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Haptic Play

Encouraging sensory exploration of 5-7 year-olds

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Abstract

This master thesis – **'Haptic Play'** – is an attempt to create a tool or toy that encourages children to spend more time exploring their senses, especially the sense of touch. The effects of mainly physically-deficient stimulating environments of everyday life have an impact on all of us, but it's even more dramatic for children.

Touch is so obvious and ordinary in our everyday experience to the extent that it is perceived as almost meaningless, but it is crucial to our existence. Everything that needs to grow must not only be nourished, but must also be sufficiently physically stimulated. In a world in which a global pandemic has pushed us to rethink every touch interaction and proximity factor of daily interactions, there is even more urgency around this topic.

In this work, I will specifically focus on 5-7 years-olds, not only because there is an overlap of extreme fascination for sensory impressions (2-6 years) with a life stage in which the sense of touch takes up (from 5 years), but also because during this life stage the sense of touch takes up significantly more room and has therefore more impact.

In part one of this thesis I will touch upon a broad range of areas, from child development theories and pedagogy approaches to the connection between learning & play and early musical education. In all these reflections I focus on 5-7 year-olds and the area of haptics. The purpose of this part is not to cover a complete overview of these theories

and topics, but rather to use a few selected approaches and methods to define a set of guiding design principles. These principles lead in part two of this thesis to a concept for a musical toy for children in the context of a kindergarten or play group with a strong emphasis on haptic exploration and sensory experiences.

This sensory music toy uses natural materials with different haptic characteristics (like stones, marbles, pieces of wood, metal or clay) to create sounds. Every haptic characteristic is linked to a sound characteristic. The round playing field has no direction and promotes collaboration between small groups of children. By exploring the haptic characteristics and the spatial relation between the objects on the playing surface, they can build soundscapes and melodies. The game can start very simple, by just placing one object onto the wooden play board. Gradually complexity can be increased, but this can always be controlled by the children. My prototype is limited to a set of defined objects, but the future goal of this concept would be to have an open system in which almost any object found in the children's environment can become part of the game.

Part 1

Part 2

Part 1

Introduction

Introduction

Why are haptic experiences so essential for our everyday life?

The average adult consumes five times more information every day than their counterpart 50 years ago. Further, we spend as much as 12 hours a day in front of TVs and computers.
(cf. Nicole Fisher, 2019, forbes online)

We used to live in a world full of rich haptic stimulations - different textures, temperatures and consistencies. This has changed dramatically over the years. Technology has created amazing tools and resources, putting useful information at our fingertips. It has simplified, changed or replaced many of our daily tasks. No need to go out and explore the world, when every imaginable information is just one click away. This resulted in many of us spending a big part of our time sitting in the very same spot behind a screen. Touching mostly smooth and cold surfaces. We miss out on a lot of the enormous variety of textures, surfaces and sensations of our surroundings. Something we are hardly aware of. The feeling of touch is so basic to our sense of being in the world that many of us are mostly unaware of it. In conclusion, we are also unaware of losing a big part of these sensations.

The latest dynamics caused by the Corona pandemic have pushed this to the next level. From retail to education, banking to dating, the virus has pushed everyone to rethink how touch and proximity factor into daily interactions.

But why does that even matter?

We can't live without touch.
A statement that surprises and raises questions: How can a sense system be so important that our lives depend on it? After all, a human being can be born blind and deaf and is still viable. Yet touch is crucial to embody existence. Without this sensory system, we wouldn't even know we exist.

Because one of its outstanding achievements is that we can always be aware of our physical presence. (cf. Grunwald, 2017, 19) The existential question of what belongs to one's own body and what differs from it develops based on sensory information provided by the tactile system.

Before we are even born, we develop a neuronal concept of our physicality, a so called 'body scheme' both through movement and through the accompanying tactile stimulations. (cf. Grunwald, 2017, 42-44) Furthermore, it is a law of nature that everything that should grow has not only to be nourished, but also sufficiently physically stimulated. According to scientists, fetal growth is directly linked to tactile stimulation. (cf. Grunwald, 2017, 29)

Martin Grunwald is director of the Haptics Research Lab in Leipzig. He found the lab in 2009. Even before he was researching in the field of haptics and has published multiple books about it like 'Homo Hapticus' in 2017 or 'Human Haptic Perception' in 2008. (cf. Haptik-Forschungslabor n.d.)

For infant bodies contact is a necessity because physical stimulation alone initiates physiological and neurophysiological growth processes that can only be triggered in this way. If the newborn is only provided with basic care for months and does not experience any physical attention, its vital functions can fail completely and it dies. According to the researchers, a lack of closeness and attention in early and earliest childhood destroys the natural abilities of the body and brain structure in a way that cannot be corrected later. Just as seriously affected by physical deficiency stimulation are areas of the brain which ensure that we link sensory stimuli with various emotions and perceive these emotions appropriately. This can lead to anxiety disorders or depression. (cf. Grunwald, 2017, 53-62)

Touch is not only crucial for fetuses and newborns, even after we've grown up, it is an essential part of our existence. Every touch sensation causes a change in the neurochemical state of the brain without us necessarily being aware of it.

It is part of our everyday life on so many levels, even if we simply sit or lie, the sense of touch system analyzes and controls our physical status. At any time. We can feel and recognize surface differences that are so small that we cannot see them without aids and a short hug can trigger positive emotions that last many hours or even days.

If the consequences of haptic sensations are already considerable for the life and health of adults, they are felt by the child's organism in its entirety to a much greater extent. Growing up, children use touch for an extensive tactile and multisensory exploration of the world. This is necessary to understand the characteristics of the physical world. It is not enough to see a picture of the world to understand the three-dimensional environment. Environments with little haptic and tactile stimulations don't promote the exploration and willingness for a child to adapt and as a result the development processes themselves are affected negatively. The more varied and diverse the material composition of the physical environment is, the more children are intrigued to explore and discover. Touch explorations are not only significant for the development of locomotive and sensory systems, but are also important to form the structures of attention and memory processes and thus the basis for all learning processes. (cf. Grunwald, 2017, 89-90)

Humans are haptic beings with a deeply rooted need for interaction with the environment. The increased replacement of real haptic stimulation with digital experiences may not only lead to losing the connection to natural objects, but also to our own bodies.

Haptics

What is haptic and how does it work?

What exactly is haptic?

Haptic perception is the active sensing of the size, contour, texture, temperature and mass of an object. It is often confused with tactile perception. The main difference is, that haptic perception is active, whereas tactile perception is the passive perception of mechanical stimuli.

In general there is a lot of confusion around the word 'touch', as this term is used in very different contexts. It could describe a tactual perception, a generalized bodily feeling or in a more metaphorical meaning an emotional affection. Aristotle uses the term 'haptsthai' to refer to tactile sensations in both 'De Anima' (on the soul) and 'De Sensu et Sensibilibus' (on sense and the sensible).

When speaking about somatic senses this often includes the sense of touch, proprioception, kinaesthesia and haptic perception. Proprioception is the awareness of body position and kinesthesia is the cognizance of body movement. These two are essential inwardly-oriented sensations for feelings of embodiment. The world of touch and somatic senses is extremely wide and interesting, but I will mainly focus on the impact of touch sensations perceived over the skin of the hands and fingers. (cf. Gendlin, 2012, III-1)

Structure and function of the sense of touch

Touch has a complex constitution being a singular sense that corresponds to no single organ. Physiologically, touch is a modality resulting from the combined information of

innumerable receptors and nerve endings concerned with pressure, temperature, pain and movement. To be able to perceive touch sensations receptors, nerve fibres and nerve cells are necessary. As they become important in the course of this work, I would like to take a closer look at the different receptors of the skin.
Depending on the classification system there are about 10 receptor types. Different receptor types are arranged simultaneously in various body parts. They are always in 'stand-by-mode' and send constant impulses. This permanent activity is the reason why we perceive stimuli on the skin immediately and not delayed. Of course this becomes an incredible amount of impulse data and this amount is one main obstacle in understanding when a stimuli becomes conscious perceptions. (cf. Grunwald, 2017, 98)

Four of those receptor types are mechanoreceptors: Meissner corpuscles, Merkel cells, Ruffini capsules, and Vater-Pacini-corpuscles.

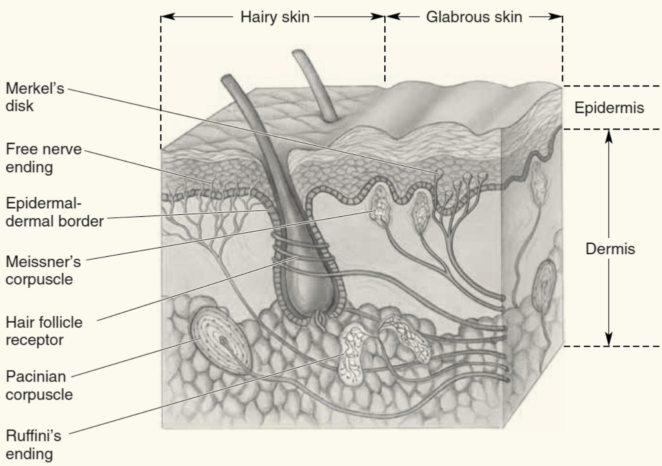

Fig. 1
Belorustceva, Kseniia:Somatic Sensory Receptors, 2016, © Kseniia Belorustceva

Tactile receptors

The Meissner corpuscles are responsible for the perception of very light and gentle skin deformations. They are located in the third skin layer and have a very complicated structure. They are very sensitive to changing pressure and stop reacting if a deformation is maintained over a longer period.
Merkel cells are simple tactile receptors located in the epidermis. They are present in very large numbers. Merkel cells tend to react to simple and constant pressure on the skin, but also to friction forces and small vibrations.

Pressure receptor

The Ruffini capsules emit electronic impulses as long as the skin is deformed. This is how long-lasting deformations are registered.

Vibration receptor

The Vater-Pacini-corpuscles are responsible for the registration all forms of vibrations like writing on paper or smartphones. They are the largest receptors and are located in the subcutis and connective tissue.

Besides mechanoreceptors we also have temperature sensors distributed all over the body. Cold is much more threatening to our organism than heat, therefore our body has many more cold than warm receptors. We are able to perceive temperature changes of +1°C or -0.2°C. Different parts of the body differ in temperature sensitivity.
Every sensory system works best across a certain spectrum. If the stimuli are too strong or weak, the sensitivity of the receptors is not sufficient or they reach their limits.

Pain-sensitive receptors have a warning function.

Touch stimulations don't increase continuously until they reach a pain point. Pain is an independent sensory modality and not an extreme variant of the sense of touch. The nociceptors react exclusively to extreme mechanical deformation, strong heat or cold stimuli and tissue-damaging chemical influences. The body skin of an adult human alone has about 200 million free nerve endings. There is no exact information about the number of receptors in the human body. (cf. Grunwald, 2017)

Why are screens particularly bad?

The one-finger pointing gesture and the isolated index finger that is mainly used when operating touchscreen devices are a form of prelinguistic communication that is relatively simple in terms of hand motor skills. Every chimpanzee is capable of operating a touchscreen, primates and children of our species find nothing easier than pointing to the world and themselves with the index finger. Coordinated touching of brightly colored and auditorily amplified surfaces is only a small step that does not require any extraordinary skills.
In addition, there is a constant flow of events as well as simple sensory reward effects.

Every touch activity on a touchpad is usually immediately followed by a virtual event. Either the optical properties or the acoustic properties change or both at the same time. A toddler's brain is eager to pay attention to changing visual and auditory events, which are more difficult to achieve in the analog world. To evoke a visual or auditory change of the analog environment there is a lot more cognitive and motor effort needed than for an index finger movement.

Even when a bored and nagging child, dissatisfied with him or herself is doing nothing, it's from a biological perspective richer in its cognitive and emotional complexity than any touchpad, mouse, or keyboard. (cf. Grunwald, 2017)

Digital worlds are therefore not an offer for young children, but rather restrictions of the physical and sensually graspable world.

With unlimited access to digital experiences, there is a high probability that growing children will lose the mental and physical connection to their peers. Because there are limited time windows for all of a person's maturational phases - so called "critical phases", there is even a danger that the biologically favorable time for learning skills and abilities will simply be missed. In particular, the formative stages up to puberty have a huge impact on later life. If no age- and maturity-appropriate experiences are neurally stored in the various phases, what is missed on the biological and psychological level cannot be made up for later at all or only with considerable effort and time investment. (cf. Grunwald, 2017)

Child development

Child development

Critical periods and different theories on development influences

What are critical periods?

Experiences have a profound influence on the brain, during critical periods the brain is particularly receptive to the effect of experiences. Such periods allow brain cell connections to form and strengthen more easily. New neural circuits are instructed to process information in a way that is adaptive for the individual. Some of these experiences provide information that is essential for normal development and alter performance permanently. If, for some reason, the organism does not receive the appropriate stimulus during this "critical period" to learn a certain skill or trait, it may be difficult, ultimately less successful, or even impossible, to develop certain associated functions later in life.
Sensory experiences are essential, as these experiences together with cellular events are the two major factors that influence the opening of a critical period. Both need to coincide for the critical period to initiate correctly.

There is a differentiation between 'strong critical periods' and 'weak critical periods'. 'Weak critical periods' are more extended periods, after which learning is still possible. Examples for strong critical periods include monocular deprivation, filial imprinting, monaural occlusion and prefrontal synthesis acquisition. Weak critical periods exist for phoneme tuning, grammar processing, articulation control, vocabulary acquisition, music training, auditory processing, sport training, and many other traits. (cf. Robson, 2002, 101-103)

For this thesis I will focus on weak critical periods. There are many research studies and theories around the critical periods, some of them overlapping, some deviating.

Maria Montessori (1870 – 1952) was an Italian physician and educator best known for her writing on scientific pedagogy and the philosophy of education that bears her name. (cf. Flaherty n.d, online)

Maria Montessori as well used the term "sensitive periods" a lot in her work. She defined it as 'a phase or window in a child's development when they are most capable of and responsive to absorbing a certain skill'. Some of the periods she identified are: movement (birth to 2.5 years), language (birth to 6 years), toileting (1 year to 3 years), small objects (1 year to 3 years), order (1.5 years to 4 years), refinement of senses (2 years to 6 years), grace and courtesy (2 years to 6 years), social Skills (2.5 years to 5 years).
So between the age of 2 years and 6 years children have a huge fascination with sensorial experiences which results in learning to observe and make increasingly sensorial discriminations. (cf. Montessoriinreallife, 2019)
This is overlapping with other studies that say that the importance of sensory play is especially high during that age span. As already mentioned, exposing children to various sensory experiences is necessary for a young brain to develop the proper sensory processing capabilities. Next to the "sensory" aspect there is another, almost equally important, component: the "play" aspect. I will look at the impact of play in more detail later on in this thesis.

For my project, I would like to focus on 5-7 year-old children, as this is not only a high time for sensory exploration and development but they also already have refined motor skills which allow for more complex set up.

Child development

Why do children behave a certain way? Why do some children develop differently than their peers? Is this related to their environment, age, family relationships or genes? There are many theories that strive to answer such questions as well as to understand and explain behaviors and other aspects of child development. The study of child development is a very broad and rich subject, we all have personal experience with development, but it is still hard to understand and explain. Existing theories examine changes across three main dimensions: physical development, cognitive development and social emotional development. Within these dimensions they look at a broad range of aspects like motor skills, moral understanding, language acquisition, emotional development, identity formation, self-concept,...
(cf. Cherry, 2020)

Not all of those I would like to mention are accepted today, but they lay the basis for contemporary perspectives that draw on a variety of theories in order to understand how kids' thinking, behaving and development changes over time.

Freud's Psychosexual Developmental Theory

One of the best-known theories is **Freud**'s personality development theory, which has always been quite controversial, both during Freud's time and in modern psychology. According to this theory, child development occurs in a series of stages, in which the child's pleasure focuses on different areas of the body. Each state comes with conflicts that have an impact on the course of development. In each stage the libido is focused on different erogenous zones and successful progress through the stages leads to the development of a healthy adult personality.

Sigmund Freud (1856 - 1939) was an Austrian neurologist and the founder of psychoanalysis. Despite repeated criticisms, attempted refutations, and qualifications of Freud's work, its spell remained powerful well after his death and in fields far removed from psychology
(cf. Jay, 2020, online)

One of the most important contributions of this theory was the idea that childhood experiences and unconscious desires influence behavior and have a powerful impact on adult life. It stresses how critical the role of early experiences in the development process and that it can have lasting effects throughout life.

According to this theory children between the ages of 5-7 years fall mostly into the 'phallic stage' (3-6 years). During this stage, the primary focus of the sexual energy is on the genitals. Children begin to discover the difference between male and female and they begin to identify with the same-sex parent as a means of possessing the other parent as a proxy. The Oedipus complex describes this feeling of wanting to possess the mother and replace the father. The term Electra complex is used to describe a similar feeling experienced by young girls. (cf. Cherry, 2020)

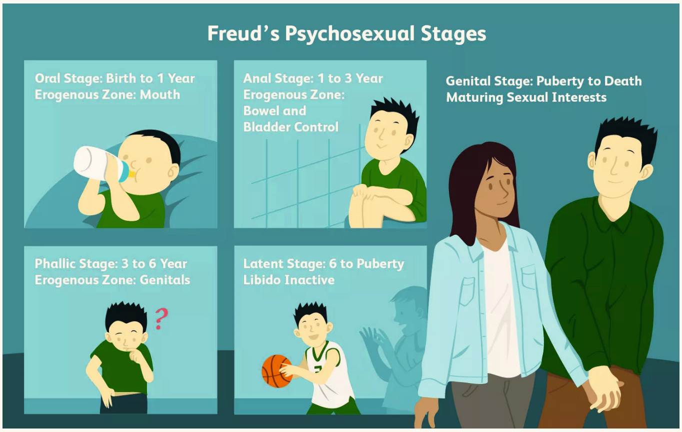

Fig. 2

Seong, Joshua: An Overview of the Psychosexual Stages, 2020 © Verywell

Erikson's Psychosocial Developmental Theory

Erikson was heavily influenced by Freud, but went on to expand on his ideas and developed his own. Rather than focusing on sexual interest as the driving force like in Freud's theory, Erikson saw social interactions and experiences as having the biggest impact on child development.
In his eight-stage theory Erikson is one of the few people who focus on development across the entire lifespan, from infancy to death. Each stage builds on the one before and paves the way for the following stages. In each stage people experience conflict that serves as a turning point and impacts later functioning and growth. These conflicts are centered on either developing a psychology quality or failing to do so. The potential for personal growth is high during this time, but so is the potential for failure.

Erik Erikson (1902 - 1994) was a German-born American psychoanalyst whose writings on social psychology, individual identity, and the interactions of psychology with history, politics, and culture influenced professional approaches to psychosocial problems and attracted much popular interest.
(cf. Britannica, 2020, online)

I will have a closer look at what this theory tells about the age span of 5-7 years. There are two stages that fall into this age span: the third stage (3 to 5 years) which focuses on 'Initiative vs. Guilt' and the fourth stage (6 to 11 years) that focuses on 'Industry vs. Inferiority'.

