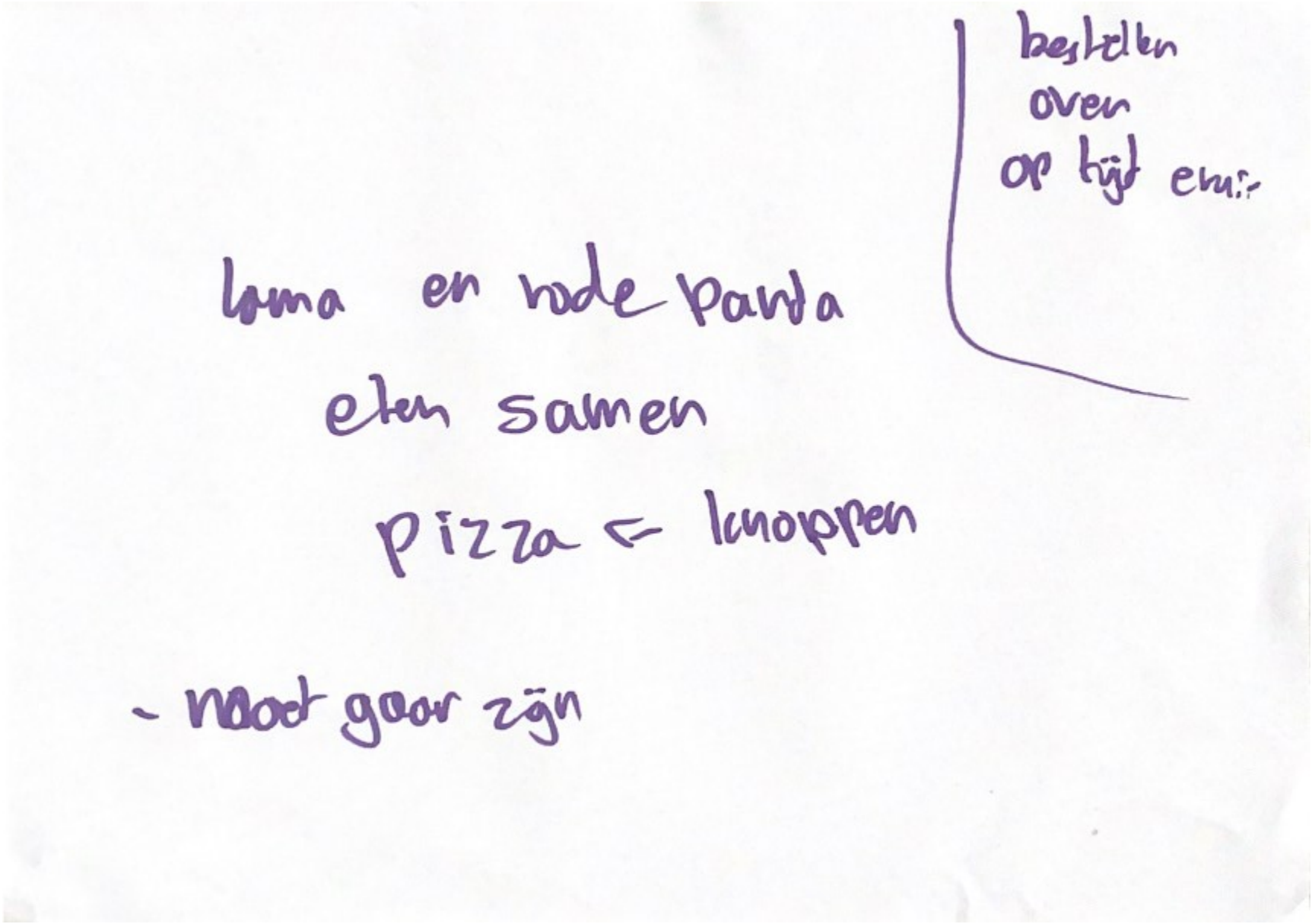
Kat krijgt superkrachten

tijger krijgt superkrachten

en red de wereld

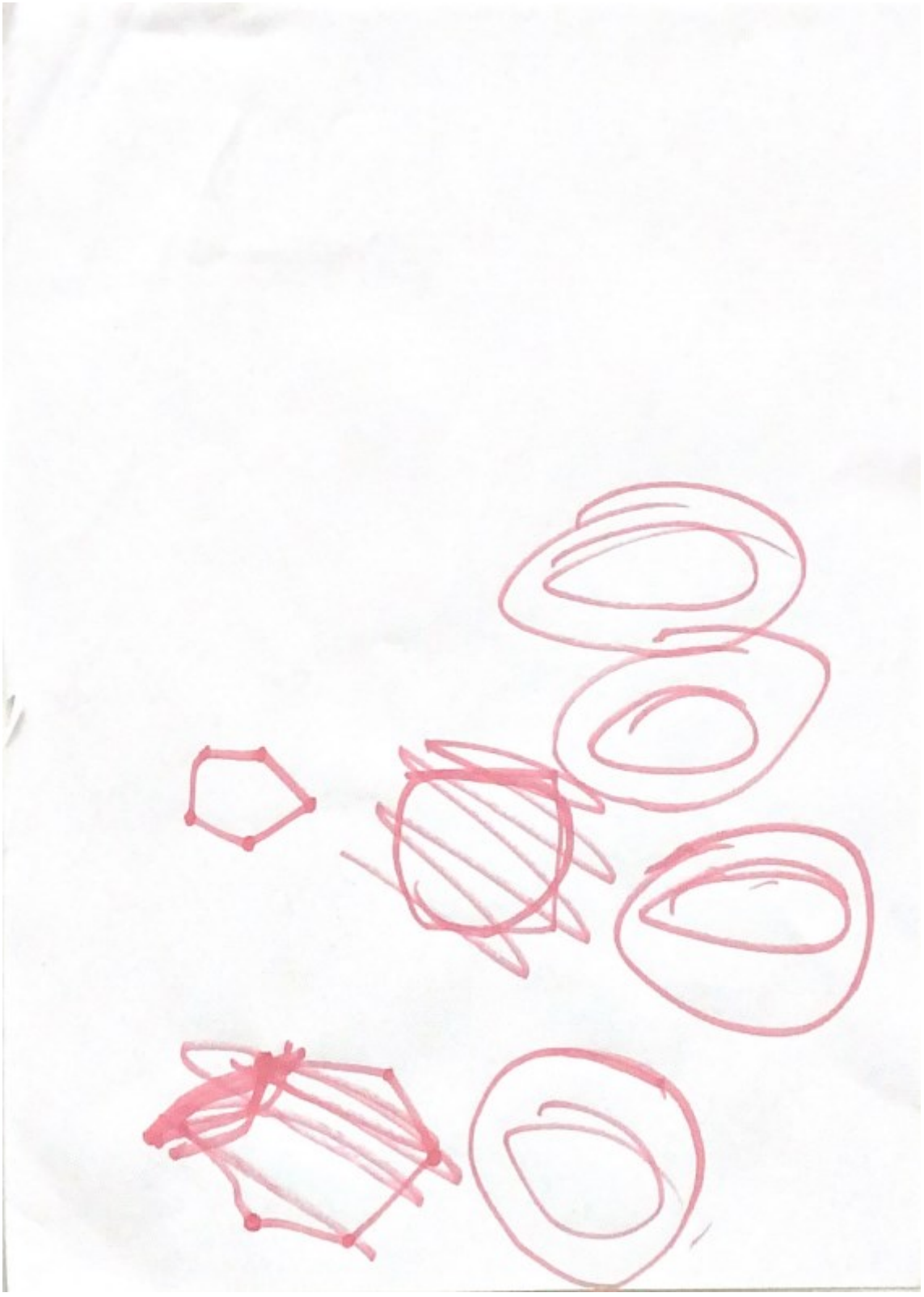
de rode knopen indrukken

Spel	eten	dier
Samenwerken	opeten	Poesje
	Pasta	lama
	Pizza	tijger
		hondje
		rode Panda
		axolotle


bestellen
oven
op tijd enz.
Ioma en rode panda
eten samen
pizza ← knoppen
- moet goor zijn

and
Blue
and Meow Meow
Tap the one
that Blinks
rainbow

rainbow
meow flash
when it goes rainboow



when hit on
gren the soud meow
plays
red the soand fuff
meow
ruf

Appendix 7 – Mixing Ideas Booklet

Lights

Rainbow effect	Red	Orange
Blinking	Yellow	Green
Circle effect	Blue	Purple
Cyan	Pink	Bright light
Soft Light	No light	Rainbow blink

Sound

Loud sound	Soft sound	Music (song)
Woof (dog)	Meow (cat)	Roar (tiger)
Roar (lion)	Ding ding (bell)	Rain
Red panda sound	Mermaid sound	Unicorn sound
“I’m here!”	“1 pizza please”	“...”

Place

Swamp	In the BSO	Underwater BSO
Squid Game	Outside	The Moon
Zoo	Forest	Deserted island

Win condition

Points	Fastest time	Working together
Team vs Team	Free for all	Singleplayer
In duos	Groups	1 vs 1
Voting	Being in time	Specific goal
Red buttons	Do something 10 x	Getting across

Effect

Superpower	Ability to fly	Tag
You get a point	Vote someone	Start/stop stopwatch
You get an animal	You get food	A road opens
You can move	You can’t move	Sound plays
Button lights up	Stops sound	Stops light