During the third stage 'Initiative vs. Guilt', children begin to assert their power and control over the environment, but using directing play and other social interactions. The successful outcome of this stage is for the child to feel a sense of purpose. This is achieved by finding an ideal balance between individual initiative and willingness to collaborate. If they exert too much power, they usually experience disapproval which results in the feeling of guilt.
In the fourth stage 'Industry vs. Inferiority' children begin to

develop a sense of pride through social interactions. Successfully coping with new social and academic demands leads to a sense of competence and belief in their abilities, whereas failure results in a feeling of inferiority. (cf. Malone et al., 2016)

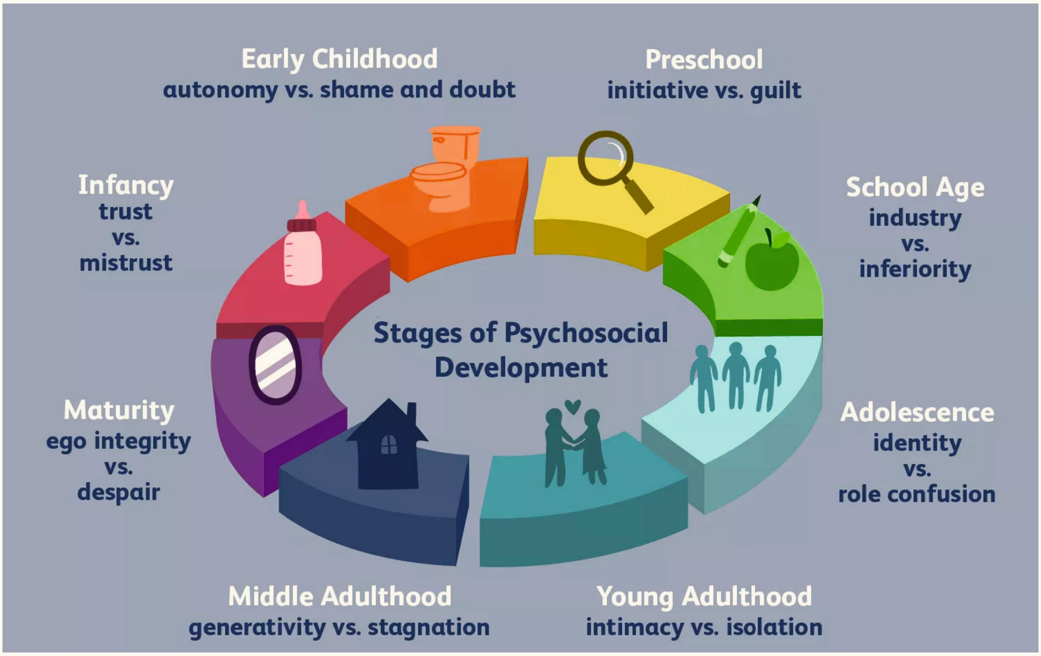

Fig. 3
Seong, Joshua: Erik Erikson's Stages of Psychosocial Development, 2020 © Verywell

John B. Watson (1878 - 1958) was an American psychologist who popularized the scientific theory of behaviorism. In his view this approach to psychology was restricted to the objective, experimental study of the relations between environmental events and human behaviour.
(cf. Britannica, 2020, online)

B.F. Skinner (1904 - 1990) was an American psychologist and an influential representative of behaviourism. Considering free will to be an illusion, Skinner saw human action as dependent on consequences of previous actions.
(cf. Britannica, 2020, online)

Behavioral Child Development Theories

The school of thought known as behaviorism is built on the idea that psychology needs to focus on observable and measurable behaviors in order to become a more scientific discipline. Theories around child development that emerged from this school of thought and are heavily driven by behaviorists like **John B. Watson** and **B.F. Skinner** differ considerably from other child development theories as they give no consideration to internal thoughts or feelings. Instead the theory is based on the assumption that all learning occurs through interaction with the environment and the environment shapes behaviour. Therefore it purely focuses on how environmental interactions influence behavior.

There are two types of learning that arose out of these theories: classical conditioning and operant conditioning. While classical conditioning is based on pairing a naturally occurring stimulus with a previously neutral stimulus, operant conditioning involves reinforcement and punishment to change behaviors. (cf. Cherry, 2019)

Piaget's Cognitive Developmental Theory

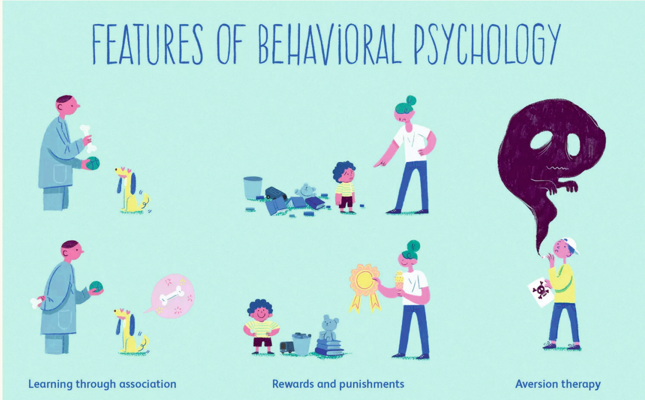

Fig. 4
Zhou, Jiaqi: Key Concepts of Behavioral Psychology, 2021
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Jean Piaget (1896 -1980) was a Swiss psychologist who was the first to make a systematic study of the acquisition of under-standing in children. He placed great importance on the educa-tion of children He is thought by many to have been the major figure in 20th-century developmental psychology. (cf. Britannica,2020, online)

The cognitive developmental theory looks at a person's thought processes and suggests that children go through four stages of mental development. (cf. Badakar, 2017, 346-350) Piaget believed that children act like small scientists and have an active role in the learning process. They learn about the world by running small experiments and observing the outcome. In that way they build up knowledge and continu-ously add to it. He also proposed the idea that children think entirely differently than adults. (cf. Marwaha, 2017) His theory does not only look at the development of thought processes and mental states, but also on how the change and devel-opment of these processes change the way we understand and interact with our environment. Piaget's four stages are: sensorimotor stage (birth - 2 years), preoperational stage (2 years - 7 years), concrete operational stage (7 years -11 years), formal operational stage (from 12 years). Let's have a closer look at the preoperational stage.

One major characteristic of this stage is that children

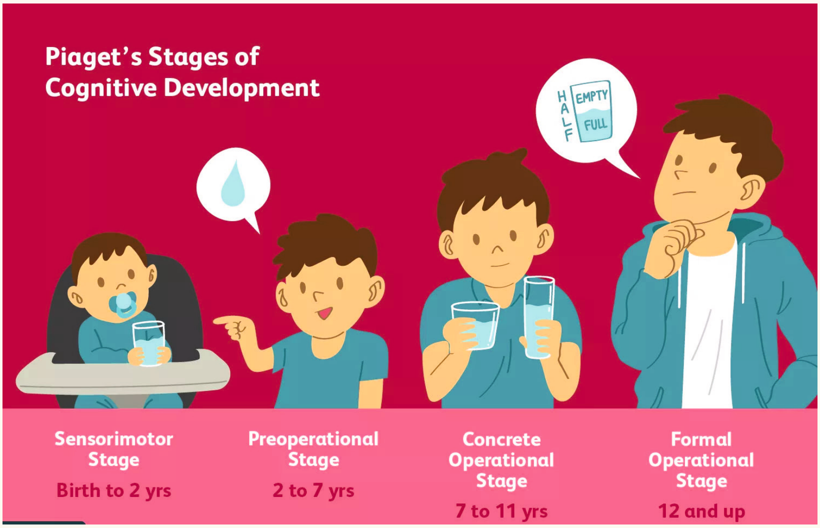

Fig. 5
Seong, Joshua: The 4 Stages of Cognitive Development, 2020
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begin to engage in symbolic play and to think symbolically. For example, a child at this stage is able to use an object to represent something else. But they still have problems understanding logic and to see the world from the perspective of another person, they tend to be egocentric. Piaget also wrote that children until the age of seven mainly learn through imitation, play and touching objects. A long-term study by scientists at the University of Florida confirmed the assumption that this also has an impact on their later life. According to this study, children who play with building blocks at an early age achieve better results in mathematics later on. Other studies around that topic show how close the connection between the sense of touch and learning processes is, even after that stage. (cf. Seng, 2017)

Bowlby's Attachment Theory

John Bowlby (1907 - 1990) was a British developmental psychologist and psychiatrist best known as the creator of attachment theory. This theory emphasizes the need of very young children to develop a close emotional bond with a caregiver.
(cf. Dijken, 2021, online)

'Attachment' is understood as an emotional bond with another person. Bowlby focuses in his theory on the earliest bonds formed by children with their parents or caregivers and how these relationships and bonds have a tremendous impact throughout the whole life. In contrast to behaviorists who believe that attachment is a learned process, Bowlby proposes that children are born with a drive to form attachments and he demonstrates that nurturance and responsiveness are the primary determinants of attachment. (cf. Draper, 1990)

Studies that build on Bowlby suggest that there are a number of different attachment styles, like ambivalent attachment, avoidant attachment, disorganized attachment or secure attachment. The secure attachment is likely developed by children who receive consistent support and care. If children receive less reliable care they may develop one of the other attachment styles. Failure to form secure attachments early in life can have a negative impact on behavior in later childhood or even throughout adulthood. Children who are securely attached tend to develop better self-esteem and self-reliance and they tend to experience less depression and anxiety. (cf. Cherry, 2019)

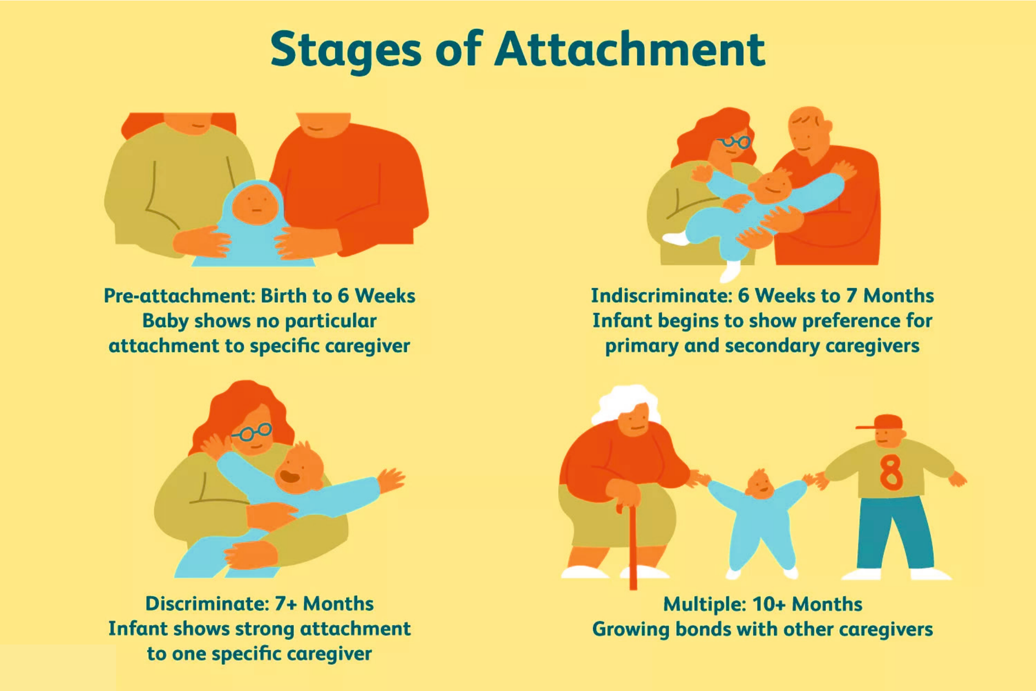

Fig. 6
Seong, Joshua: Stages of Attachment, 2019 © Verywell

Bandura's Social Learning Theory

Albert Bandura (1925) is a Canadian-born American psychologist and originator of social cognitive theory. He demonstrated in a study (referred to as the "Bobo doll" experiment) that children can learn behaviours through the observation of adults (cf. Nolen, 2020, online)

The psychologist Albert Bandura developed his social learning theory because he thought that human learning can't be sufficiently explained just by the conditioning and reinforcement process. In his book Social Learning Theory of 1977 he said: "Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do." (cf. Esteban-Guitart, 2018, 384-401)

At the heart of his theory there are three core concepts. Firstly, he introduced the idea that children and people in general can learn through observation and modeling. Like for example by watching other people including parents, peers perform a certain task. Secondly, Bandura realized that reinforcement doesn't always come from the outside, but the child's mental state is essential for acquiring knowledge or learning a new skill. Lastly, according to this social learning theory, learning doesn't necessarily lead to change. In contrast to behaviorists who believe that learning inevitably leads to changing behavior, Bandura believed that children are able to learn without demonstrating new behaviors. He also identified a few steps that are key to successful learning: attention, retention, reproduction and motivation. Paying attention is crucial to learn and if there is a novel aspect involved in the process is far more likely for the child to pay full attention. Retention is the ability to retrieve information later and act on it which is vital to acquire new skills. Once a child has retained information, it needs to reproduce the behaviour in order to improve and advance. In order to be really successful in learning there is a need of motivation to imitate the behavior that has been modeled.

Many classroom strategies that are used today have their roots in social learning theory, like for example encouraging children and building self-efficacy. (cf. Fryling, 2011, 91-203)

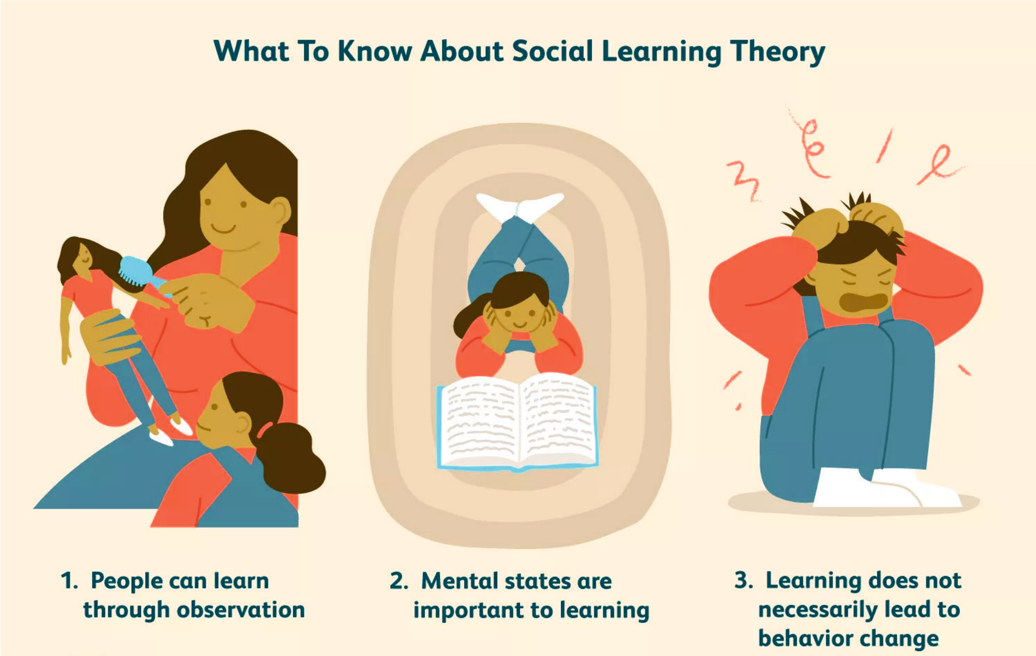

Fig. 7

Bee, JR: Social Learning Theory, 2019 © Verywell

Lev S. Vygotsky (1896 - 1934) was a Soviet psychologist. He is best known for his work on psychological development in children. One of his most famous concepts is about the zone of proximal development: the distance between what a pupil can do on their own, and what they can accomplish with the support of someone more knowledgeable.
(cf. Britannica, 2020, online)

Vygotsky's Sociocultural Theory

Similar to Piaget, Vygotsky based his theory on the assumption that children learn in an active way through lived experiences. The difference between these two theories is that Vygotsky put a greater focus on how social factors influence development. (cf. Forman, 1985, 23-39) He believed that human learning is largely a social process and he also takes into account how cultural beliefs and attitudes affect the learning process and child development. Every child is born with basic biological constraints, but each culture addresses these constraints with different tools. (For example in one culture it might be more common to take notes to remember things, other cultures might use rote memorization.) Only by interaction with other people, learning becomes integrated into the understanding of the world of a child. The support of more knowledgeable people helps the child to continuously progress and increase their skills and scope of understanding.

One important concept that was introduced by the sociocultural theory is called 'the zone of proximal development.' (cf. Meijer, 2001, 93-113) Vygotsky describes this as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers." So essentially this describes everything that a child might not be able to do on its own yet but is capable of learning with the help of someone. Often children stretch their knowledge by observing someone slightly more advanced, they slowly extend this zone of proximal development.

Vygotsky's theory has become more popular in recent years and finds its application in many classroom settings. (cf. Sanders, 2005, 203-207) Teachers can offer instructions that slowly stretch the limits of each child's knowledge by first assessing the pupils' current skill level. Over time the amount of assistance needed can be decreased and the zone of proximal development will expand. They might use methods such as organizing the class into smaller groups and pairing less skilled children with a little more advanced pupils, using hints, prompts and direct instruction or scaffolding.

Vygotsky also believed in the importance of play for learning and development. Through playing and imagining, children are able to strengthen their conceptual abilities, understanding of the world around them and promote the growth of abstract thinking. (cf. Van Oers, 2013, 511-534)

I'd like to take a closer look at the connection between learning and play, but first I would like to finish this chapter around child development by going back to the topic of haptics and the physical part of child development like gross and fine motor skills.

Fig. 8

Gilmartin, Brianna:
Sociocultural Theory of
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Motor Skills

Developmental stage of 5-7 year olds

In essence motor skills are the ability to perform a predefined movement outcome with high confidence and maximum certainty. There is usually a distinction between gross and fine motor skills. Gross motor skills mostly develop during early childhood and use large muscle groups to perform movements like running, walking, jumping, balancing or even throwing, kicking or swimming. (cf. Stallings, 1973) The performance level of these skills is very stable, even over a longer period of non-using this skill. In contrast there is generally a retention loss of fine motor skills over a time of non-use. Fine motor skills use smaller muscle groups to perform tasks with the hands, fingers, feet, toes or wrists. There are many aspects that can have an effect on fine motor skills and decrease the control like injury, illness, stroke or even problems with the brain, muscles, peripheral nerves or joints. (cf. Liddle, 2003)

Motor skills develop along three principles. Firstly they develop from head to foot, the head develops earlier than e.g. the hand and the coordination of the legs and feet develop even later.
Furthermore, limbs development depends on their proximity to the body, limbs that are further away develop later. Lastly, larger muscle movements develop earlier than smaller movements. (cf. Newton, 2012)

A critical period for motor skill development is between the ages 3-5. During this time there is significant development of neuroanatomic structures. Motor skill acquisition is age-related but not age dependent. Typically by the age of 5 years, children are expected to attain gross motor skills that are essential for postural control and vertical mobility.

Fine motor skills gradually develop throughout our lifetime. They are seen during child's development stages and 'basic' fine motor skills are typically acquired between the ages of 6-12 years. Essential to mention is that they develop with age but it also takes a lot of practise and an increased use of the muscles.

Initially when babies are born, the first motor skills are characterised by involuntary reflexes. (cf. Wells, 2014, 756-760)
After the first year, the fine motor skills have developed to enable the manipulation of objects a bit more intentionally. Children gain more experience of ability to identify objects based on their shape, size and weight. By playing with objects in their environment, children know only develop motor skills but also learn how the world works. (cf. Childcare, 2019, online)
Between the ages of 2 and 5 children develop the ability to grasp objects using the static tripod grasp. This technique combines using the index, thumb and middle finger. The skills at this age are moderate, children are able to cut shapes out of paper, pick up objects, draw and button their clothes. Furthermore, they have greater sensory awareness and analyse their environment with their senses. This helps them to coordinate their movements better and adapt them to the environment. Between the ages of 5 to 7 years, children's movements are more focused on the wrist and fingers and the rest of the arm is less involved. Their fine motor skills are more refined and their movements become more fluid and synced. Typically they are able to make precise cuts, like e.g. a circle, to open a lock key, to tie their shoes and copy a triangle shape. (cf. Children's Therapy & Family Resource Centre, 2011, online)

Educational Approaches

Pedagogical concepts

After looking at different theories on child development and the development stage of 5-7 years olds, I'd also like to take a closer look at a few pedagogical concepts and approaches. Pedagogy and educational science are terms for a scientific discipline that deals with the theory and practice of education and upbringing, mainly of children and young people. Pedagogical concepts describe the combination of methods, procedures, goals and techniques. Pedagogical approaches, on the other hand, form a starting point from which concepts can be developed. (Gartinger, 2014, 260)
There are numerous pedagogical concepts. My aim is not to cover the full breath of different approaches, but to mention a few that I found very inspirational for my project.

Montessori education

Montessori education goes back to the Italian educator and doctor Maria Montessori. In 1907 she founded the first Montessori children's home in Rome. (cf. Seitz, 1996, 20)
At the core of Montessori education are the child and its needs. A child's personality should be respected and educators should support the child in acting and thinking independently. (cf. Ludwig, 2003, 52)
According to Montessori every child itself chooses the necessary materials from the environment that it needs for development. The role of the caregiver or educator is to prepare and provide a rich environment. (cf. Ludwig, 2003, 22) This environment should be sense-stimulating because Montessori observed how important it is for children to perceive the environment with all senses. (cf. Seitz, 1996, 37)

Her motto is ‘help me do it myself’. The children should have all the necessary time and the space to try things out until they find the right solution on their own. They should be allowed to make mistakes because this is the only way they can learn independently.

Fig. 9

The education innovator, in London, 1940 © AP Photo

“He does it with his hands, by experience, first in play and then through work. The hands are the instruments of man’s intelligence.”

Maria Montessori - The Absorbent Mind 1949

Fröbel's pedagogy

Friedrich Wilhelm August Fröbel is considered the founder of the kindergarten. In 1840, he opened the so-called play circle for children in the town of Blankenburg. The most important element of Froebel's pedagogy is free play. He believed that education shouldn't and in fact can't be imposed on children from outside, but it's rather controlled by the children themselves. The aim is to raise independent thinking and self-reliant personalities. (cf.Ebert, 2007, 9)

Children's development is stimulated and promoted through play activities and play materials. Fröbel used special toys oriented to the developmental needs of the child, so called 'Fröbelgaben'. The three-dimensional basic shapes developed by Fröbel are still popular elements of children's toys. (cf. Ebert, 2007, 15)

Like Montessori, Fröbel believed that children are the experts of their own development and the main responsibility of educators is to provide an engaging and inspiring environment.

Fig. 10

Haftmann-shop, n.d.

Waldorf education

Rudolf Steiner founded the Waldorf education. He took a very holistic approach in his educational concept. Artistic and practical elements are at the core of Waldorf education. (cf. Seitz, 1996, 103) In his opinion children should not be suppressed in their own development and independence. Education is calm and slow and it's better to just observe and register than to control. Educators should make sure that the surrounding conditions support the work of nature. (cf. Seitz, 1996, 113) Steiner categorised 12 different senses and aimed to stimulate all of them with his holistic approach. (cf. Seitz, 1996, 120) In his opinion senses can only be stimulated when the material and the environment are as original and natural as possible. It was important to him to use geometric archetypes, natural colours, textures and materials to simulate the children's imagination. (cf. Seitz, 1996, 121)
Rhythm and movement are also central elements of Waldorf education. The whole approach should reconnect thinking and feeling and Steiner used to call it 'the education of head, heart and hand'. (cf. Seitz, 1996, 118)

These were some examples of pedagogical concepts.
The three I have briefly touched on here all belong to the area of reform education. The term 'reform education' is not clearly defined but often these methods are based on the pedagogies of Comenius, Rousseau and Pestalozzi. One commonality of these approaches is the child-centricity and the value of exploration, experimentation and an element of play. I'll continue to take a closer look at the connection between learn and play.

“If a child has been able in his play to give up his whole loving being to the world around him, he will be able, in the serious tasks of later life, to devote himself with confidence and power to the service of the world.”

Rudolf Steiner -Education as an Art 1988

Learn and play

Play

The role of play in children's development

Learning and Play

Learning sometimes is seen in a very academic and strictly cognitive sense, but child development research has shown that it is so much broader and interconnected. Many of these studies show that different domains of development are not silos and they extend the view of learning to areas like social development like empathy or theory of mind, physical development like fine and gross motor skills, emotional development like developing self-regulation or creative development like divergent thinking or creating something new. Physical development, for example, lays the foundation for cognitive and social skills in later life. (cf. Karaski, 2013) Studies conducted with children across the span of their childhood showed that infants who explore more sensually and are more physically active show more success in school. (cf. Bornstein, 2013) The impact of these early childhood exploration is massive, some studies even found evidence that children's ability to control their impulses in preschool predicts a wide range of outcomes in their adulthood like better health, lower rates of substance abuse and better grades. (cf. Mischel et al., 2011)

But what is the best way to build these crucial skills for the future?

Playful learning experiences appear to be particularly effective for the development of broad, dynamic and interconnected skills. Throughout the different theories mentioned above, the importance of play has been acknowledged by multiple researchers. I'd like to take a closer look at different types of play and how they benefit children throughout their lives. As this topic is extremely broad I will focus on the aspects that are connected to sensory stimulation, especially haptics and the development of motor skills and what types of play are most beneficial for children between the ages of 5-7 years.

Play is a natural inclination not only for human children but other animal species as well. There is a considerable body of research which indicates that play helps individuals within a species to learn, grow and thrive. (cf. Pellegrini, 2007)

To be able to successfully learn through play children need to have a certain degree of freedom. They should be supported rather than directed and they need to experience agency. This doesn't mean there shouldn't be any guidelines or rules at all, it means to see children as capable individuals rather than a blank slate to fill. To promote children's executive functions, which is a crucial skill for goal setting and flexible thinking children should play an active role in a problem-solving task. (cf. Matte-Gagné, 2015)
Many research studies show that play incorporates many aspects that lead to deeper learning and that it creates an environment that is optimal to develop many skills and knowledge that is needed to thrive as an adult. One of these aspects is the intrinsic motivation children have to play, which makes this a fertile ground for developing new skills. Furthermore children are able to make decisions and choices during play about what they do and how. Many play types are highly social and allow children to learn from each other. However, not all learning is play, and not all play is learning. There are a few characteristics that define an optimal setting for playful learning experiences: (cf. Zosh, 2017, 12)

→ **Children experience it as joyful**

→ **It helps children to find meaning in what they are learning**

→ **Children are actively engaged and are in a state of minds-on thinking**

→ **It involves iterative thinking**

→ **It involves social interaction**

Children experience it as joyful

The predominant emotions of play are interest and joy. Joy is necessary for an experience to be playful. Joy can be seen in a broad sense, it could be enjoyment, motivation, thrill or another positive emotion. It can be experienced for a short moment or over the entire play session. This doesn't mean there shouldn't be any negative or neutral emotions involved, in fact some frustration is needed to feel the joy of breakthrough when a problem is solved. (cf. Zosh, 2017, 18)

It helps children to find meaning in what they are learning

This means children should be able to connect the knowledge they gain to something they already know and find meaning in the experience. The opposite of meaningful learning is a "learning illusion" which describes gaining information in isolation and without context. Children might be able to recite the alphabet, but they are unable to identify the letter or the relevant sounds that go with each letter. They must learn to connect the illusory fact to something in their life or their environment to move past rote learning. Learning through play can help them to tap into existing knowledge, see relationships and gain deeper understanding. One example of this is 'dialogic reading'. This means parents or teachers would not simply read the words on a page but ask the children how they think the story goes on or how a character might be feeling. This enables children to relate the story to their own experiences and is directly linked to greater vocabulary gains. (cf. Zosh, 2017, 20)

Children are actively engaged and are in a state of minds-on thinking

There are lots of benefits to learning if a child is immersed in a task so much that he or she persists through distractions and is truly minds-on. To enable children to actively engage there must be enough freedom for exploration. This does not mean that there should be zero guidance, but often less structured environments nudge children to more experimentation and these more discovery based techniques can support a more conceptual understanding. Neuroscience finds that the brain activation increases significantly when there is active and engaged involvement, it enhances memory encoding and retrieval processes. (cf. Zosh, 2017, 22)

It involves iterative thinking

Play that helps children to try out new options, discover new questions or test hypotheses leads to deeper learning. The agency a play scenario provides to explore unknowns in a safe space and to experiment without risk encourages iterative behaviour. In one study one group of children was shown a very clear demonstration of the functionalities of a toy, another group of children viewed a much more ambiguous demonstration of it. The time spent on playing with that toy was significantly higher in the second group.

Over time practising iteration engages brain networks that are related to flexible thinking, creativity and taking alternative perspectives. (cf. Zosh, 2017, 24)

It involves social interaction

An even stronger context for both play and learning is social interaction, although it can also happen on one's own. When playing together, children not only enjoy being with others, but they also form more powerful relationships and build a deeper understanding. The importance of social interaction is probably best highlighted in Vygotsky's sociocultural theory mentioned above. Social interactions in early childhood set the stage for learning and development throughout the life course. Positive relationships build the neural foundations for developing healthy socio-emotional regulations and protecting from learning barriers, like e.g. stress, as well as promote plasticity in the brain. (cf. Zosh, 2017, 26)

Play types - Play with objects

Within the area of play there are five types of play (proposed by Whitebread 2012): physical play, play with objects, symbolic/semiotic play, pretend play and games with rules. I'd like to take a closer look at the 'play with objects' play type.

This play type is widely observed in primates. It is mainly concerned with children's developing explorations of the objects they find in the world around them. There are also some links to physical play, especially concerning fine motor development. Children start really early to explore how objects and materials feel and behave, which is known as 'sensorimotor' play. Over time they begin arranging objects, which gradually develops into sorting activities. By the age of 4 years, children are able to perform building, making and construction tasks.

According to Vygotsky, 'play with objects' is particularly related to the development of problem-solving strategies and thinking skills. There were also studies around the connection between play with objects and the development of mathematical skills. In a study that he conducted in 1992 with children over the course of 2 years from age 5 to age 7 Pellegrini found that object play in recess significantly predicted their first-grade school results, particularly in maths. (cf. Whitebread, 2017, 10 -14)

Now that we talked about the benefits of the combination of play and learning and we know what needs to be true for an experience to be effective, how should an interaction or toy should be designed to create joyful play experiences in which children are actively involved and engaged? One aspect that comes up often in the context of engaging children and creating joy, is music. I would like to incorporate an aspect of music into my design, not only because it is fun and engaging for children, but also because it involves sound as a second focus sensory system. Multi-sensory interactions as mentioned above, are also extremely beneficial for children's brain development. Let's take a look at what role music plays in the lives of 5-7 year-olds and what we can learn from early musical education.

Early musical education

Early musical education

Besides enabling joyful experiences, there are many other benefits that music itself provides for growing children, including cognitive development, social skills or emotional self-regulating abilities. On a physical there is a big impact on gross and fine motor skills, because they e.g. learn how to move their body to music or later learn to play an instrument. (cf. Parlakian, 2010) Children are able to start building a musical foundation as soon as they are born, but I will have a closer look at the musical development of children from 5-7 years. As mentioned above, they are much more able to control their physical abilities by that age, and start benefiting from more structures, yet not necessarily from formal music instruction on a real instrument. There are some aspects that are important to ensure high quality music education for this age group. I picked a few that I'd like to explain in more detail : hands-on music making and using multi-sensory experiences to develop musical thinking, learning through play, learning in a group, rather than as an individual and the focus on the process of music making, rather than on a performance.

Multi-sensory, hands-on music making

Like mentioned in the play chapter children between the ages of 5-7 years need to be actively engaged in a task to learn best, and it's the same for music making. Multi-sensory experience can help with that. Seeing, hearing and feeling objects is essential, because these children are still in the concrete learning stage. This means that before they are able to understand abstract concepts (like in this case reading sheet music) they must first see and experience individual elements and practise them on their own. Therefore multi-sensory experiences are especially beneficial for this age group, even though they are recommended for all early childhood education. They might be able to learn an instrument and play sheet music at that age, but it is not developmentally appropriate and might hard-wire their brain to think about music in a different, more logical, mathematical way rather than developing music intelligence. (cf. Feierabend, 1995, online)

Learning through play

This topic was already covered in depth earlier. Children that are still primarily learning through play and being engaged in this playful experience, build love for the process of music making and music intelligence.

Learning in a group

Children that age love playing together and interacting with their peers. Over time and with a bit of guidance they begin to bond and start to support each other. They are motivated by watching others accomplishing more challenging tasks and are eager to teach others what they already know and learned.

Focus on the process of music making, rather than on a performance

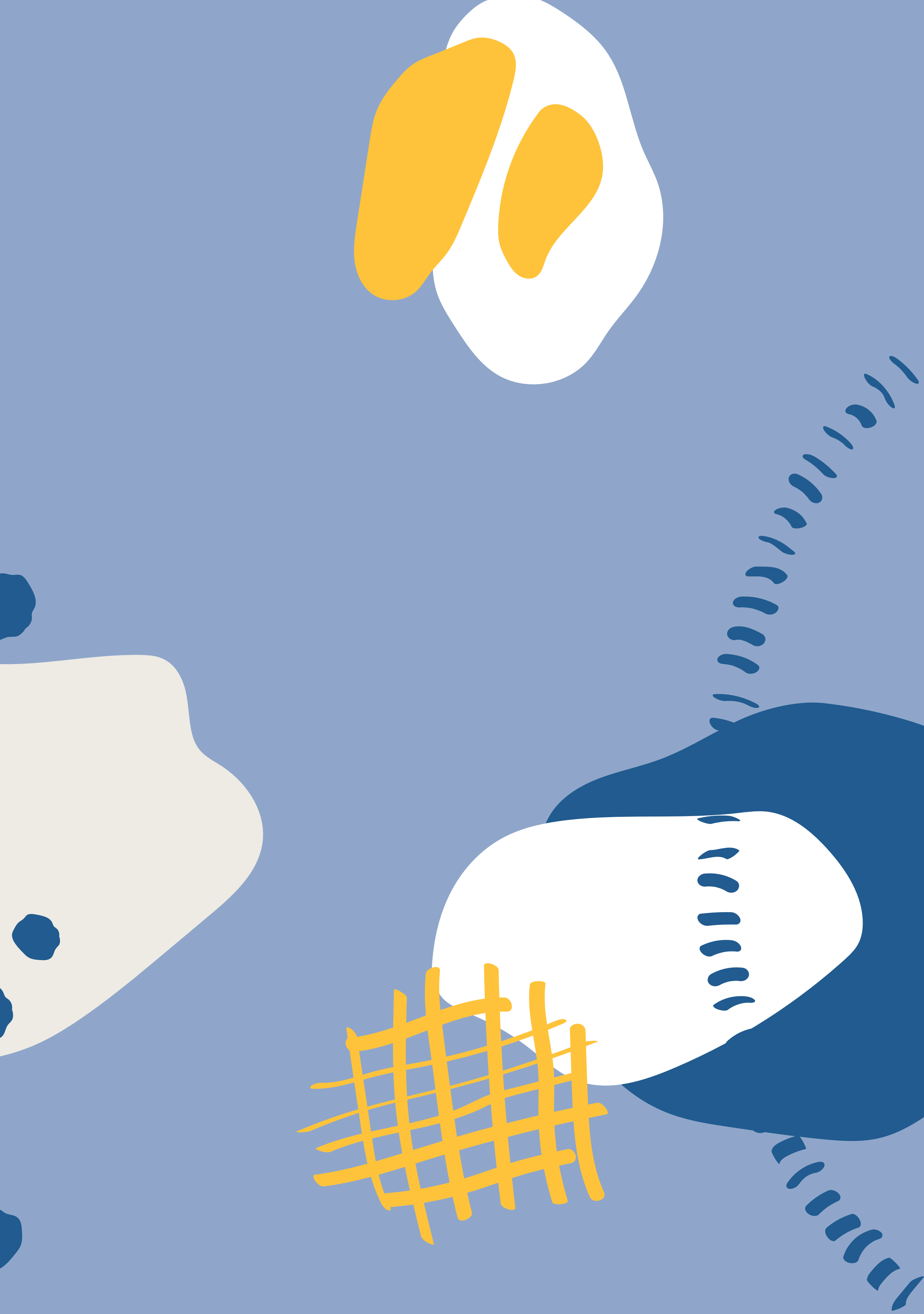
At the age between 5-7 years children still want to explore a variety of techniques without perfecting a song in order to perform it. They are typically not ready on an emotional and social level to perform in front of others. They should enjoy the process and if they just focus on learning one piece of music the joy might get lost. It is really helpful to break down bigger concepts and skills into smaller attainable steps. (cf. Mondale, 2015, online)

There are of course many different methods of early musical education, one that I'd like to point out is the approach of Orff. Carl Orff was a German composer who lived 1895-1982 and developed a 'child-centered way of learning' music. He believed that every child has the ability to learn music if done in a gentle and friendly way. He combines music, movement, speech and drama in a way that is very close to the child's world of play and engages with his methods childrens' minds and bodies. He also developed a range of instruments that are also known as 'Orff instruments'. They are mainly percussion instruments like xylophones, glockenspiels or metallophones. All of these instruments are intuitively to handle and invite children to just explore and try them without any long introduction. His method also uses many materials that are very basic, natural and close to a child's world of fantasy. Another important aspect is that his lessons mostly happen in groups and sometimes even involve parent participation. One example Orff lesson might start with a poem that is read out by the teacher. The children are then invited to choose instruments or materials and make a sound or noise that describes the characteristics of one of the characters in the poem. The children might also act out part of the poem or accompany it by singing and clapping. (cf. Estrella, 2019, online)

"Since the beginning of time, children have not liked to study. They would much rather play, and if you have their interests at heart, you will let them learn while they play; they will find that what they have mastered is child's play."

Carl Orff

Part 2



Design Principles

Based on the research I did on haptics and child development I would like to identify a few design principles that should help moving forward towards designing a toy or learning tool that nudges children between the ages of 5 and 7 years to explore their different sense modalities.

1 Multisensory

Haptic is at the core of my thesis, but it should not be limited to the sense of touch. Experiences on multiple sensory levels reinforce each other and become much stronger.

2 Self-explanatory

It should enable exploration and experimentation without long explanations or learning complicated rules. It should become intuitive how it works.

3 Play

There should be a strong element of play and joy to engage children actively in the process. In this case I would like to incorporate sound and music as one part of a joyful interaction.

4 Collaboration

The set up should promote collaboration between children. There should not be hierarchy or limitation of how many children can participate.

5 Natural

Used materials and textures should be as raw and as natural as possible. No plastic parts if avoidable, no screens. Technology should stay in the background.

6 Expandable

It should not be a limited set up. It should be easily expandable and adaptable to different levels of complexity and difficulty.

Inspirational Research

Desk Research

Inspiration

Multisensory & haptic toys and tools

Here are some great examples I found in the field of learning tools and toys with a strong haptic component.