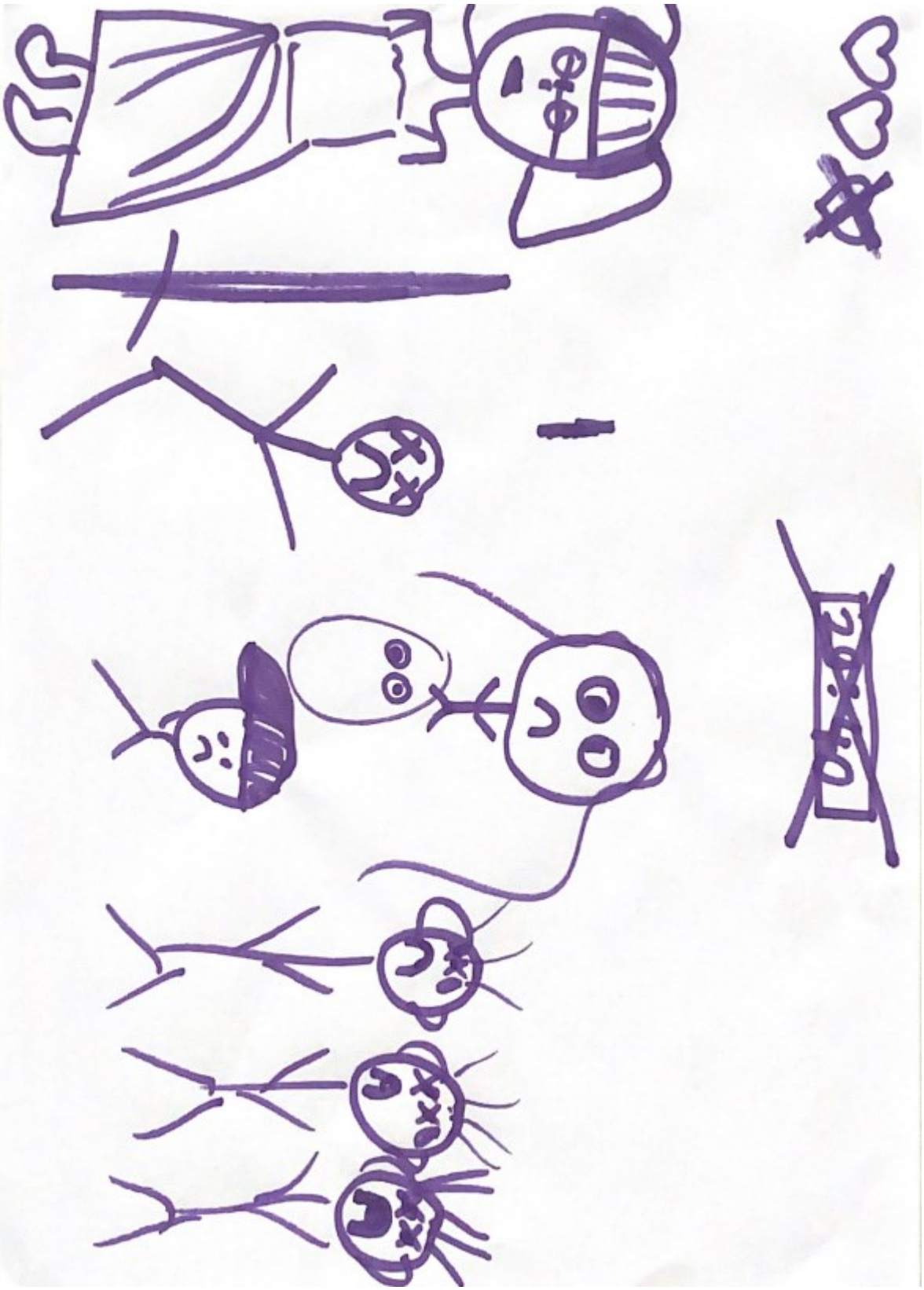
Extra

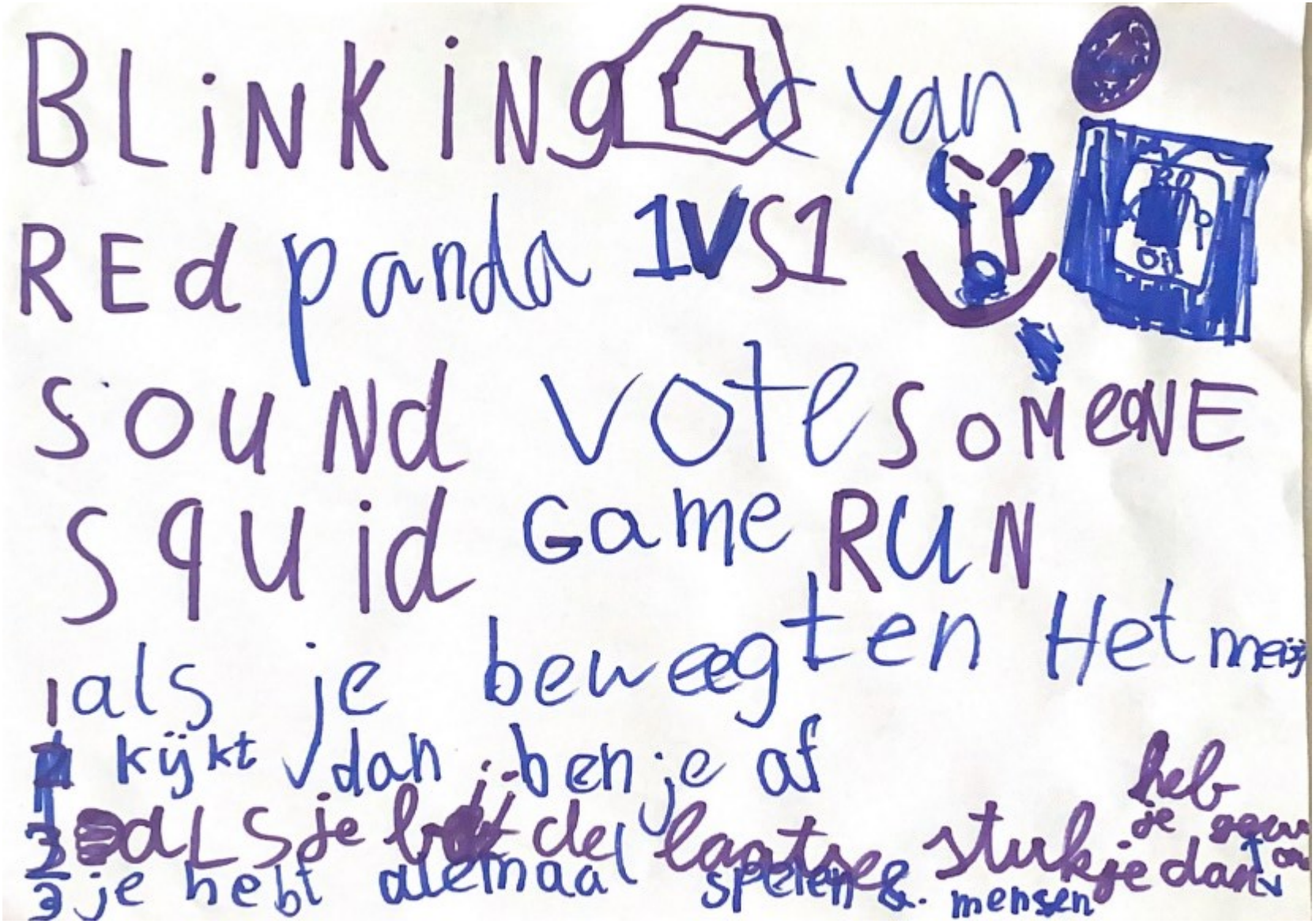
Animal	Searching	Puzzling
Hiding	Food	Dance
Run		

Appendix 8 – Design Artefacts Session 3

Dier maakt geluid naar ander dier, als je hoort wil je

Consequente / vraag / spelen-uit




BLiNKiNG yan
RED panda 1VS1
SOUND VOTE SOMEONE
SQUID GAME RUN
ials je beweegt en Het meis
kijkt dan ben je af
als je het deel laatste stukje
je hebt allemaal spelen &. mensen
heb
je

Winnen: ?

Manier: ?

thema: ?

Regels

1. Als de licht regenboog is op druken.
2. met 2 tot 7 mensen spelen
3. als je op drukt makt het een dun ~~da dra~~ duu daa.
4. iedereen heeft een en als je ~~nie~~ niet snel genog bent ben je af.
5. Als je af bent makt het buam buam buam.
6. en wie het snelste doet wint!


meow meow

To win: [redacted] got to the end of the maze first

players: team VS team

theme: you are traped in a maze team1 VS team2

Rules

① if you get roehd fist then you win

② if you finish all the pusles then you win

③ Do not hurt the other team

Winnen: escape
manier: Samenwerken
Thema: Swamp

Rules)

① Als C goan dan +1 punt
endrukken
Is na een bepaalde hoeveelheid zeewater
② met punten kun je dingen kopen
Is like a pet cat/lion that can help/defend you
③ if hit & red the -1 point

Red and Black housing can be used to distinguish between + and - points and shop places
-> dif. colours & sounds > diff shop items