A project that really caught my eye is the tactile picture book for blind children by Croatien designer Zrinka Horvat. In her graduation project she explores tactility in the book medium. One of her main conclusions is that books for blind children ignore the lack of visual memory and she wanted to create tactile pictures that create a memorable feeling for blind children. (cf. Horvat, 2015, online)

The 'i spy' set by Aleta kids is designed to help children discover shapes, scale, perspective and depth. They are able to play with shadows and see how they change when moving the shapes. The toy can be used in many ways and allows for exploration. Ultimately this should support children to be more creative and express themselves. (cf. Aleta-kids, n.d., online)

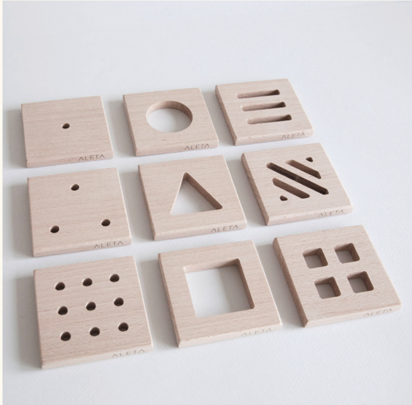
The flash card kit 'hello haptic' was designed by Korean designers Rhea Jeong , Young Soo Hong, Sunmin Lee and Sae Hee Lee. They wanted to help visually impaired children to explore and learn about their sense of touch. Textured flashcards give them tactile knowledge and help them to stimulate outdoor activities. There are different kits inspired by locations such as the zoo, sea shore or forest. (cf. Choi, 2009., online)

Fig.11

Horvat, Zrinka: Tactile Picture Book
for Blind Children 2015 © Zrinka Horvat

Fig.12

Horvat, Zrinka: Tactile Picture Book
for Blind Children 2015 © Zrinka Horvat



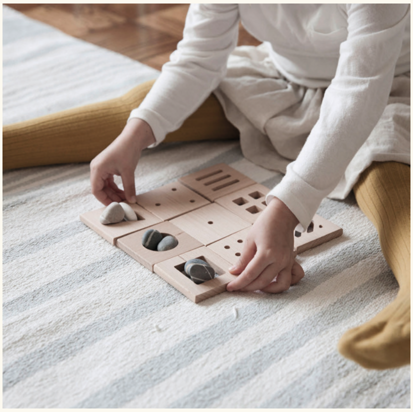


Fig.13

Aleta-kids: i spy n.d.
© Aleta-kids

Fig.14

Aleta-kids: i spy n.d.
© Aleta-kids

Fig.15
Jeong, Rhea: Hello Haptic 2009
© Rhea Jeong

Fig.16
Jeong, Rhea: Hello Haptic 2009
© Rhea Jeong

Fig.17
ThreewoodShop:
Pre-writing tracing
Interhemisphere board n.d.
© ThreewoodShop

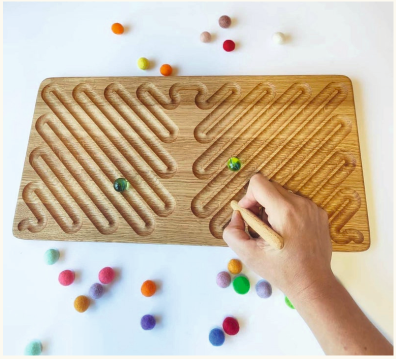


Fig.18
ThreewoodShop:
Pre-writing tracing
Interhemisphere board n.d.
© ThreewoodShop

Fig.19
Odinparker: Wooden
Math Board n.d.
© Odinparker

Fig.20
SensoryPlay: Weather n.d
© SensoryPlay

Fig.21
Teenytinymom: Thumbelina
n.d.© Teenytinymom

Fig.22
SensoryEdge: Gonge
Children's Tactile Discs n.d
© SensoryEdge

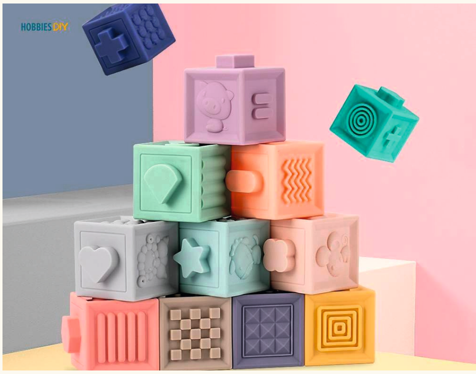


Fig.23
Busykids: Soft Musical
Squishy 3D Building Blocks
n.d.© Busykids

Fig.24
Busykids: Soft Musical
Squishy 3D Building Blocks
n.d.© Busykids

Fig.25
MirusToys: Tactile
memory game n.d.
©MirusToys

Fig.26
SensoryEdge: Pig Wooden
Sensory Play Wall Decor n.d.
©SensoryEdge

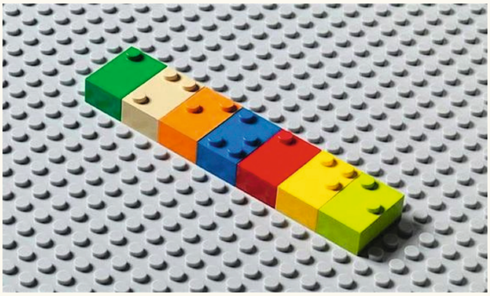


Fig.27
LEGO® Braille Bricks
n.d.©LEGO® Braille Bricks

Fig.28
Mocosubmit:
Tactile Picture Book n.d.
©MocoLoco

Montessori learning tools

The body of work created by Montessori and Waldorf are reflected a lot in many tools and toys which are used in schools, kindergartens and at home.

One principle that is used quite often in the Montessori sensorial works is the contrast between rough and smooth surfaces. Rough and smooth boards help children to explore their sense of touch and learn the difference between textures. Sandpaper letters is another format that guides the children's hands to write and learn the alphabet in a more sensory way. Another popular object is the sandpaper globe that helps children to develop a concept of the shape of the earth and the distribution of water and land over the earth.

Another section of Montessori tools are sensory puzzles. This haptic puzzle by Serenitytoysboutique is a newer version of the original by Montessori. Children flip the pieces over to feel them and identify the different tactile surfaces. The big puzzle pieces match to a spot on the puzzle board. Children learn to differentiate and match bumpy ridges, smooth surfaces or soft plushes and practice classification.
Sound boxes are auditory puzzles. Two sets of sealed wooden boxes contain different materials which make a distinctive sound when shaken. Children try to distinguish sounds and pair the same sounds.

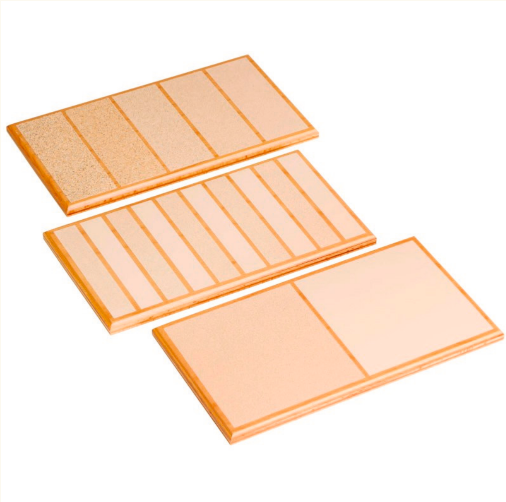


Fig.30
Amiispe: Letters Sensory Sandpaper Board n.d. © Amiispe

Fig.29
Nienhuis: Rough And Smooth Boards Set n.d. ©Nienhuis

Fig.32
SerenityToysBoutique: Tactile Search and Match n.d.
©SerenityToysBoutique

Fig.33
SerenityToysBoutique: Tactile Search and Match n.d.
©SerenityToysBoutique

Fig.31
Nienhuis: Globe Of Land And Water: Sandpaper n.d.
©Nienhuis

Fig.34
Nienhuis:
Sound Boxes n.d.
©Nienhuis

Fig.35
Headu: Tactile Puzzle
Montessori n.d.©Headu

Fig.36
OnWoodLt: Montessori
Counting Tracing Boards
n.d. ©OnWoodLt

Fig.37
SensoryPlay: Solfege
hand sign Set n.d.
©SensoryPlay

Fig.38
FromJennifer: Montessori
Shapes Tracing Cards n.d.
©FromJennifer

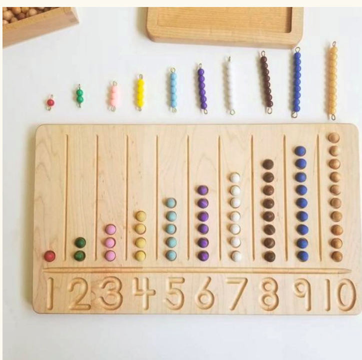


Fig.39
MirusToys: Number
counting board n.d.
©MirusToys

Fig.40
MirusToys: Rainbow
color sorting toy n.d.
© MirusToys

Fig.41
OnWoodLt: Wooden Alphabet Letters Puzzle n.d.©OnWoodLt

Fig.42
Montessori-shop : Tastkasten, Fühlbox n.d.©Montessori-shop

Fig.43
HappyTreeStore: Mathematics Sorting Toy n.d. ©HappyTreeStore

Fig.44
Montessorinature : DIY Montessori n.d. ©Montessorinature

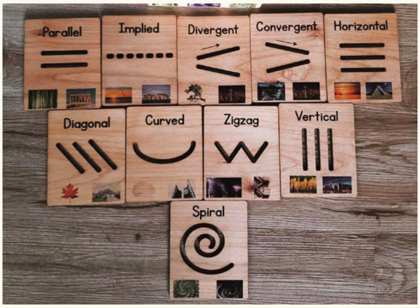


Fig.45
MirusToys: Art of elements n.d. ©MirusToys

Fig.46
SmekalkinToys: Activity busy board n.d. ©SmekalkinToys

Phygital toys and tools

Another interesting section are multisensory toys and learning tools or toys that combine analog and digital components. Some of these toys with digital components avoid to base their play interaction on screens, others augment scenes with other tactile components.

The YotoPlayer is a screen-free speaker that can be controlled with physical cards. These cards can be bought or even made by the children themselves and allows them to play only the audio content that they want to listen to. A similar example is the Toniebox. This speaker needs small figures so called "Tonies" to enable listening to stories. Each Tonie 'stores' and represents a story. As soon as children place it, the Box recognises the figure, downloads the story and plays it directly. (cf. Yotoplay, n.d., online)

A very popular toy, especially in Germany and Austria, is the TipToi. It's a pen that augments children's books with sound. If a child taps on a picture or a text with the TipToi pen a suitable music, speech or sound is played. (cf. Ravensburger, n.d, online)

The Vai Kai companions always come in pairs. The small wooden dolls can communicate through giggles, heartbeats, kisses, sneezes and squeaks. They are designed to stimulate all senses and activate children's imagination without screens. When the two companions come closer you can feel their heartbeats going faster and they can also react to each other's calls. (cf. VaiKai, n.d., online)

Fig.47
YotoPlay: Yoto Player
n.d. © Yotoplay

Fig.48
YotoPlay: Yoto Player
n.d. © Yotoplay

Fig.49
TipToi: Stift n.d.
©Ravensburger

Fig.50
Tonies: Die Toniebox
n.d. ©Tonies

Fig.51
VaiKai: Vai Kai
Companions n.d. ©VaiKai

Fig.52
VaiKai: Vai Kai
Companions n.d. ©VaiKai

Techwillsaveus is a UK company that wants to spark children's creativity using hands-on technology. To offer make-it-yourself and kits to help kids make, play, code and invent using technology. One very successful kit is their conductive dough kit. Children can use dough to build electrical circuits through tactile play. Another example is the Microbit and the Microbot kit that teaches children to build and code their own robots. ˝ (cf. Techwillsaveus, n.d., online)

DragDrop is a haptic game played on the iPad. Children learn to recognise and mix colours. They use wooden building blocks in different shapes that serve as the input medium. Children also have to recognise and combine basic shapes and composite shapes. Through using haptic experiences rather than purely digital elements, children can much better grasp and understand shapes. (cf. Fahlke, 2018, online)

Osmo enables children to use objects in the real world to interact with the digital world shown on their tablets. In hands-on learning games they merge tactile exploration with actively engaging tasks and innovative technology. (cf. Osmo, n.d., online)

Cubetto is a cube-shaped wooden robot designed to teach children the basic principles of coding. There are a variety of colorful instruction blocks that can be arranged and combined in different ways. Each block represents a chunk of code that in combination with other blocks generates commands for the robot. Red blocks for example are used to move forward, blue to turn left and so on. (cf. Primotoys, n.d., online)

Fig.53
Techwillsaveus:
Electric Dough n.d.
©Techwillsaveus

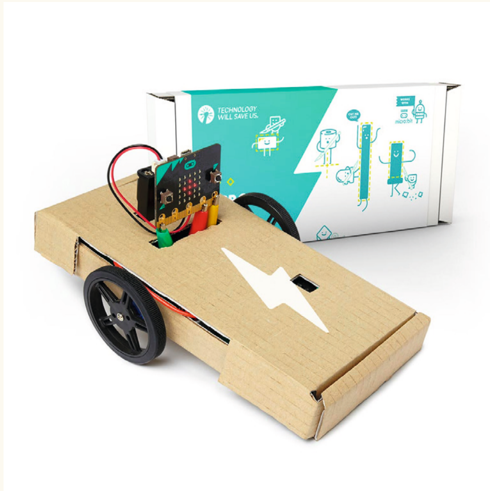


Fig.54
Techwillsaveus :
micro:bot Kit n.d.
©Techwillsaveus

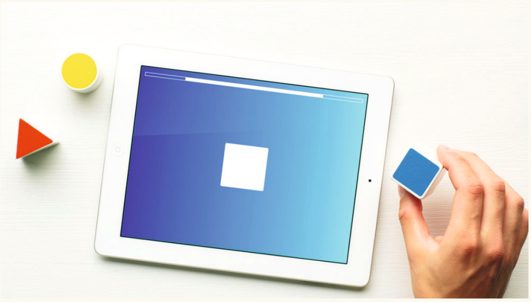


Fig.55
Fred Fahlke: Drag Drop
n.d. ©Fred Fahlke

Fig.56
Fred Fahlke: Drag Drop
n.d. ©Fred Fahlke

Fig.57
PrimoToys: Cubetto n.d.
©PrimoToys

Fig.58
Osmo: PlayOsmo n.d.
©Osmo

Haptic Interfaces & multisensory music making

During my desk research I also looked outside the area of toys and learning tools and found many interesting applications of haptic interfaces and multisensory experiences especially in combination with music making and using objects as input sources. Rather than using only flat buttons, designer Ming Kong wanted to explore three-dimensional shapes for navigating digital environments. Kong developed a conductive material that can be moulded into different shapes. With this project the designer tried to explore the possibility that a new form language could also be a useful technology itself. (cf. Howarth, 2015, online)

The project 'A Moment of Transition' is the latest iteration of the project 'Tangible Scores' of sound artist Enrique Tomás. In his work he investigated possibilities of musical embodiments into musical instruments. This project is a live electronics work performed with a novel interface. Tomás explores tactile patterns that are engraved on the instrument. The tactile and sonic contents are analyzed by a machine learning system. Together with a generative lighting system this creates a live performance where sound, light and interface become both instrument and musical notation. (cf. Tomás, 2018., online)

Interaction Designer Jonas Friedemann Heuer developed 'Noteput' an interactive music table with tangible notes. Not only plays touch a huge role in this concept, the music table actually combines all three seses of hearing, sight and tough. The purpose of this is to make it easier and more interesting for children to learn classical notation of music. Whole, half, quarter and eighth notes differ not only in their shape, but also in their weight. (cf. Heuer, 2010., online)

Fig.60
Kong, Ming: Tactile interface to navigate CAD environments, 2015 ©Ming Kong

Fig.59
Kong, Ming: Tactile interface to navigate CAD environments, 2015 ©Ming Kong

Fig.61
Tomás, Enrique: A moment of transition, 2018 ©Elisa Unger

Fig.62
Tomás, Enrique: A moment of transition, 2018 ©Elisa Unger

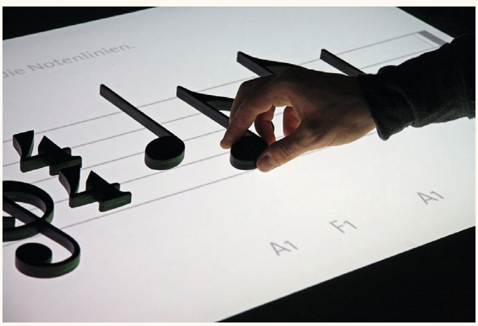


Fig.63
Heuer, Jonas: Noteput, 2010 ©Jonas Heuer

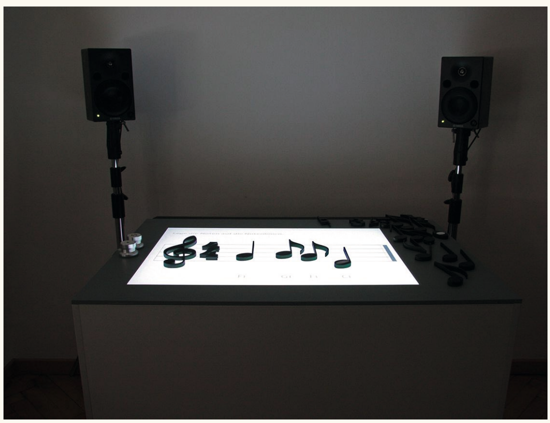


Fig.64
Heuer, Jonas: Noteput, 2010 ©Jonas Heuer

Fig.65
Roli: Seabord n.d.© Roli

Fig.66
Roli: Seabord n.d.© Roli

Fig.67
Van Pottelbergh, Simon:
Tac.tiles 2017 ©Simon Van
Pottelbergh

Fig.68
Van Pottelbergh, Simon:
Tac.tiles 2017 ©Simon Van
Pottelbergh

Fig.69
Joines, Kale: Soundscape 2012
© Kale Joines

Fig.70
Joines, Kale: Soundscape 2012
© Kale Joines

Fig.71
Kaltenbrunner, Martin: TUIO
n.d.© Tangible Music Lab

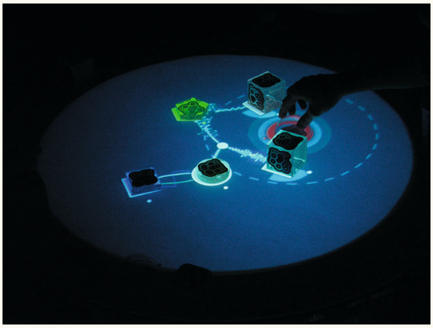


Fig.72
Kaltenbrunner, Martin: TUIO
n.d.© Tangible Music Lab

Fig.73
UniformThis Musical
Paper, 2013 © Uniform

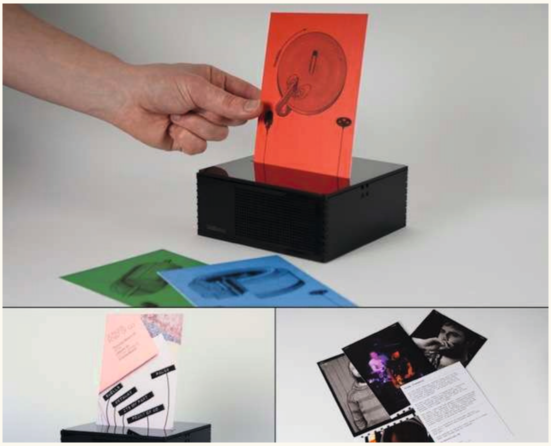


Fig.74
UniformThis Musical
Paper, 2013 © Uniform

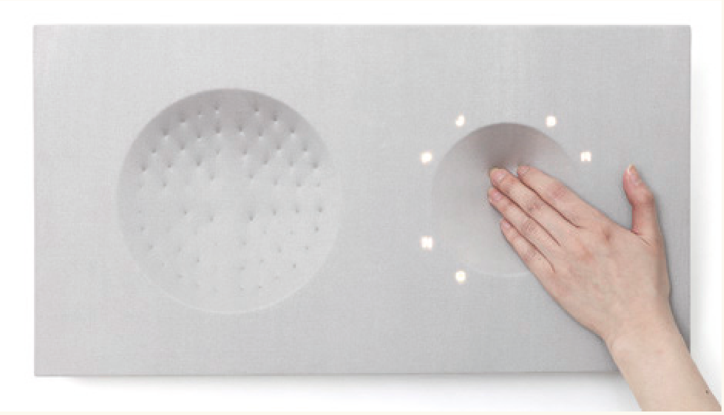


Fig.75
Jo, Eunhee: Tangible Textural
Interface, 2012 ©Eunhee Jo

Fig.76
Jo, Eunhee: Tangible Textural
Interface, 2012 ©Eunhee Jo

Expert interviews with a Montessori teacher

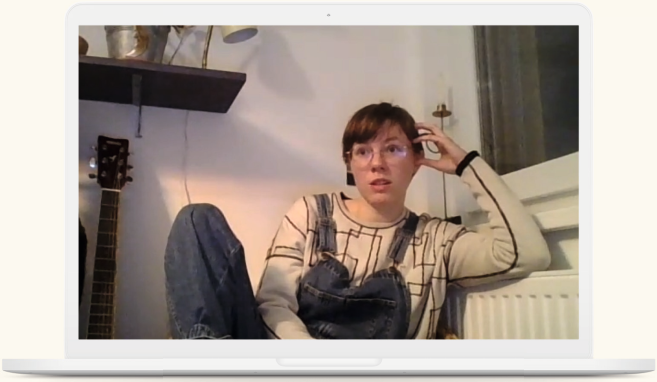
I had the chance to interview Hannah, a Montessori trained teacher living and working in Vienna. After her study she first started to teach in integrative classes and worked with children with special needs and migration background. She quickly became frustrated by the lack and the limitation of available methods and therefore decided to do an additional Montessori education. After finishing this additional education she took over an inter-grade learning group and is applying many Montessori methods and tools in her daily teaching. Especially the use of supportive physical learning materials has proven to be very beneficial in her point of view. Here are some highlights of that very rich conversation:

“It is really important that children can experiment and find out things by themselves without long explanations of rules.”

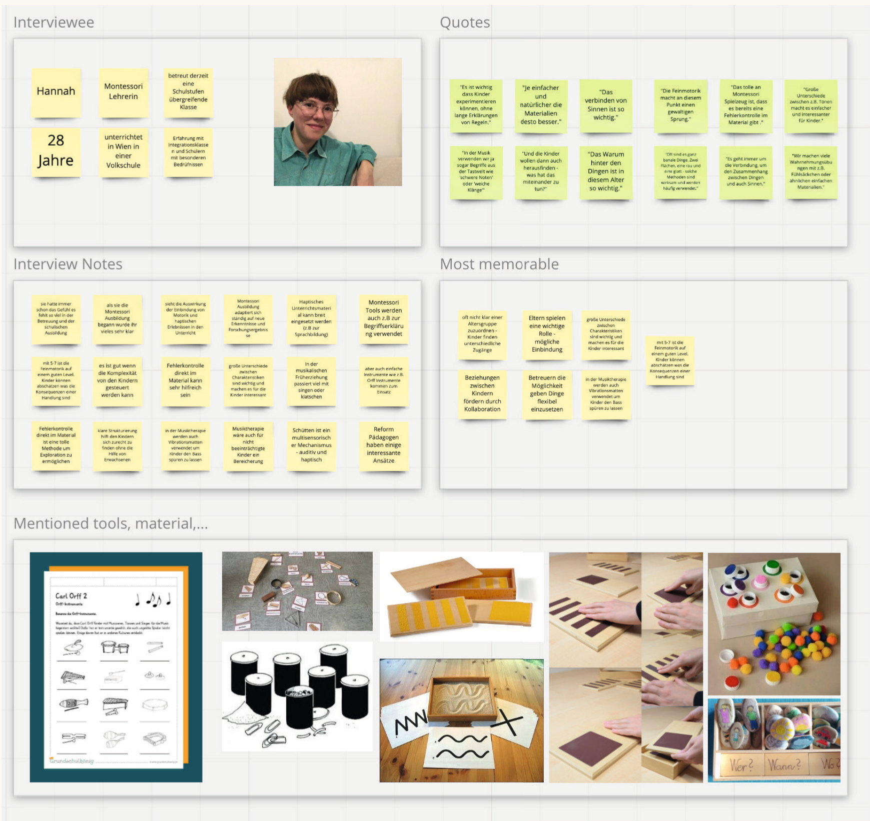
“The combination of music and haptic feels very natural and makes total sense. In music there are even terms from the world of touch in use, such as ‘heavy notes’ or ‘soft sounds’.”

“The simpler and more natural the materials the better. There is a lot of benefit in just working with what you find in the environment and nature.”

“Within the methods of Maria Montessori there is an abundance of sensory perception exercises. It’s a really strong and frequent component. From working with smooth and rough surfaces to different feeling bags or sensory memories.”



"When I started the Montessori training, many things became clear to me. Haptic elements are completely missing in our school education and yet they would be so important for the children's development."



Ideation

Ideation

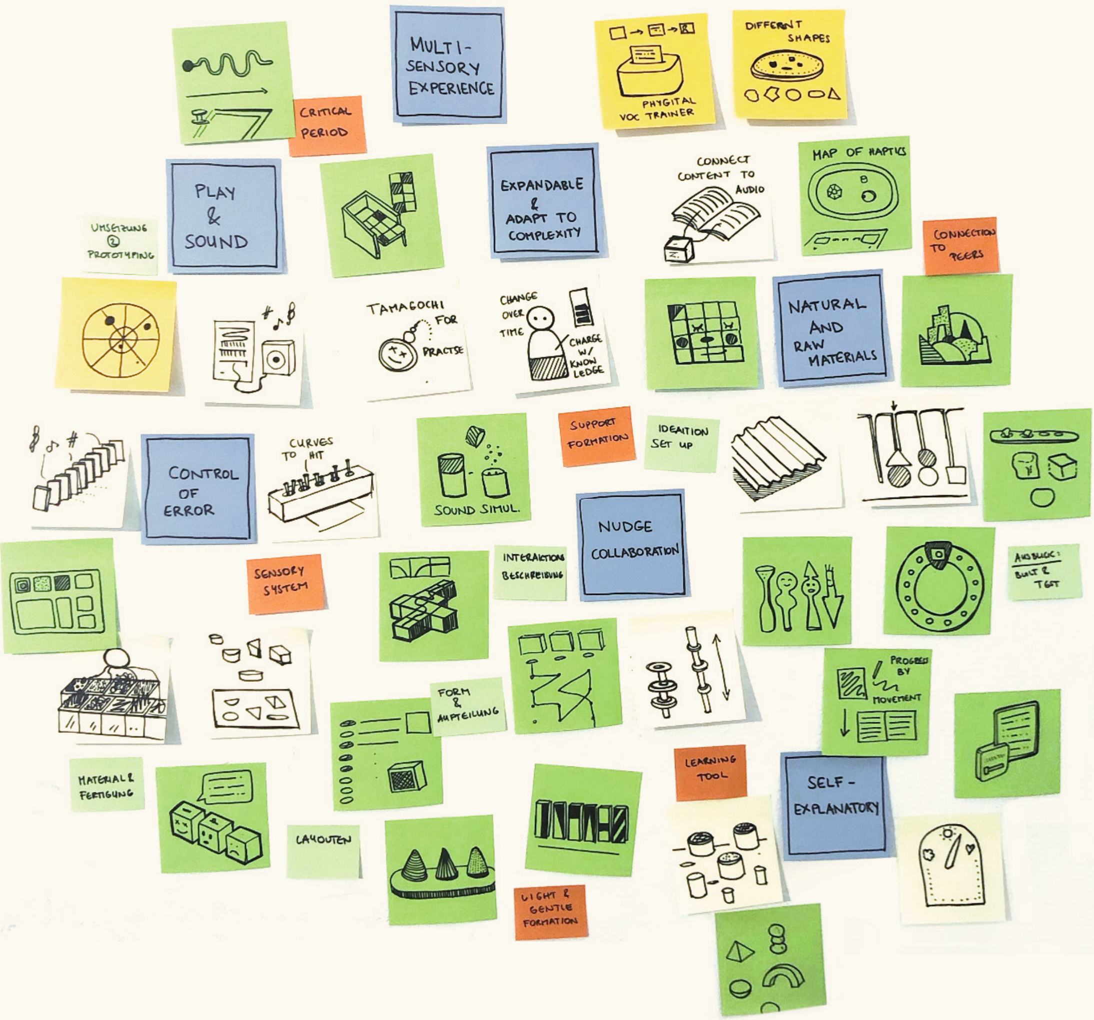
Brainstorming

In my first ideation phase I looked at the topic from many different angles. One of the first decisions to make was around the learning objective. Should this be a concept that supports children to obtain specific knowledge or a certain skill? After reading so much about the benefits of exploration, experimentation and the importance of fun and joy, I decided to not set a specific learning goal but to keep it open and a bit more general.

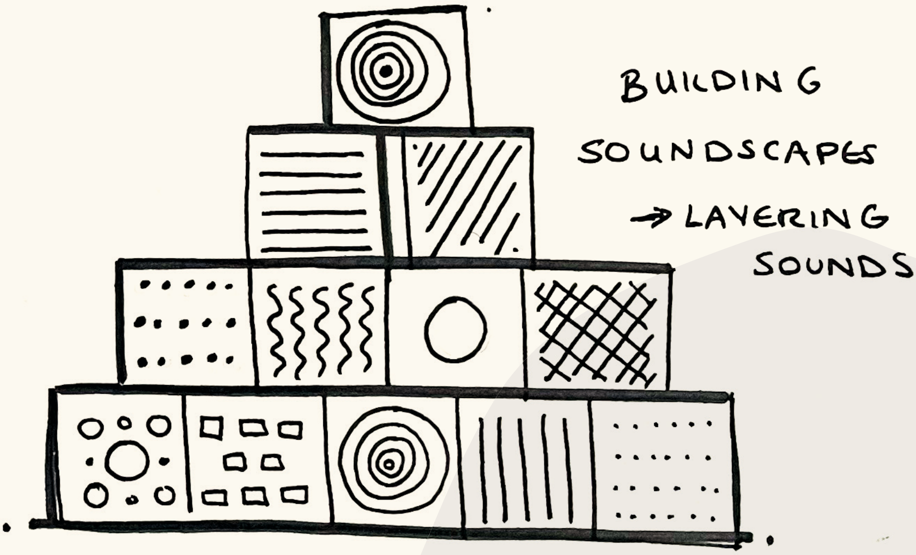
Exploring different areas of multisensory approaches and the combination of digital and analog, it became clear that I wanted to avoid screens and put the focus rather on auditory and haptic experience rather than leading with a visual experiences.

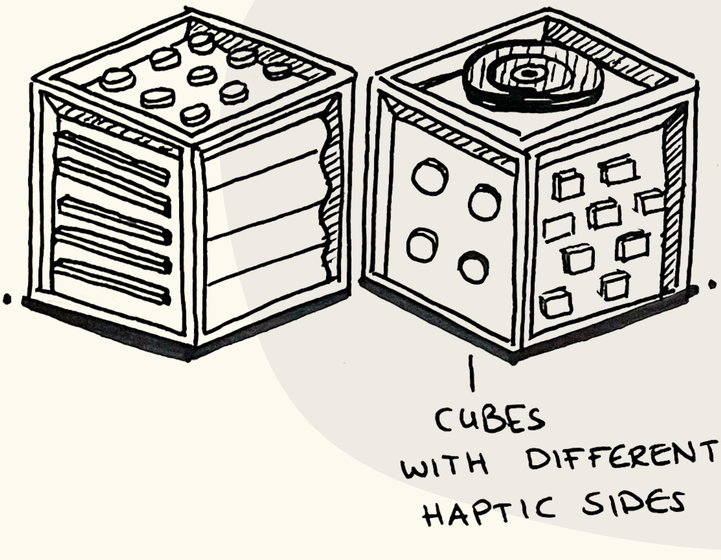
I quickly gravitated towards a round board, as this setup has no direction and promotes collaboration without hierarchy. It also doesn't predefine the number of players. Thinking about the musical aspects, a round shape makes it easy to set up a loop and keep the handling simple.

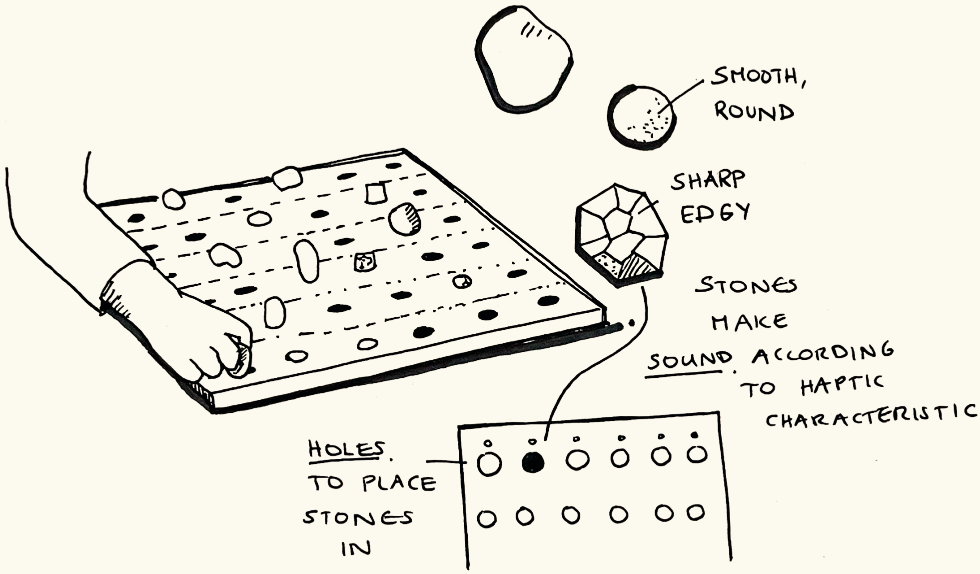
After a few rounds of iterations, it was quite clear to me that I wanted to create a haptic simplified synthesizer for children.


CRITICAL PERIOD
MULTI-SENSORY EXPERIENCE
PHYGITAL VOC TRAINER
DIFFERENT SHAPES
PLAY & SOUND
UMSETZUNG (2) PROTOTYPING
EXPANDABLE & ADAPT TO COMPLEXITY
CONNECT CONTENT TO AUDIO
MAP OF HAPTICS
CONNECTION TO PEERS
TAMAGOCHI FOR PRACTSE
CHANGE OVER TIME
CHARGE W/ KNOWLEDGE
NATURAL AND RAW MATERIALS
CONTROL OF ERROR
CURVES TO HIT
SOUND SIMUL.
SUPPORT FORMATION
IDEATION SET UP
NUDGE COLLABORATION
SENSORY SYSTEM
INTERAKTIONS BESCHREIBUNG
AUSBLICK: BUILT & TEST
FORM & AUFTEILUNG
PROGRESS BY MOVEMENT
MATERIAL & FERTIGUNG
LAYOUTEN
LEARNING TOOL
SELF-EXPLANATORY
LIGHT & GENTLE FORMATION

After exploring different ideas around play and multisensory educational material, building blocks and haptic expriences, I focused strongly on the intersection between sound/music & haptics. There are endless possiblities to create sounds using haptic materials and using either spacial arrangement or haptic characteristics to determine the type of sound that is created.