Win: all buttons are green

How: together, team vs team

Theme: legos

Rules

1) if you red Press ? then red

2) if you and red then green

3) if blue and Press then you red

to do an exercise

is sound tells you what

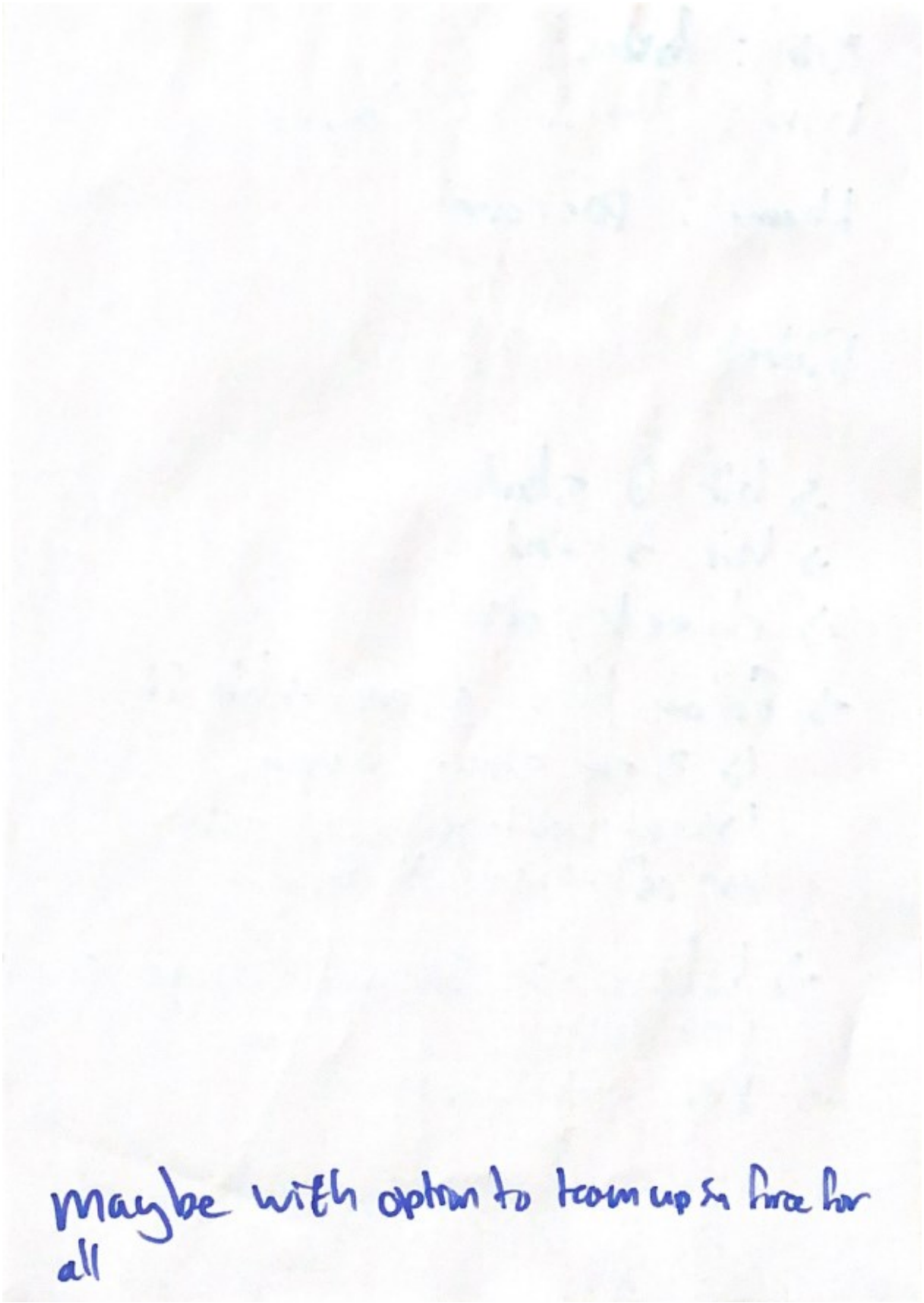
4)

Win : Fastest
How : Free Car at / alone

Theme : Parkour

Rules)

-> Hit to start
-> Hit to end
-> checkpoints
-> follow the green shit it
    -> 3 sec stays green
    -> what points after 1 win
    or after you 2 done
-> blue -> second stage of parkour
-> red -> restart

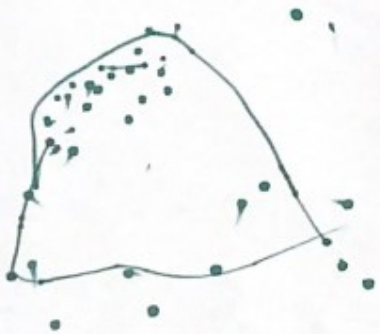

maybe with option to team up in force for
all

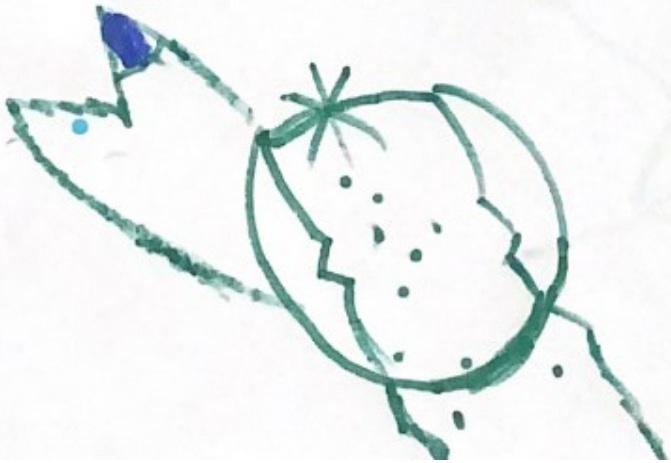
punten

Team VS Team

samenwerken

oranje





win: First to click the button

how: free for all,

theme: Legos

Rules

1) if done making mc legos the button turn red

2) if judge hits your button then you win

3 if button = color when building then you need to use that color

4 button shows you how to make it
5 to go to next step press a button

- need to run to get the building materials/ Legos
- papers in hat help to figure out what to build
  to button gives random prompt