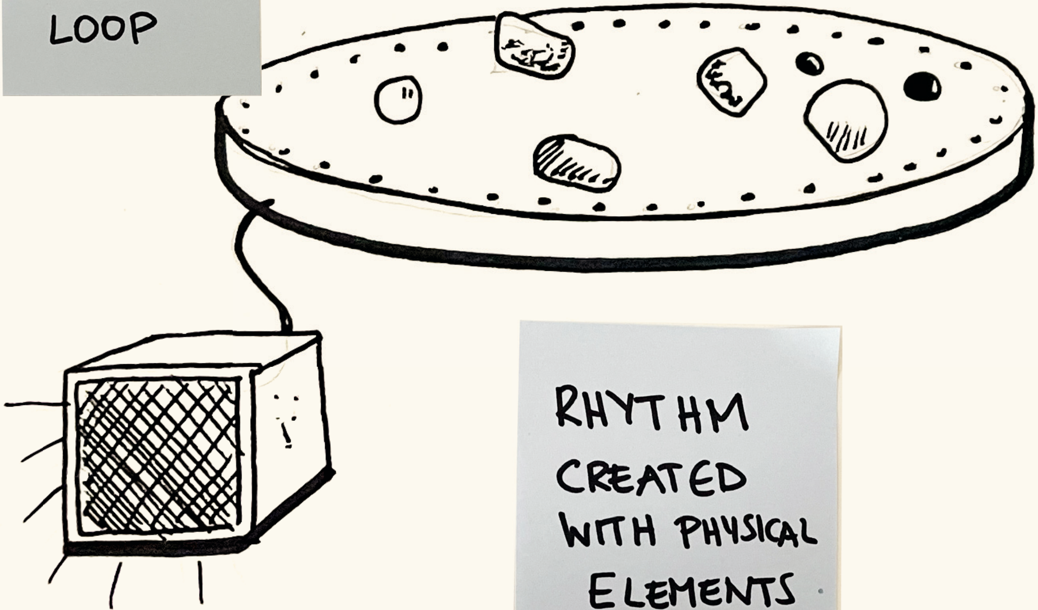

BUILDING
SOUNDSCAPES
→ LAYERING
SOUNDS


CUBES
WITH DIFFERENT
HAPTIC SIDES


SMOOTH, ROUND
SHARP EDGY
STONES MAKE SOUND ACCORDING TO HAPTIC CHARACTERISTIC
HOLES TO PLACE STONES IN

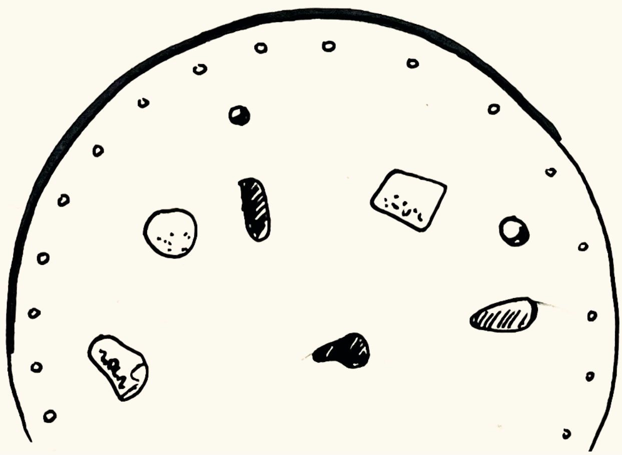

ATTACHMENT AUDIO PLAYER TO AUGMENT BOOKS
HAPTIC SURFACES TRIGGER SOUNDS

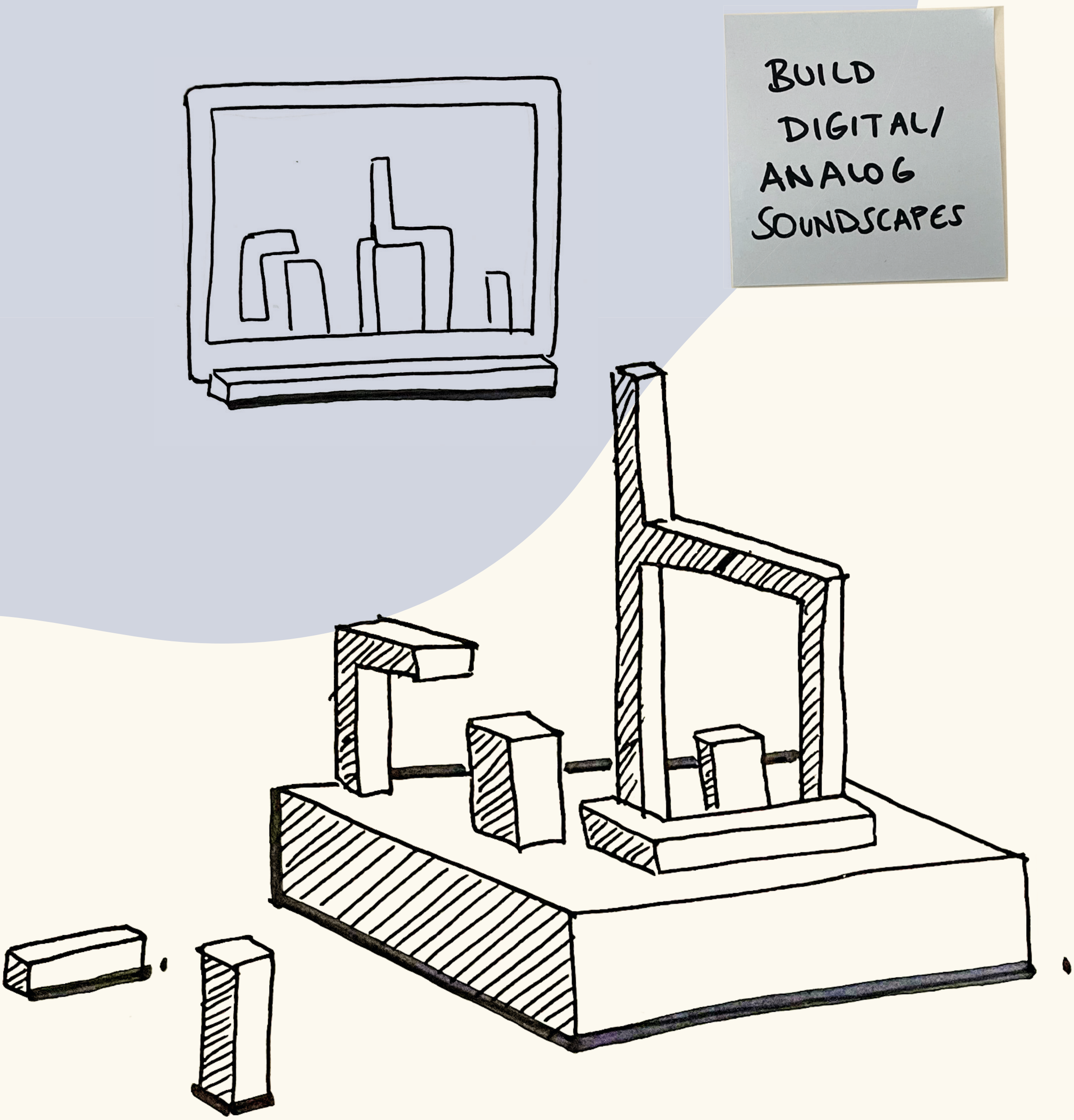
CREATE A LOOP

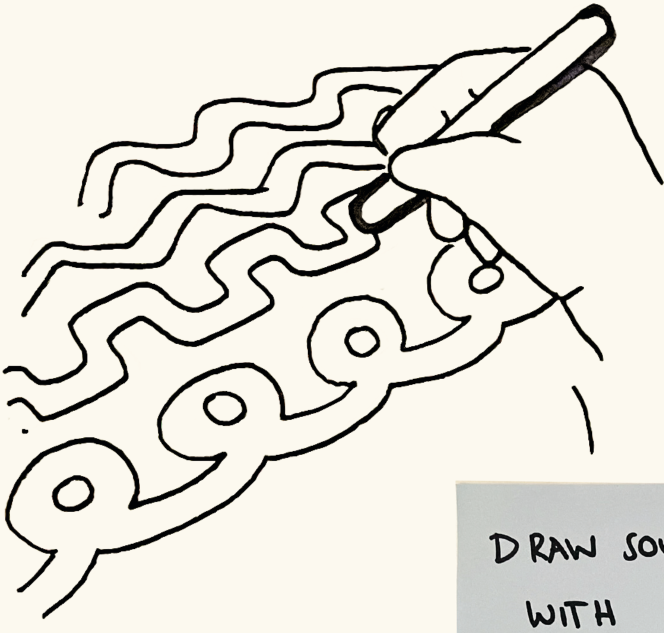


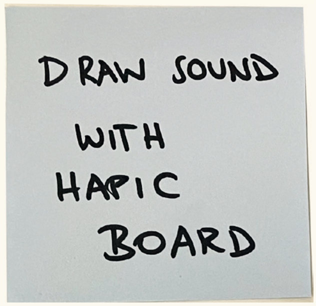
RHYTHM CREATED WITH PHYSICAL ELEMENTS

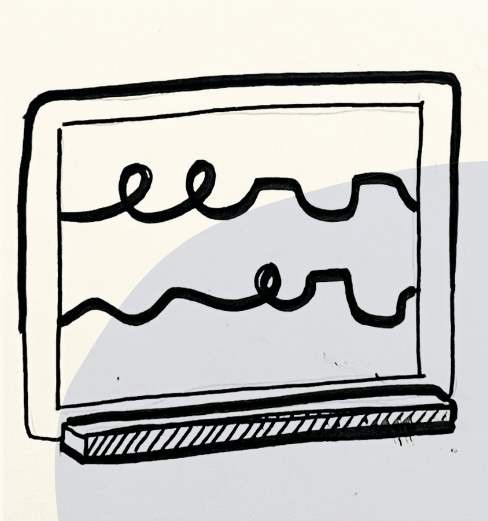
HAPTIC CHARACTERISTICS
→ TO AUDIO CHARACTERISTICS




BUILD
DIGITAL/
ANALOG
SOUNDSCAPES




DRAW SOUND
WITH
HAPIC
BOARD



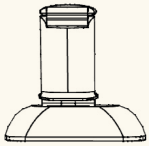
Concept

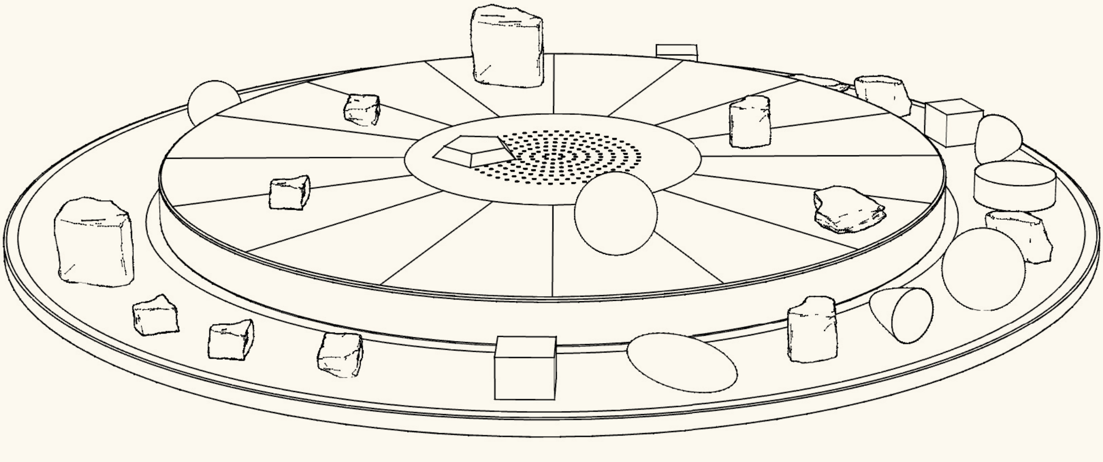
Concept

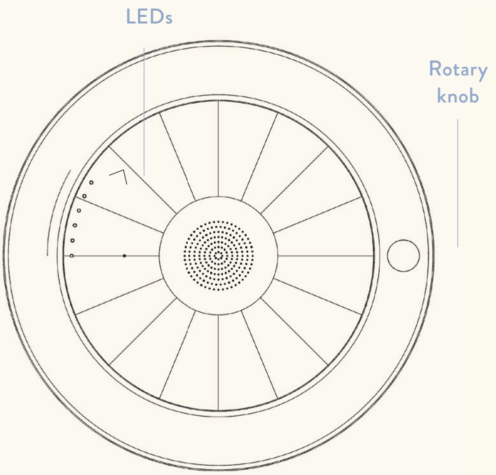
Description

After a phase of ideation and creating many different options, I went back to my design principles and reflected upon them. I could see a few different options fulfilling most of my requirements, but there was one concept that I found particularly interesting and that I wanted to pursue further in an in-depth prototyping and testing phase. The idea of this concept is to link haptic properties with sounds characteristics and use objects with different haptic characteristics to create soundscapes and melodies.
How does “sharp” sound?
What is the difference between a heavy and a light sound?
Or between a rough or a smooth one?
What could be the influence of the size and the form of an object on sound?

This game consists of two parts. One part are different natural objects like stones, marbles, sticks or dried plants. Each of these objects has a different sound stored within them and children are invited to find out how these different objects sound and how their haptic characteristic is connected to the sound characteristics. To be able to listen to the sound they have to place the object onto the second part of the game - a big wooden plate with an engrained structure on top. Only when the object is lying on top of the wooden plate it releases the sound and children are able to hear the object. But also the placement on the wooden board has an influence on how and when the sound is played. Let’s go into a step-by-step explanation of the functionality and the process.

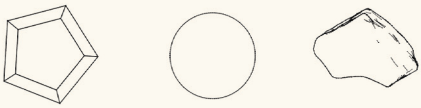






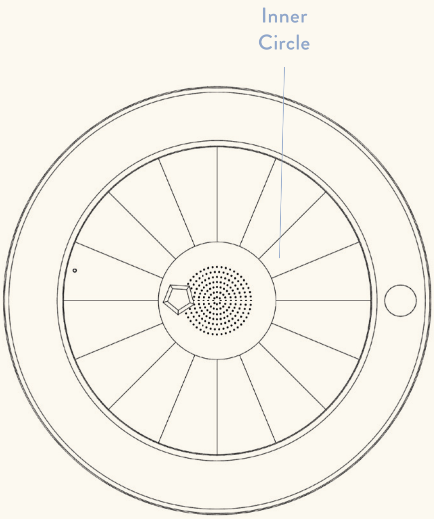
1.

When switching on the game, a small LED shines through the wood on the outer edge of the wooden plate. This LED cycles around and defines a pace and rhythm. A rotary knob allows to speed up or slow down the circulating LED and therefore to speed up or slow down the tempo of the instrument.



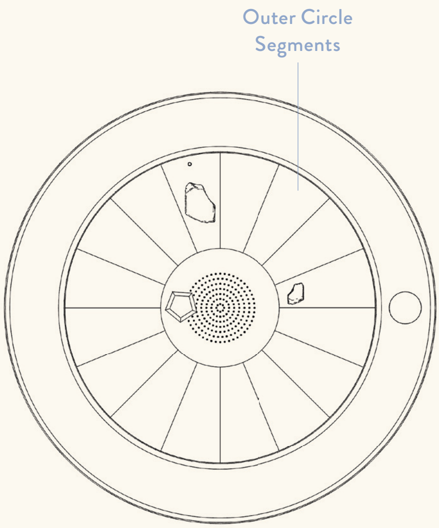
2.

The second element of the game as mentioned above are a range of objects with different haptic characteristics. They are just placed around the wooden board, ready to be explored and placed by the children. At this state they don’t have a defined space and there is also no set number of objects. In fact almost anything with roughly the right size could be used. Children can also incorporate stones they find or other objects in the game.



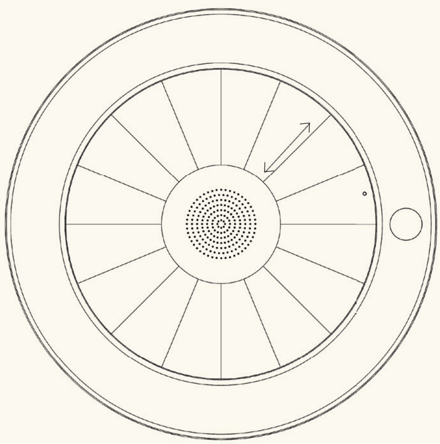
3.

The game really starts when a child places the first object onto the wooden board. There is a distinction between two different areas on the board which behave slightly differently. If objects are placed into the smaller concentric circle in the middle, the objects create a constant sound as soon as they are placed. This could be a constant bass, sound or melody. This creates the background and base of the soundscape or the composition.



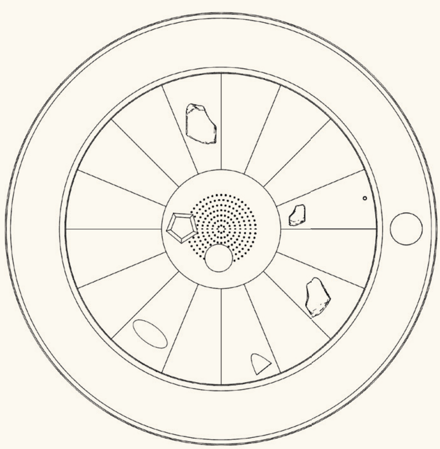
4.

If the objects are placed into the outer circle the sound is only triggered when the LED is in the circle segment of the object. This will loop as long as the object lies in there whenever the LED cycle arrives at the respective segment. The pitch and key of the sound are determined by the haptic characteristics of respective object.



5.

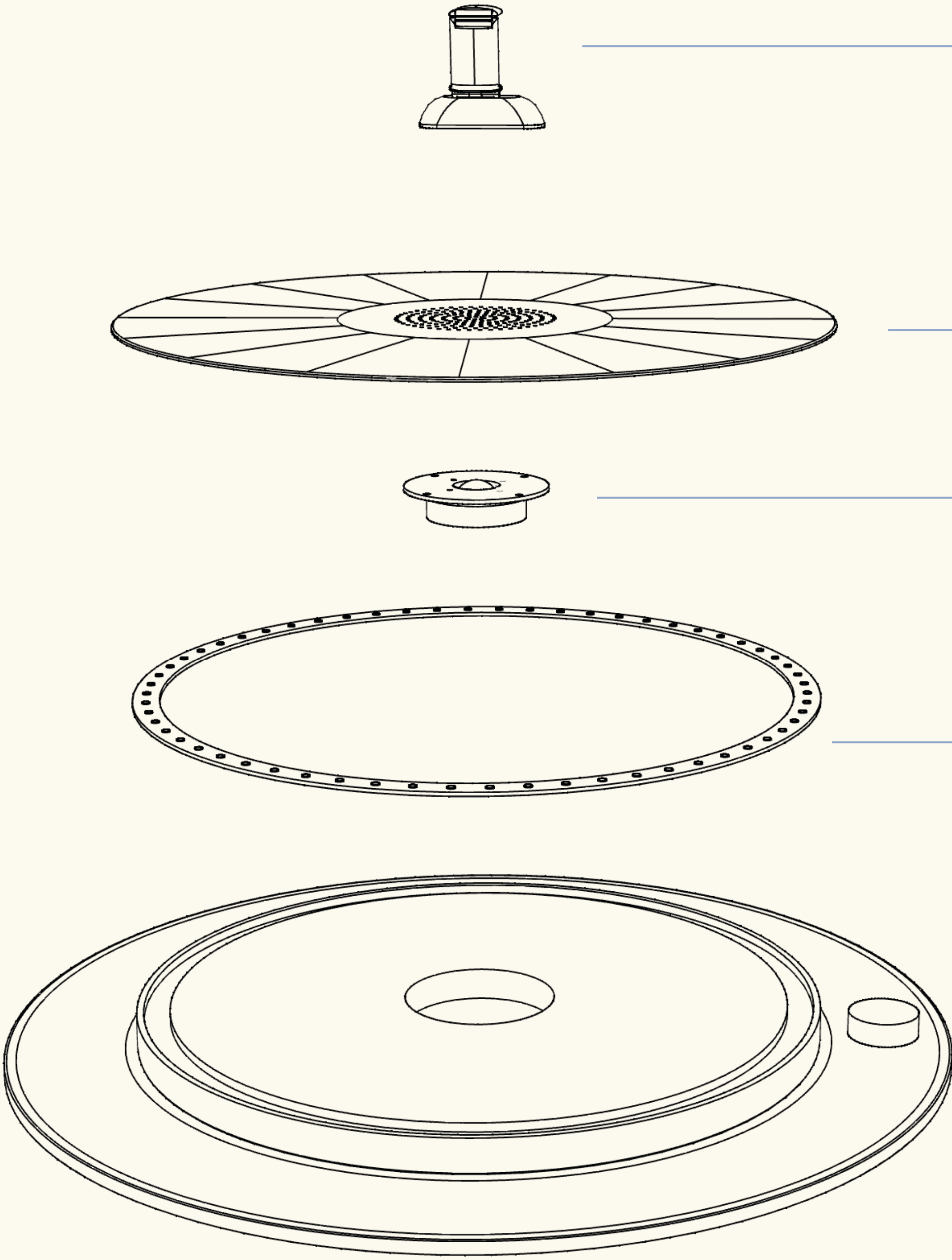
The volume of the sound can also be manipulated by the placement of the object. The further inwards an object lies, the louder the sound of the respective object is audible.



6.

In this way more and more objects are placed onto the board and slowly build up a composition and an audio representation of the haptic objects that are lying on the wooden board.

Overview
Detailed components



Camera
- to track object on the board
- high frame-rate to ensure the system reacts fast and tracks all movements of the objects
- for prototyping I will use the Otha M9 Pro Stream Webcam (1080p, 60fps)

Wood Veneer
- thin (1-2mm) wooden veneer (exact thickness will be tested) to enable the LED lights to shine precisely through the veneer
- engraved pattern on top to distributed board into different areas
- middle part is perforated to enable good sound quality from the speaker

Speaker
- round loudspeaker, sits in the middle of the board to create an integrated product without any additional speakers
- ensure easy handling and set up

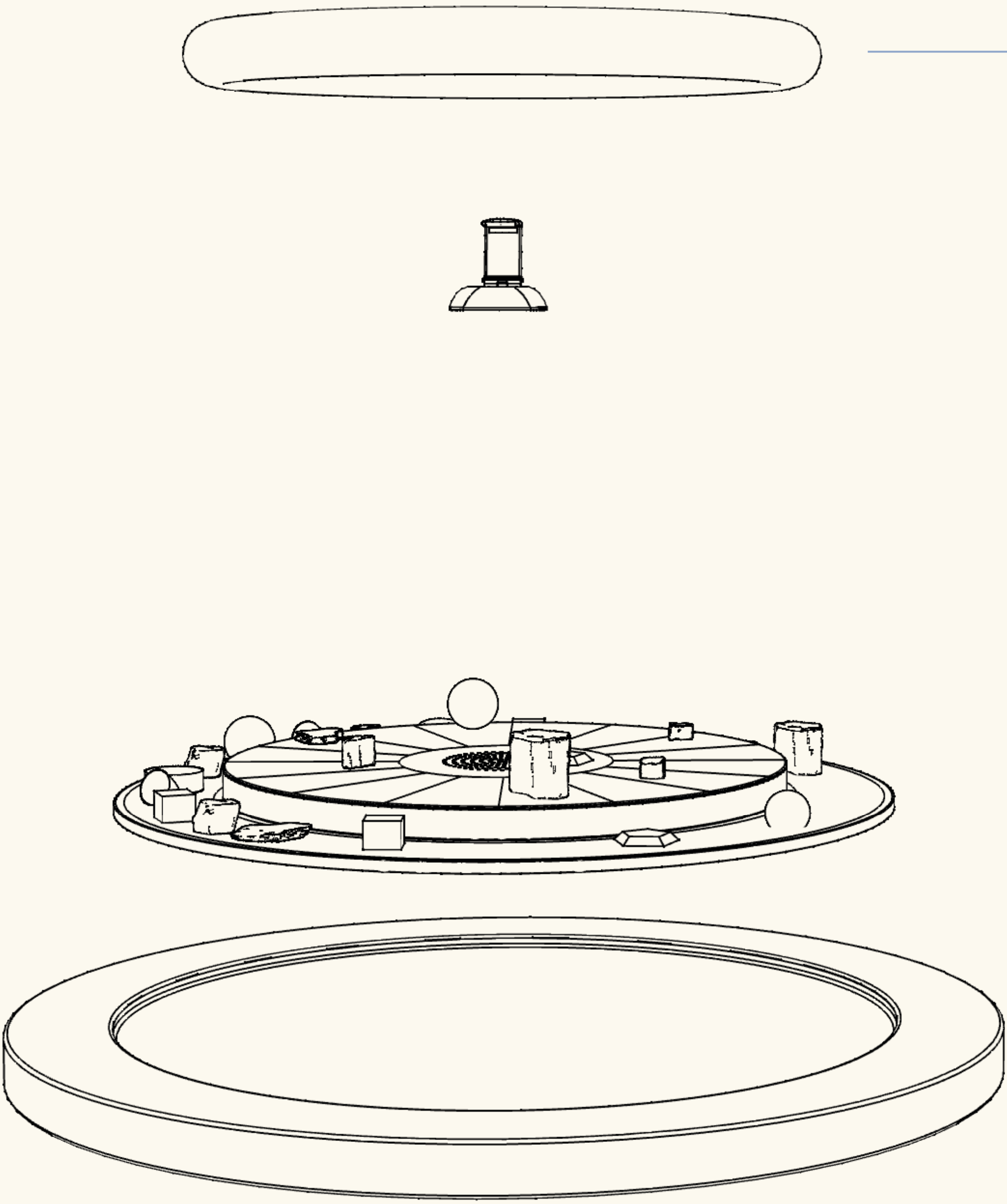
LED stripe
- individually controllable LED on a stripe sitting directly under the wooden veneer

Wooden base
- the weight and size of the board communicates quality and ensures that it is not easily moved by children during play