1 person has 4 buttons
↳ controls the other person

1 person has 1 buttons
↳ gives the controls accross

→ parkour / maze

Winnen : meeste huisjes veren

Manier : de meeste regen- elkaar

Thema : moeras

regels

1 M = 1·B + 1·G

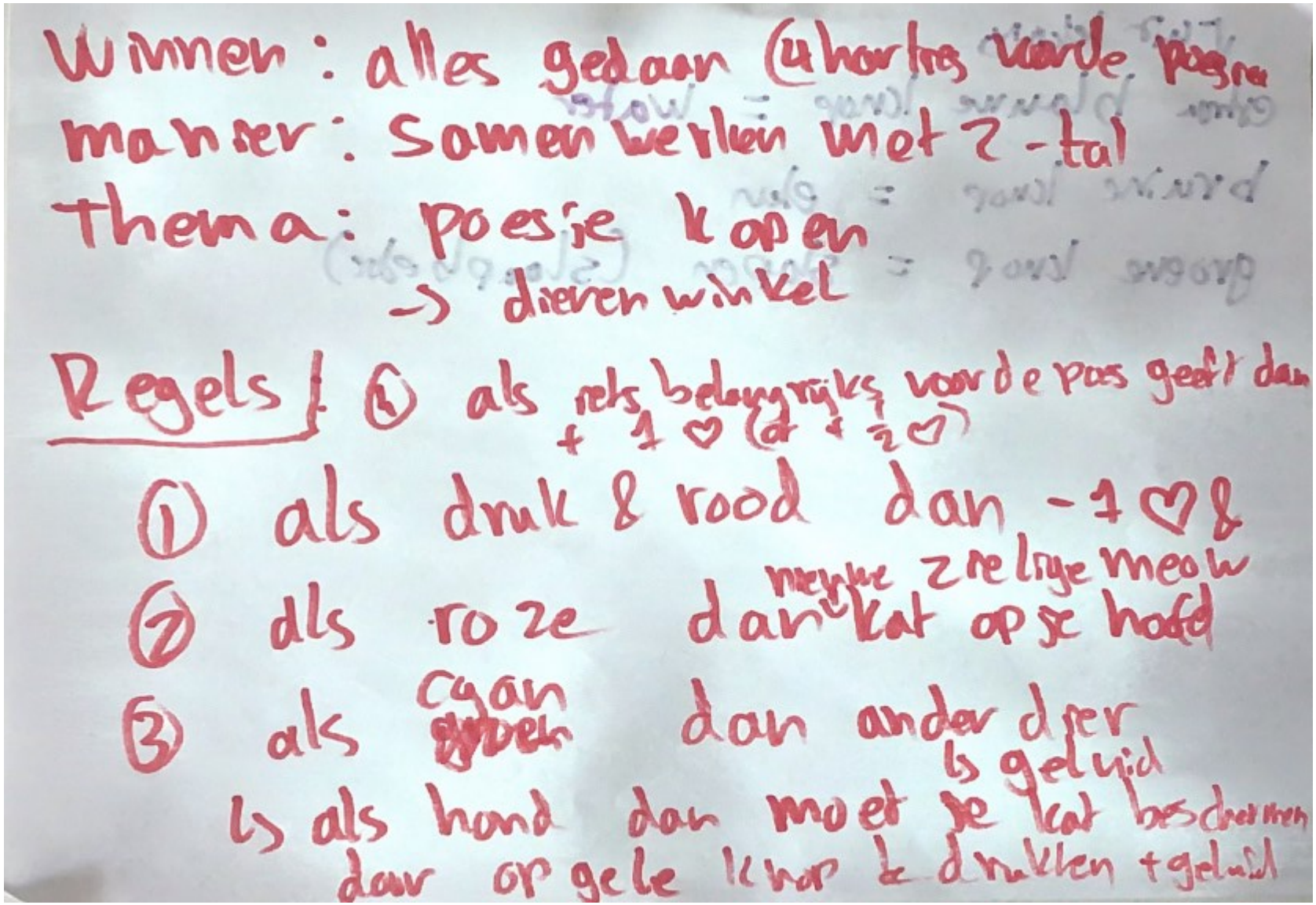
1 1c

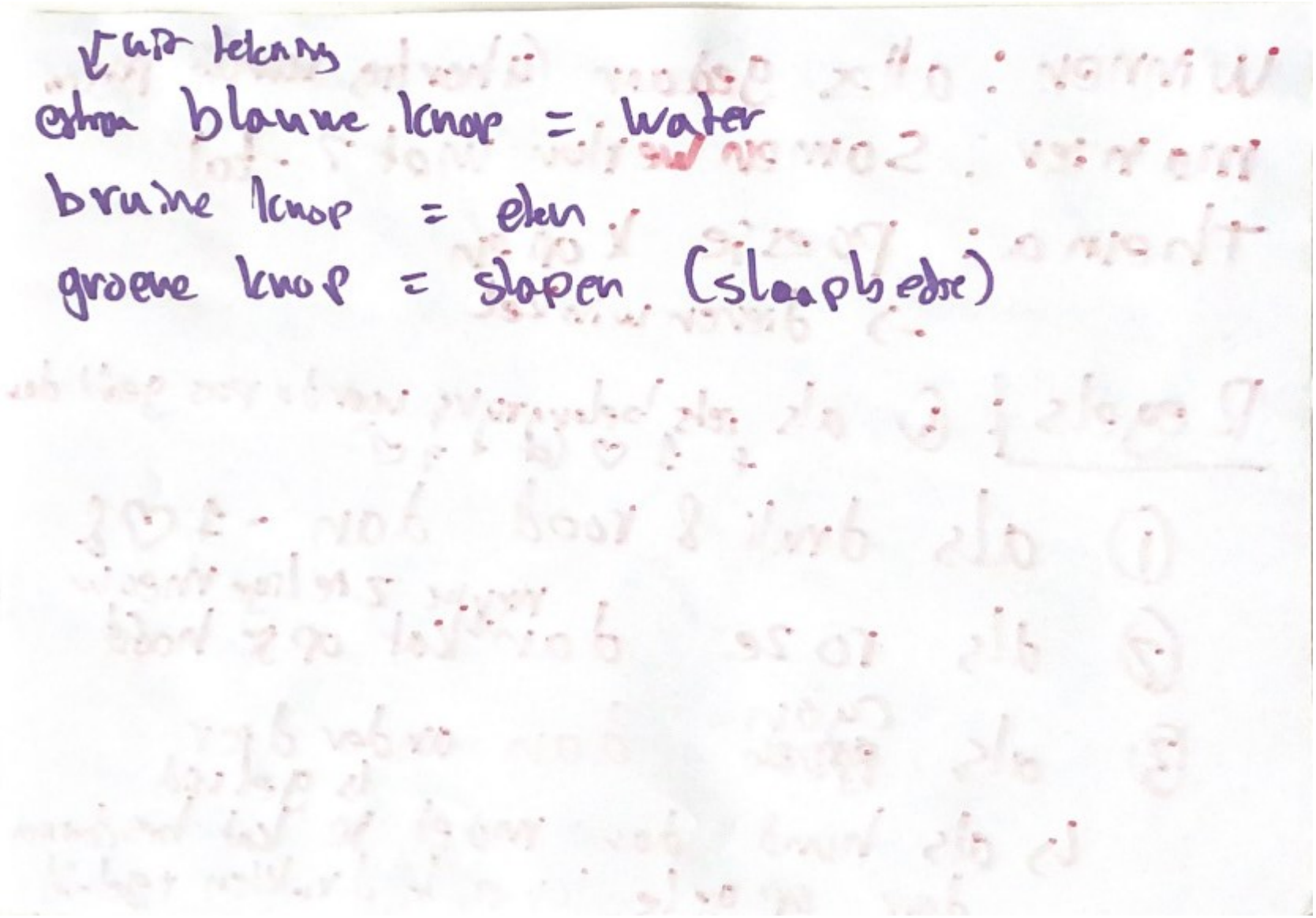
① als de knop uitdaan dan draai je

② als rood dan -1 punt

③ dieren kiezen!!!


Winnen:
Manier:
Orion
naam
drinken
eten


Winnen: alles gedaan (4 hartjes verdiend)
manier: samen werken met 2-tal
thema: poesje kopen
-> dierenwinkel
Regels!
1) als rots + 1 ♡ (of + ½ ♡)
1) als druk & rood dan -1 ♡ &
2) als roze dan meerkat op je hoofd
3) als cyaan dan ander dier
als hond dan moet je kat bos dieren
door op gele knop te drukken + geluid


kaptekening
etwa blauwe knop = water
bruine knop = eten
groene knop = slapen (slaapbedje)

als regenboog, druklan, iedereen heeft er 1, druk

Je hebt een bepaalde tijd om te drukken

-> gaat steeds sneller

-> als dat -> knop rood

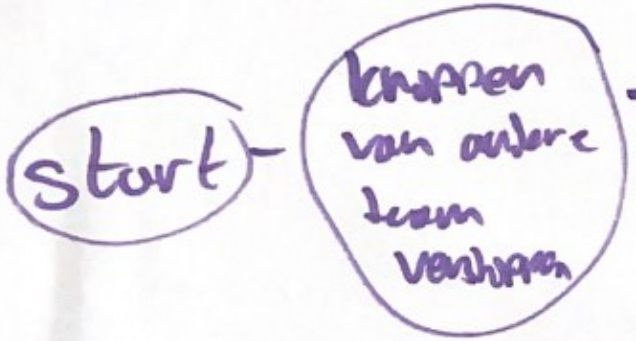
-> het meerdere keren

-> iedereen 1 knop

Appendix 9 – Design Artefacts Session 5

2] odd-one-out & hiding / verstoppen

- rondes?
- team vs team
- estafette?
- geluid / sound?
- win?