Not show:
- Microcontroller
(for prototyping I will use VVVV for control)
- Haptic objects
amount of objects is not restricted

Overview

Setup

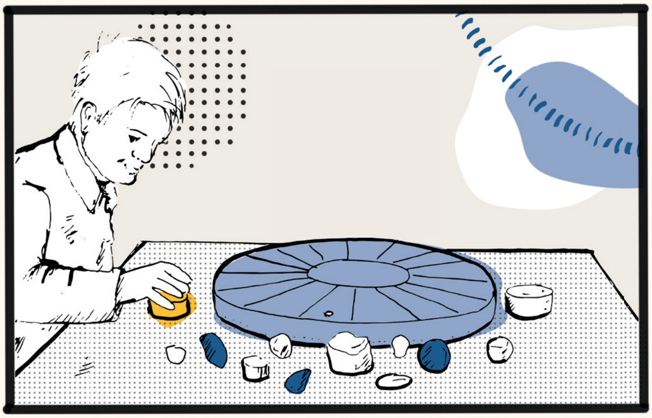


Room Setup
(for current technical implementation)

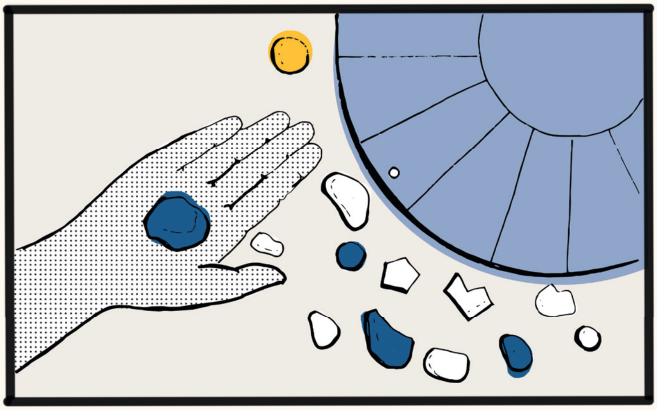
Ring light
- fixed and dedicated for that setup
- ensures accurate tracking
- consistent light settings are necessary in order to set and adjust the thresholds properly

Fixed Base
- there needs to be a fixed position for the wooden plate
- this should be adjusted to the environment and could either be a marking on the floor or table if the plate needs to be removable
- it could also just be fixed in the position and stay there if possible

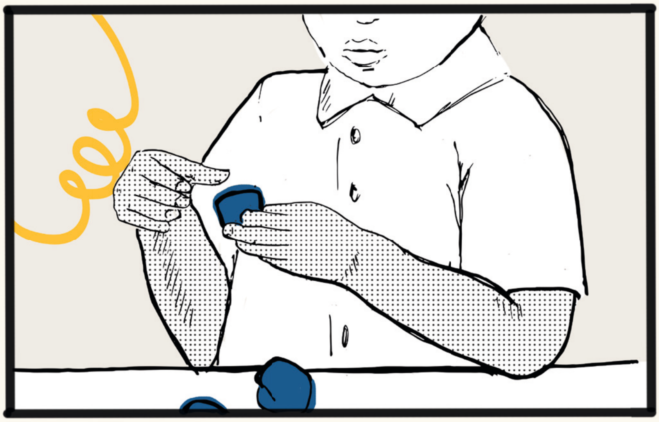
Scenario



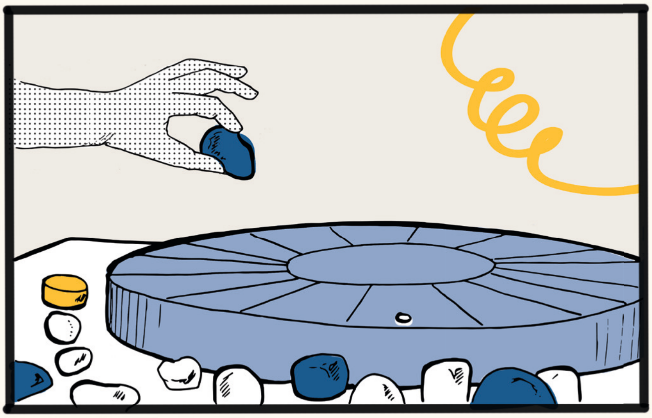
1.
Leon has never seen this new toy. He is intrigued and turns on the big switch. A small light appears and circulates along the outer edge of the big wooden board. There is another big button. Leon rotates the big knob and sees the light circulating faster.



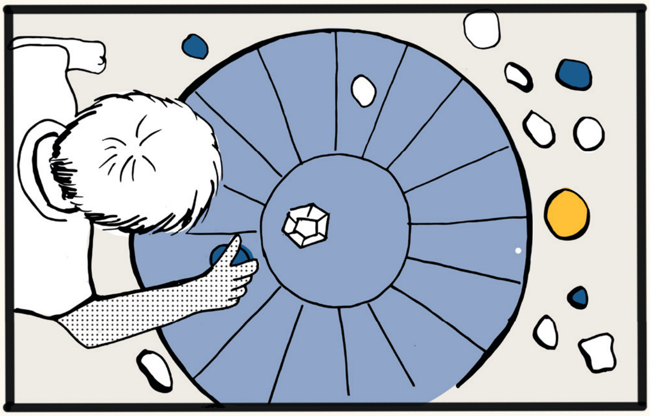
2.
He wonders what to do with all the small stones and objects that lie around the wooden board. He picks up one of them. It feels heavy and cold, with a round, soft shape.



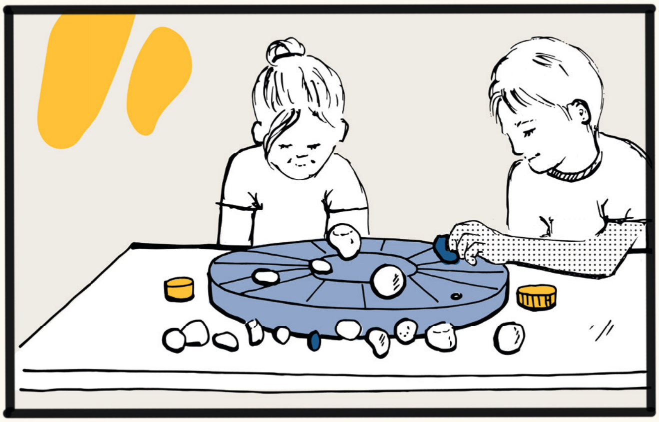
3.
He turns the object around in his hand and picks up another one. This one is made of wood and feels warm, with sharp edges.



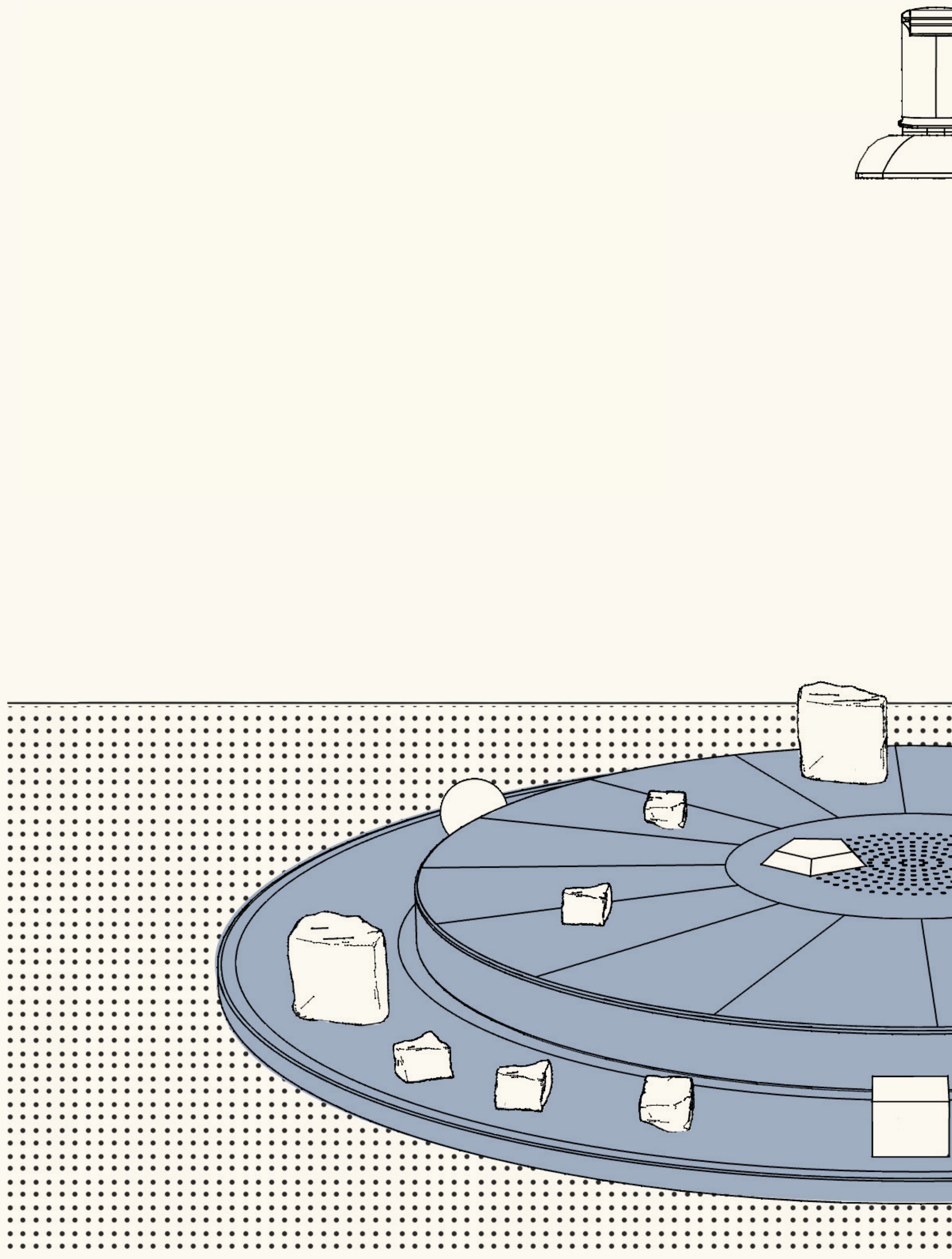
4.
He takes the first object and places it in the middle of the wooden board. Immediately a bassline begins to play out of the speaker in the middle of the board. Leon moves the object to the outer area of the board and the sound stops.

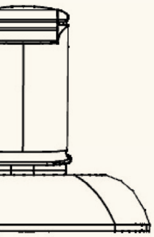


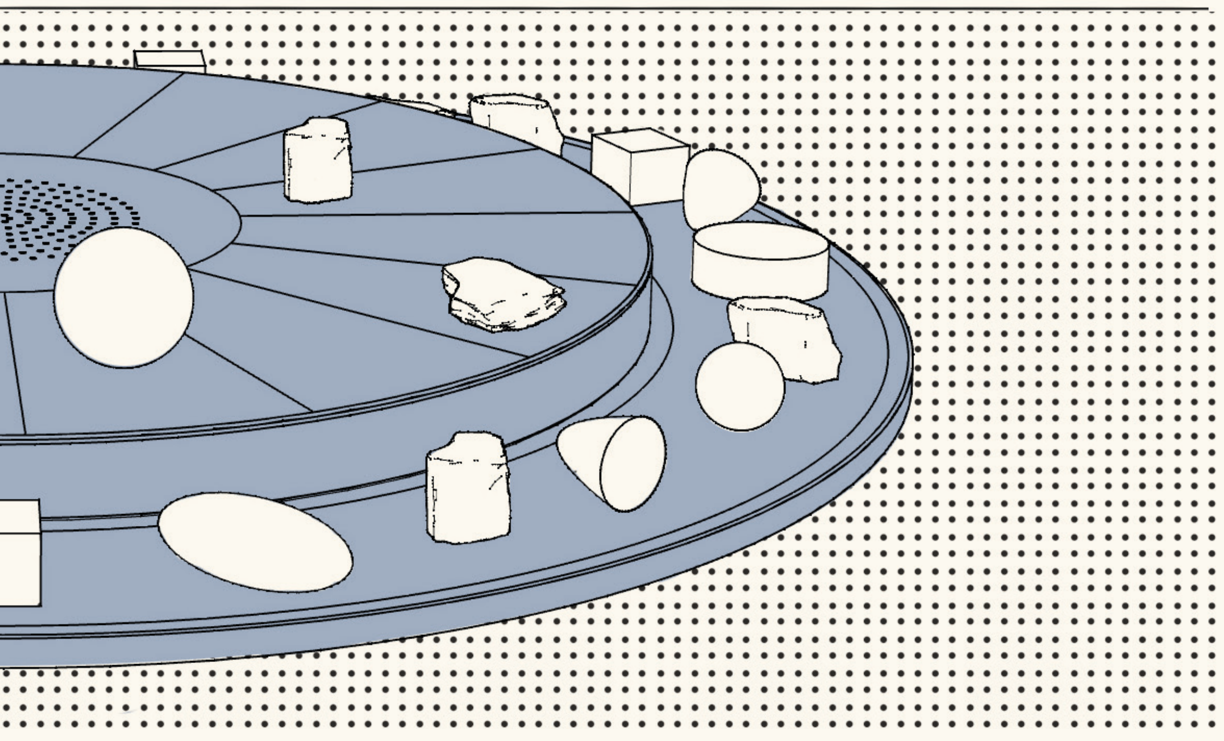
5.
But as soon as the light travels through the area of the stone he can hear the sound again. Just for a short moment, and as the light travels further the sound stops again. Leon begins to pick up other objects and places them on the board.



6.
He moves them around the board, and the sounds become louder or quieter. With more and more stones a nice melody begins to form. Flora hears the sound and is intrigued, she watches Leon a bit and then puts a stone herself.







Prototyping

Prototyping

Low fidelity

Paper mockups and role play

I started off with very low fidelity mockups of potential setups and used role play to prototype first interactions. This helped to get a feeling for sizes and usability. It should be small enough for my user group to be able to reach the whole playing area and use it properly, but big enough to enable collaborative play for small groups. Similarly the sizes of the play elements need to be big enough to avoid possible swallowing, but small enough to sit nicely in a child's hand. After a few different variations, I decided on a playing are ao 800mm diameter and elements from 15mm to 80mm diameter.

Open CV and VVVV

After these first low fidelity mockups, I thought about different options on how to track the objects on the wooden board. One really important part of the concept is the naturalness of the objects. I also wanted to avoid, that there is only a limited amount of objects that can be used. Ideally children would be able to use almost any stone, stick or other object they find in their surroundings and use it in the game. Therefore it was not an option to make the objects the "intelligent" part of the system. Other methods like e.g. inductive sensors also limit the tracking to only one characteristic of the object (in this case the resistance of an object). One very promising method I came across is to use a camera and computer vision to visually recognise the object and its position on the board.

Computer vision is a process that trains computers to understand images and videos. It is the base or mostly used for Artificial Intelligence. Using huge amounts of digital images and videos and deep learning algorithms, machines can accurately classify and identify objects.

For prototyping and experimentation I used OpenCV, a huge open-source library for computer vision, machine learning and image processing. There are more than 2500 optimized algorithms in this library, which can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track objects, find similar images from an image database or follow eye movements.

The purpose of OpenCV is to prove a common infrastructure for computer vision applications and in this way accelerate the use of machine perception. OpenCV is free for both academic and commercial use and has C++, C, Python and Java interfaces. In the prototypes I used VVVV to leverage the OpenCV algorithms.

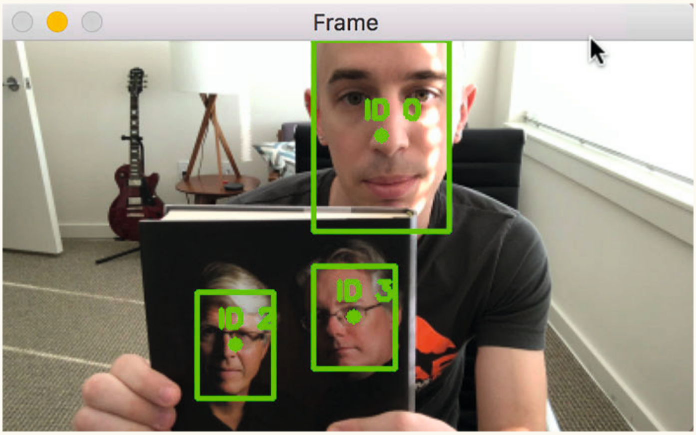


Fig.77
© Adrian Rosebrock

Fig.78
© Anna Petrovicheva

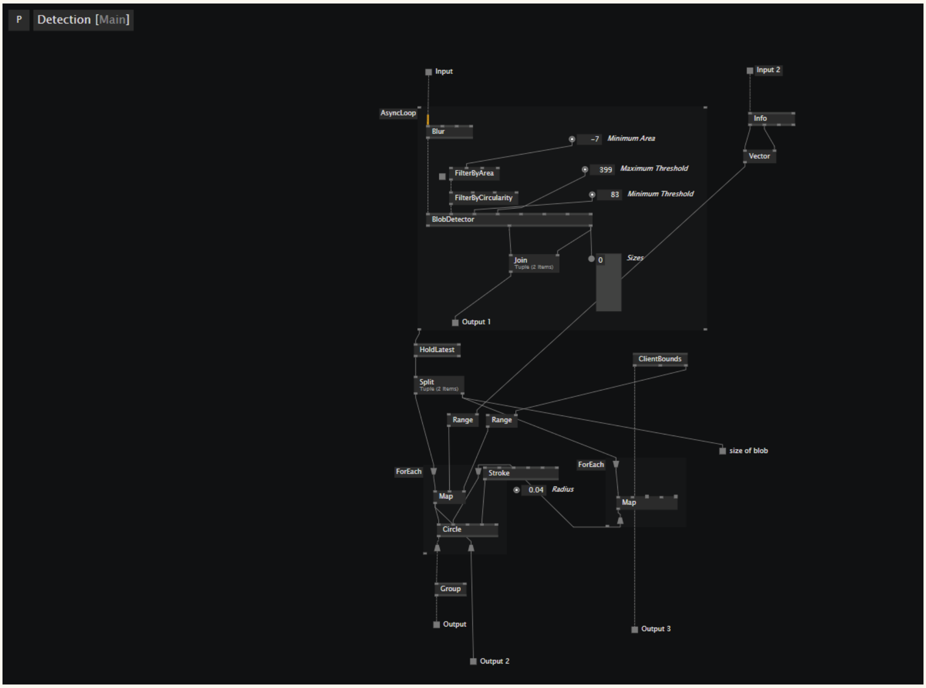
VVVV is a general purpose toolkit and a node-based visual programming environment. Its special focus lies in real-time video synthesis and programming large media environments with physical interfaces, real-time motion graphics, audio and video. The tool uses a dataflow approach and its visual interface makes it easy to rapidly prototype and develop even if users are not able to code. (cf. VVVV, n.d., online)

Previously I mostly used VVVV beta, but switched to VVVV gamma to be able to use the OpenCV library. VVVV gamma takes a novel approach to visual programming. It's a visual-first live programming environment for the .NET ecosystem and therefore allows you to directly consume almost any .NET library from nuget.org (like the OpenCV nuget).