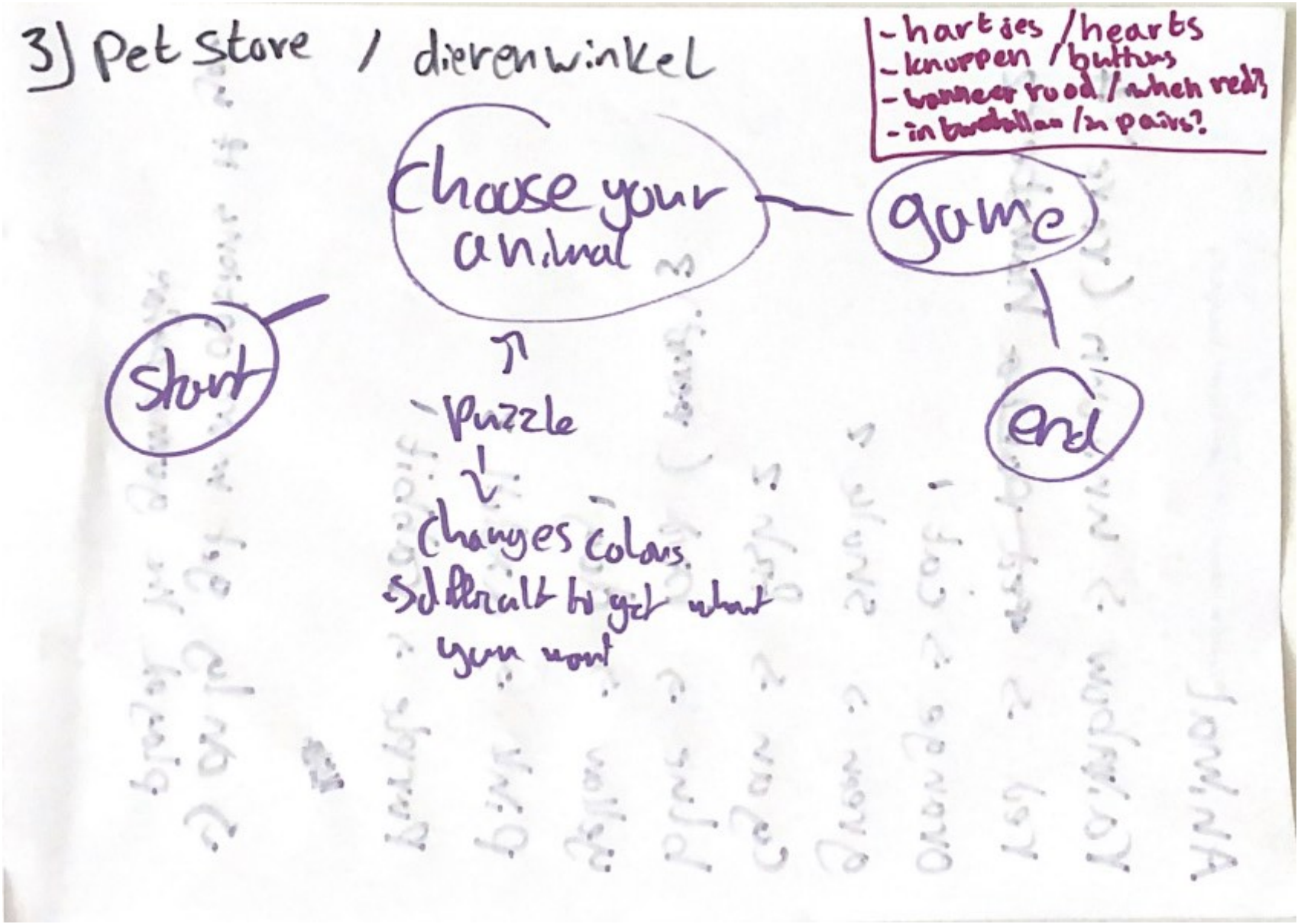


elke knop drukken als die de odd one out is

-> als ze die van het andere team drukt krijgen zij een punt

1 ronde

-> herhaal


3) Pet store / dierenwinkel
- hartjes / hearts
- knuppen / buttons
- wanneer rood / when red?
- in tweetallen / in pairs?
Choose your animal
game
Start
Puzzle
Changes colors
Difficult to get what you want
end

Animal

rainbow → unicorn (rare)

red → ~~red panda~~ hamster 2

orange → cat 1

green → snake 2

Cyan → fish 2

blue → bird (parrot) 3

yellow → dog 1

Pink → axolotl 3

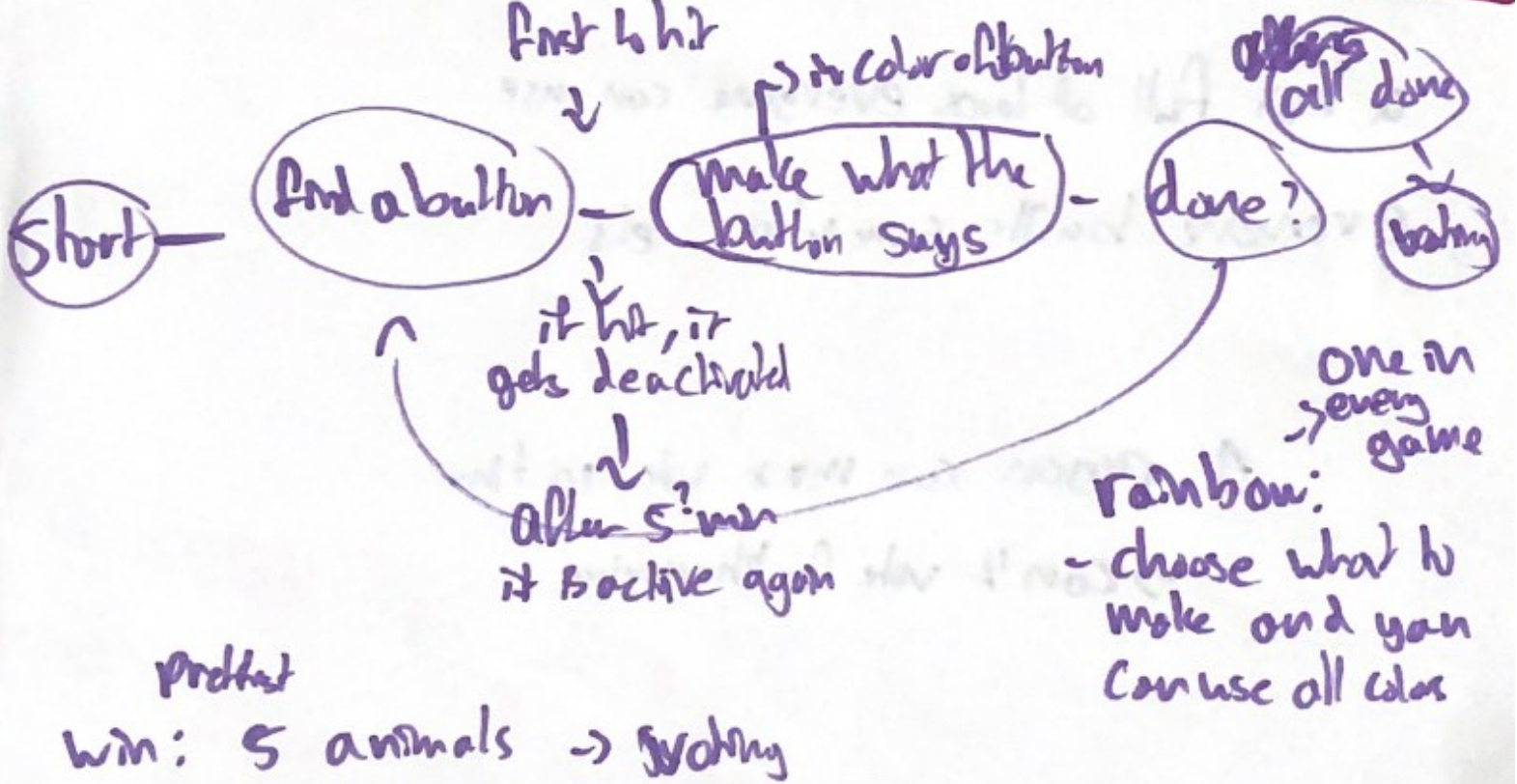
Purple → rabbit 1

→ only get more options if you played the game before

4] Lego teams or ~~solo~~ free for all

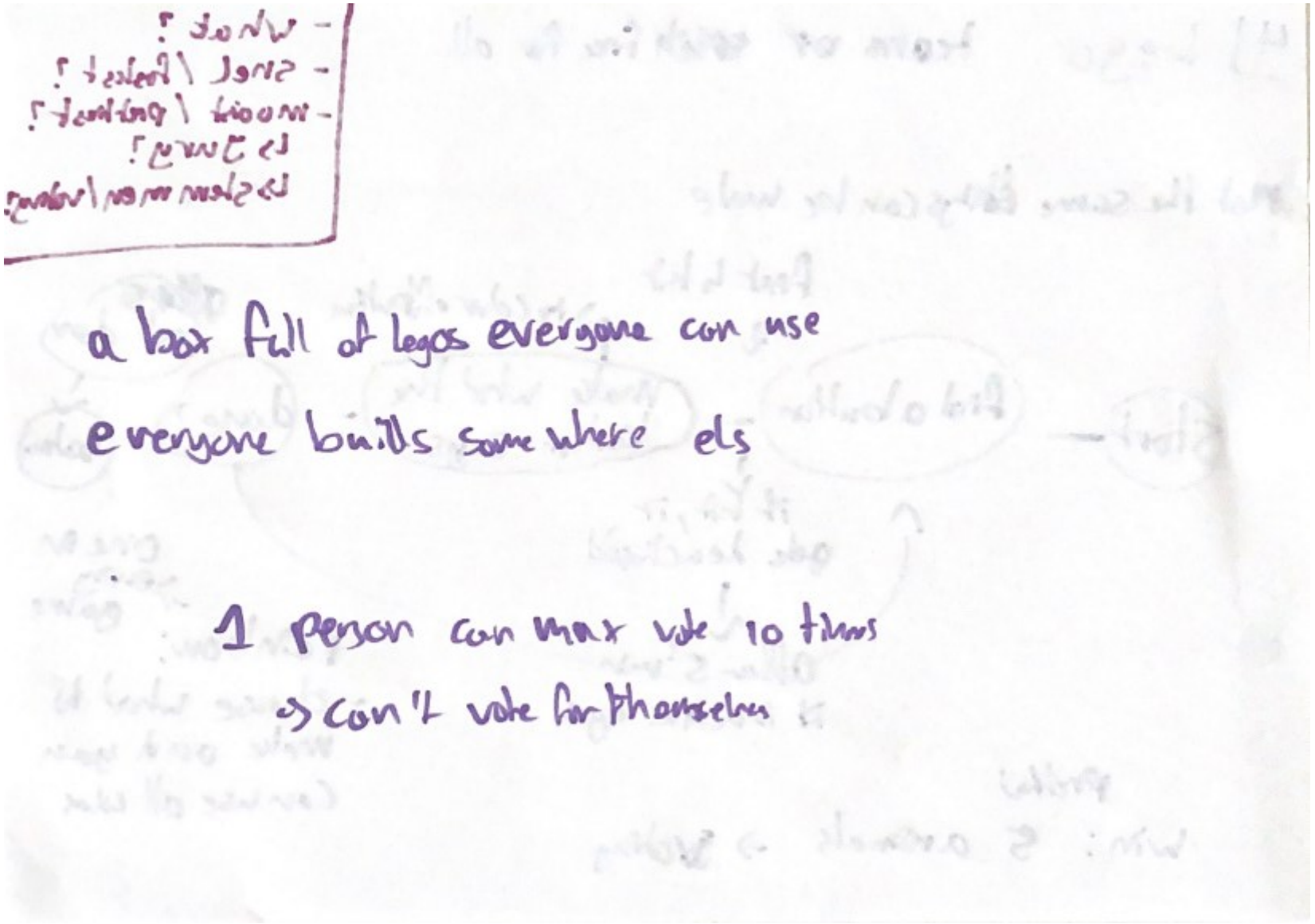
- what?
- snel / fastest?
- moost / partiest?
  Is jury?
  Is steen men/rating?