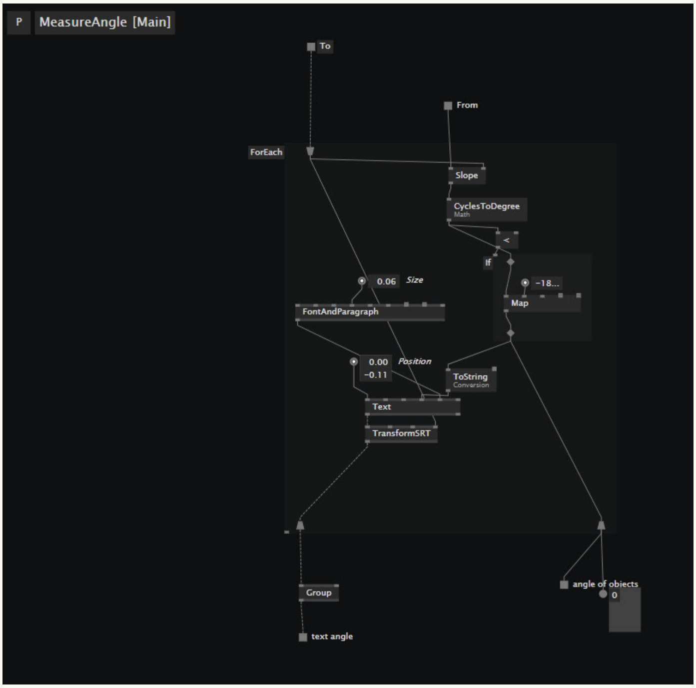
Fig.79
© VVVV

Patch Structure

In my prototype patch structure I eventually used a blob detection to detect elements from the image of my camera input. This of course gives no information about the material characteristics of the object, but as I am prototyping with a defined set of elements materiality is easily assigned specifically to the respective object. The blob detection provides coordinates of the centre point of detected objects and the size of the object.

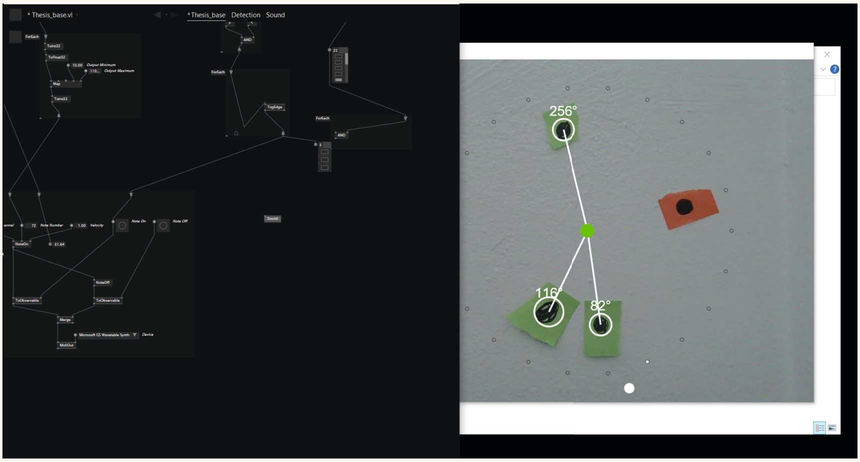


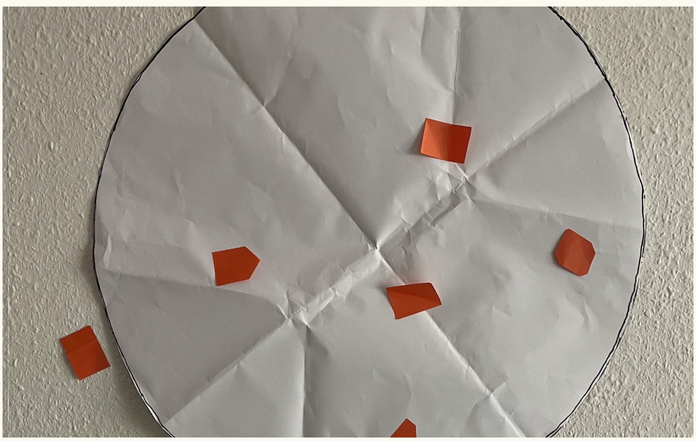
As a next step I defined the centre point of my board and calculated the distance between this point and the centre point of the object as well as the angle. A LFO creates a loop sequence and comparing the angle of the elements placed on the board with the LFO output helps to determine the moment in which a sound is produced. The distance is used to control the volume of the sound. This enables users to create sounds with different volumes depending on how close or far they put the element to the centre point.

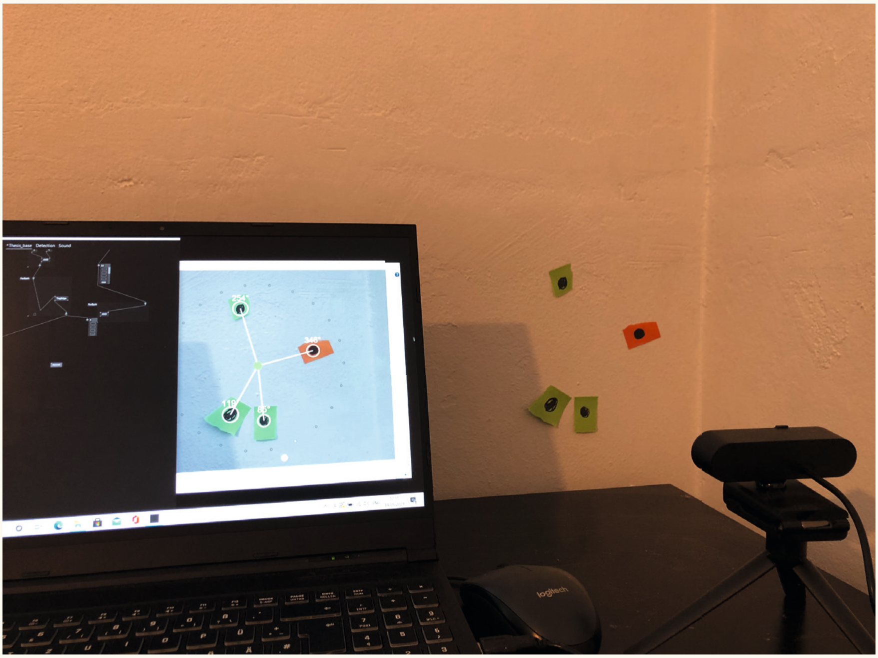


Basic Setup

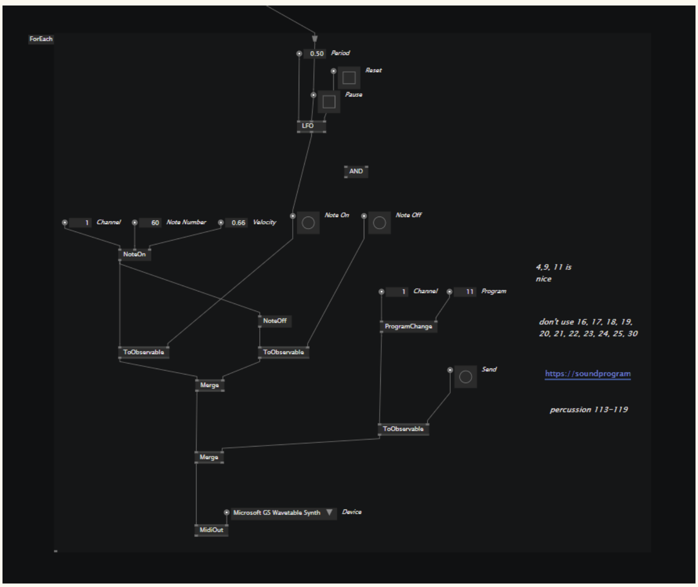
This creates the basic logic of my prototype and enables me to define a sequence, trigger sounds at the right time and influence the sounds based on the distance and size of the element. At this stage I used a paper mockup on the wall to quickly test tracking to be able to build the basic structure of the patch.





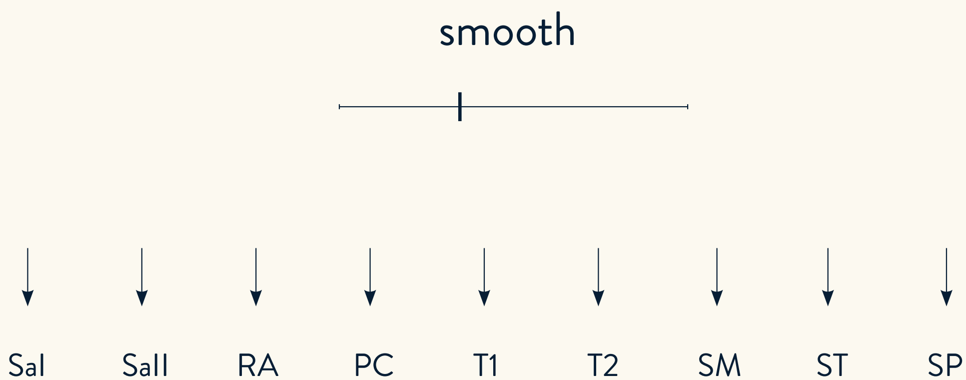


The next step was to use the detected values to create a midi sound. It was an interesting task to think about the translation of a haptic characteristic into a sound.



The difficulty is that there is no objective classification or quantitative system for counting sensory sensations, whereas my patch is based on numbers and values. How to take something as soft and subjective as sensory experiences and translate it into concrete values? I had to create a framework for myself to be able to realize this concept. The framework is based on the thought that touch is a modality resulting from the combined information of innumerable receptors and nerve endings concerned with pressure, temperature, pain and movement. As mentioned previously, there are only around 10 different receptors. Therefore, there are only 10 primary sensations. Everything else is a conclusion from combined sensory inputs. For this reason, any haptic sensory sensation can be split up into these primary sensations.

Smooth, for example, is also not a primary sensation, but a conclusion from a combination of sensations. In my patch I tried to trace these conclusions back into its original components and use primary sensations to manipulate e.g. pitch and key of the sound.



Mechanoreceptors

SA1	→	simple and short tactile stimuli
SA2	→	pressure, stretching of skin
RA	→	subtle tactile stimuli
PC	→	vibration

Temperature sensors

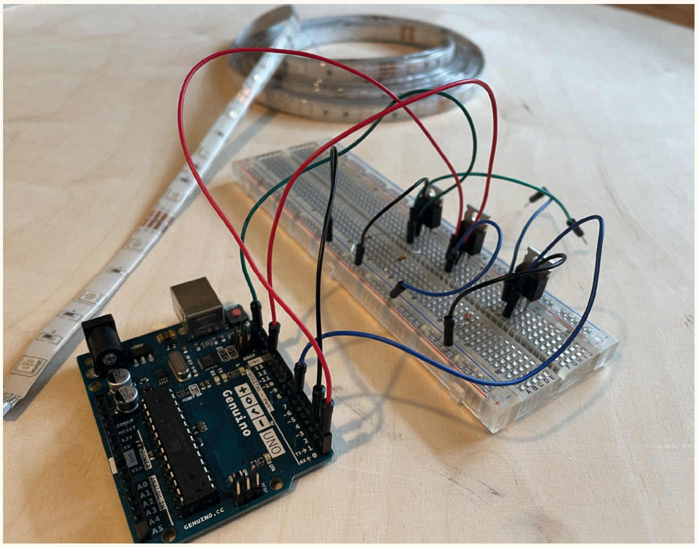
T1	→	heat
T2	→	cold

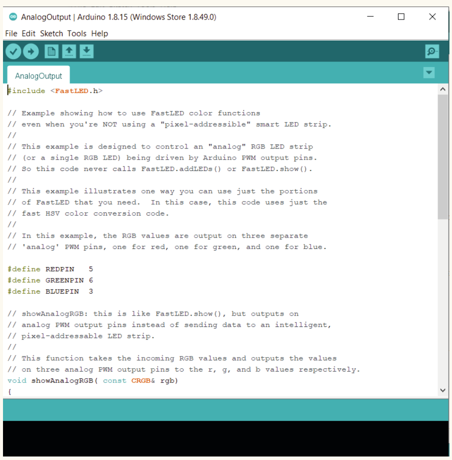
Pain-sensitive receptors

SM	→	pain through extreme deformation
ST	→	pain through heat, chemicals
SP	→	long-term pain

Physical Object

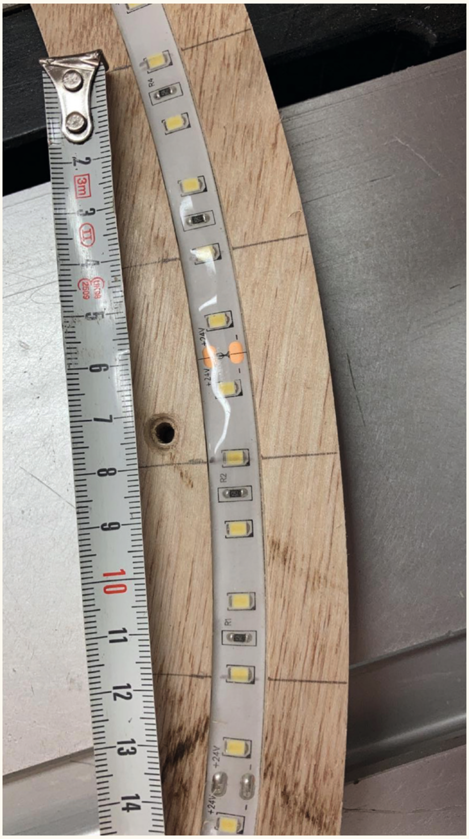
After setting up the software and logic side of the prototype I started building the physical object. First, I started by programming the LED stripe to be synchronized with the loop sequence in my VVVV patch. I used an Arduino Uno to control the LED stripe and the FastLed Arduino library to set up a running light. My next step was to transfer certain inputs into the VVVV patch to be able to control and manipulate the pace of the LEDs in real time.



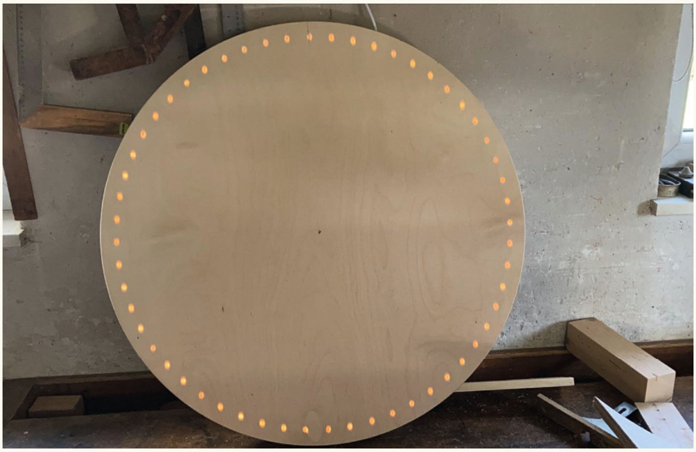



```
#include <FastLED.h>

// Example showing how to use FastLED color functions
// even when you're NOT using a "pixel-addressible" smart LED strip.
//
// This example is designed to control an "analog" RGB LED strip
// (or a single RGB LED) being driven by Arduino PWM output pins.
// So this code never calls FastLED.addLEDs() or FastLED.show().
//
// This example illustrates one way you can use just the portions
// of FastLED that you need.  In this case, this code uses just the
// fast HSV color conversion code.
//
// In this example, the RGB values are output on three separate
// 'analog' PWM pins, one for red, one for green, and one for blue.

#define REDPIN   5
#define GREENPIN 6
#define BLUEPIN  3

// showAnalogRGB: this is like FastLED.show(), but outputs on
// analog PWM output pins instead of sending data to an intelligent,
// pixel-addressable LED strip.
//
// This function takes the incoming RGB values and outputs the values
// on three analog PWM output pins to the r, g, and b values respectively.
void showAnalogRGB( const CRGB& rgb)
{
```

After that, I did a few tests on how to best make the light subtly shine through the wood, trying to hide technology as much as possible and retain the rawness. In the first attempt I used wood veneer, but it turned out that drilling holes from the back side of the wood was overall a better option. It made the whole structure more stable and created a clearer and more
precise aesthetic.



Displayed on this page, you can see a few more image of the latest physical prototype. This setup with the real materials and sizes enabled me to do more testing and to adjust certain aspects of the tracking and the interaction, like e.g. leaving the playing field unstructured and re-adjusting the pitch and key of the sounds to the materials.



Outlook

Outlook

Learnings and next steps

The first learnings during the process of developing my final concept that I'd like to mention is centred around restriction of modules and elements. After defining my design principles I assumed that keeping the system open to any object or element kids could find in their surroundings and bring into the game would add a lot of value. I still believe that allowing situations like e.g. children finding haptically interesting stones and trying to discover what auditive characteristics are hidden in these stones, would nudge beneficial exploration. Nevertheless, it is even more important that the concept works coherently and there is an understandable connection between the object and the triggered sound. Especially in my prototype it is difficult to ensure frictionless functionality for any given object. Therefore, I decided to change the set up to a very defined set of objects in a range of different materialities and sizes. This is more feasible for the realisation of my prototype and ensures that children don't fall into the mode of indiscriminate and random play and quickly lose interest. This defined and limited set up would also be the preferred option for unguided environments in which kids are exploring the haptic instrument on their own. In guided environments like playgroups or early education classes I could see great benefit in opening the set-up up to a more extendable and adaptable version that can fit the teacher's or supervisor's lesson.

This leads into the second learning I had while talking to different early education teachers and pedagogues about if and how they would use a tool like that in their classroom.

One thing that came up a couple of times was language education. Similar to some Montessori learning material that uses rough and smooth surfaces to familiarize children with the words “smooth” and “rough” and contextualize them by attaching a physical sensation to them, this could work for a broader spectrum of haptic sensations. The connection with sounds and rhythms additionally fosters synaesthetic impressions, which are said to be beneficial for neurological development.

Overall the benefit that was verbalized the most is the possibility for children to explore this tool on their own without any instructions but also being able to use it in a classroom setting and with a more guided structure. This was surprising to me as I mainly designed for the use case of exploration and intuitive understanding and didn’t see the opportunity to incorporate this into different lessons.

I see this project as a work-in-progress and even though I am happy with the state it is in now there are many more options for further exploration. There are a few concrete next steps I’d like to take from here. Firstly, there needs to be another round of testing with the latest prototype in multiple different scenarios. I’d like to observe how children in different age groups interact with it. I would be really curious to see the differences between a guided classroom set up and an open exploration. For the next iteration of this concept it is definitely necessary to spend a lot of time with children who would actually use it and learn about how they understand the combination of sound and haptics, what does and doesn’t make sense and where it would possibly break.

Another next step would be to explore other technical implementation possibilities. I choose the current approach because it enables me to use unmanipulated and raw materials as interaction objects and avoid any intelligence in the objects themselves. The downside of this approach is that the set-up has to be very defined and fixed in its position and lighting situation. The current version is limited in its capabilities of recognizing subtle differences between materials and analyzing surfaces. Therefore I'd like to explore if there are any other possibilities that I didn't consider before that could make the experience and interaction even more seamless and robust in a variety of setups and environments.

Lastly, I'd also be intrigued to further explore other applications, variations and extensions of the idea.
One example would be to explore using different materials or surface treatments on the wooden plate to reinforce the idea of having haptic as a focus point. In this way there could be different sounds triggered depending on the combination of the material of the surface as well as the material of the elements. In this scenario a metal element would sound entirely different placed on a wooden part of the surface than when placed on a softer part of the surface.

This leads to another area of possible further exploration, namely the division of the playing surface. I tried a few variations and could see benefits and fun in a few different configurations. With my latest prototype I went for a not divided area, because of the clean aesthetics and because the limited amount of elements and the clear definition of these lead to an understandable setup that can also work on a clean playing surface. In the next version of this haptic instrument I'd like to treat the playing area division in a similar way like running sequencing light. If the division would also be made

visible through light coming from the back side of the plate, there could be multiple play setups that could be turned on and off and enable different modes of interaction. In this way it could be more easily adapted to different age groups or used in more use cases like e.g. a classroom setup.
One last addition that would be very beneficial for a limited elements setup is to incorporate appropriate storage for the elements themselves inside the plate or as a part of the set up. A dedicated place for each element could help the children to make sure everything is in the right place and nothing is missing.

I'd like to end this thesis with a quote by Martin Grünwald: "Humans are haptic beings with a deeply rooted need for interaction with the environment." Since I started intensively investigating this topic, this sentence feels more and more important. I learned a lot not only about my own haptic sensations and sensory experiences but also the effects of a decrease in these sensations. It was even more interesting to engage myself in this topic during a global pandemic in which touch becomes something that must be avoided at all costs. My ambitious hope would be to make a small contribution so that some children get more involved with different sensory impressions of the world and enjoy exploring their haptic senses.

Acknowledgment

Thank you

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Appendix

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Fig.1

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Fig.10

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