Not the same things can be made



Prettiest

win: 5 animals -> baby

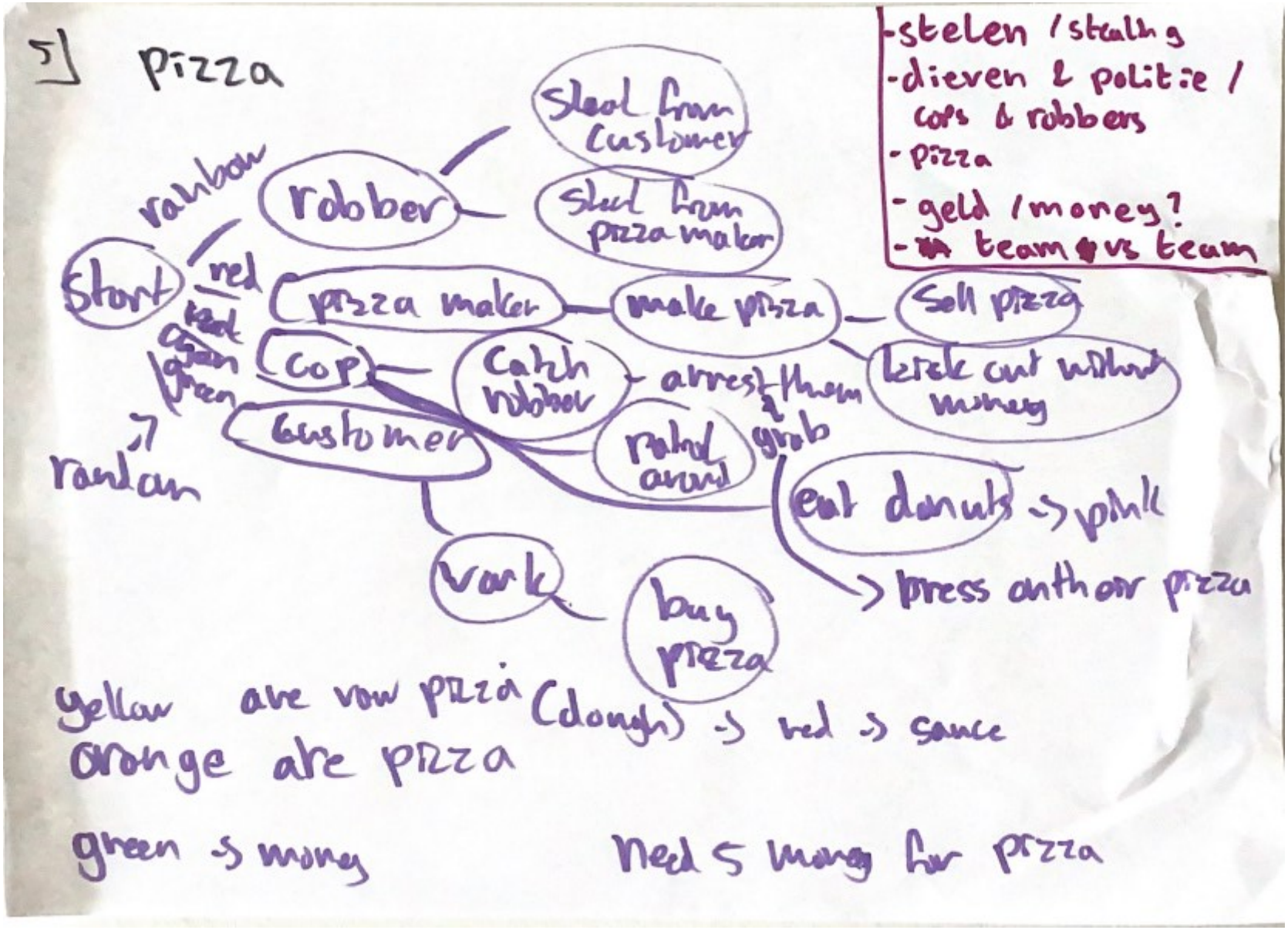


a box full of legos everyone can use

everyone builds somewhere els

1 person can max vote 10 times

→ can't vote for themselves


5] Pizza
-stelen / stealing
-dieven & politie / cops & robbers
- pizza
- geld / money?
- team vs team
Steal from customer
robber
Steal from pizza maker
rainbow
Start
red
pizza maker
make pizza
Sell pizza
cop
Catch robber
arrest them & grab
Leave out without money
customer
Walk around
random
eat donuts -> pikk
-> press anthor pizza
work
buy pizza
yellow are raw pizza (dough) -> red -> sauce
orange are pizza
green -> money
red -> money for pizza

6] Escape / Ontsnappen

- checkpoints?
- eind knop/end button
- puzzels?
- parkour?
- stop watch?

Puzzel maken → goed → door
→ fout → vast en opnieuw

1 richting
links/door

Checkpoint

ontsnap knop

geel → sleutel

→ met sleutel binnen 30sec ontsnap knop drukken

Appendix 10 – Sounds

Table 20: This table shows all sounds used during the project. Some sounds were not included in the final realisations but were included during the design process.

Sound	Application
Boom	Not used: possible addition when a pizza got burned
Coin	Pizza game: when a green button is pressed (+ 1 money)
Coins	Pizza game: when the customer has 5 coins
Correct	Tinkering: when the correct button is pressed
Countdown	Not used: possible addition to the start of the games.
Door	Pizza & Escape game: when a door is opened
Fail	Not used: when an action was failed (eg. raw pizza)
Lose	Not used: when a game failed
Meow	Tinkering
Nom	Pizza game: when a purple button is pressed (doughnut)
Pay	Pizza game: when an orange button is pressed (buying it)
Pling	Pizza & Escape game: when a pizza is created / a key is obtained
Police	Pizza game: when the cop stops the robber (police siren)
Sad	Pizza game: when a pizza was stolen
Splat	Pizza game: when the pizza sauce falls to the ground
Timer	Not used: possible addition to baking the pizza
Win	Pizza & Escape game: when there is a winner / you have escaped
Woof	Tinkering
Wrong	Pizza & Escape game: not enough money / wrong button

Appendix 11 – Evaluation Interview Questions

1. What was your experience playing this game?
2. How would you compare it to the idea you had in mind?
    a. Which elements did / did not overlap with your idea?
3. Would you play this game again?
    a. How often would you play it?
    b. In what situation? (with who and where)
    c. Would you recommend it to others?
4. What did you like about this game?
5. What did you dislike about this game?
6. If you can change anything, what would you want to change?
7. How much did you move around during the game?
    a. What do you think of the amount of movement during the game?
        i. Is it enough, too little, too much?
8. What do you think of the use of buttons in this game?
    a. Can you think of a way to play it without technology?
    b. Do the buttons have an added value?
9. Can you imagine playing this game with picoo instead of the buttons, what do you think?
    a. Which version would be your preference? (why)

Appendix 12 – Physical Activity Scoring Sheet

Observaties			
Beweging Participant: Comments:	**Lopen**	**Joggen**	**Rennen**
Beweging Participant: Comments:	**Lopen**	**Joggen**	**Rennen**
Beweging Participant: Comments:	**Lopen**	**Joggen**	**Rennen**
Beweging Participant: Comments:	**Lopen**	**Joggen**	**Rennen**