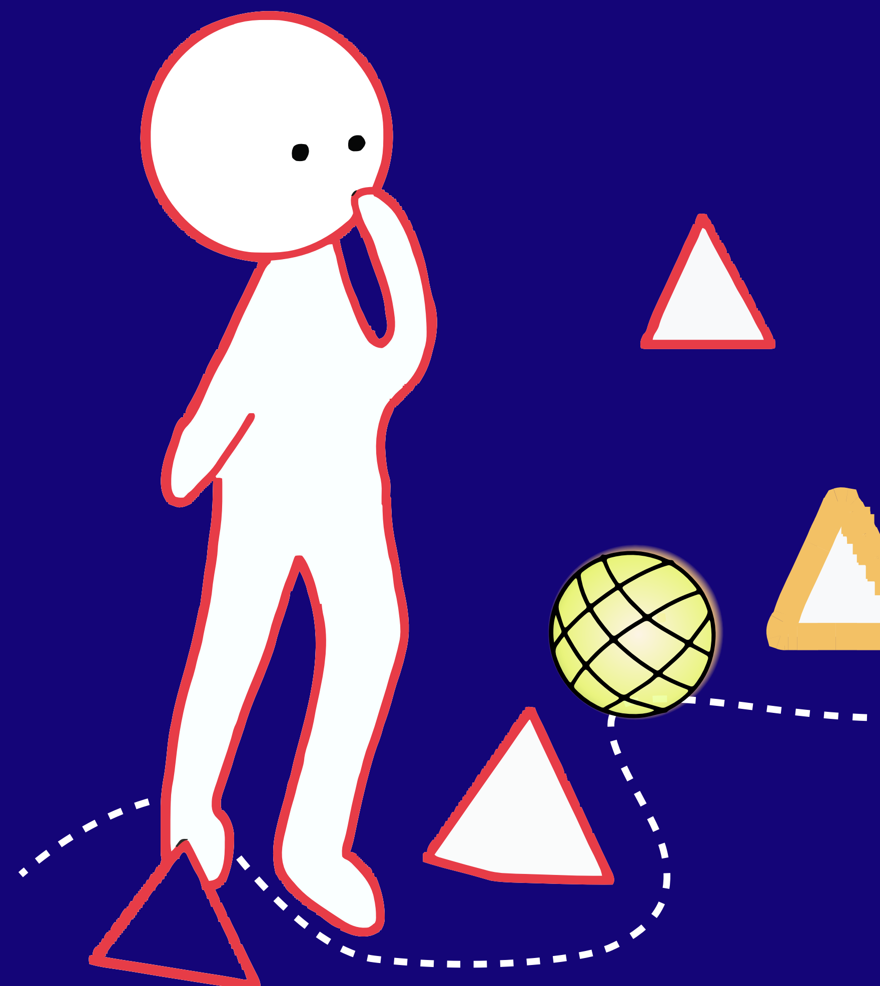
STIMULATING ENGAGEMENT IN THERAPEUTIC ACTIVITIES FOR NEURODIVERGENT CHILDREN THROUGH A ROBOTIC BALL.



TU Delft

MSc Thesis, Design For Interaction | Kumsal Kurt | August 2024


FIZZY EDU

Project
Msc Graduation Project
Stimulating Engagement in Therapeutic Activities for Neurodivergent Children through a Robotic Ball.

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When I began my Design for Interaction master's degree at TU Delft, I was eager to discover my identity as a designer through the interactions and relationships that design can foster. This journey opened my eyes to a world of design research that goes beyond simply designing—it's about understanding people, their emotions and values, recognizing users as experts in their own experiences, and being able to step in and out of their world. Through the program's emphasis on real-world applications, I learned how design and research can bring meaningful value to different environments and diverse groups of people. This transformative experience wouldn't have been possible without the support and guidance of many incredible people along the way.

I would like to start by expressing my deepest gratitude to my supervisors, **Marco and Eda**. From the moment I approached you with my proposal to use Fizzy for children's well-being, you believed in me. You consistently provided constructive feedback, supported me, and encouraged me to engage with my target group as much as possible. Whether I came to you with excitement or feeling stuck, our meetings always felt like co-creation sessions. Your critical lens and suggestions pushed me to step outside my comfort zone, and for that, I am genuinely grateful. I truly enjoyed working with you.

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To my lovely family, thank you for always supporting and believing in me throughout my design journey.

Mom, you are the true creator of my design career. You recognized my strengths long before I did and encouraged me to pursue a path that has brought me immense joy. Thank you for believing in the child who cut up her clothes and collected random materials from the streets, seeing potential where others might have seen a mess. (I know it was still messy, but it got me here!) I've come a long way from hiding things under the carpet, thinking I would build something out of them, to actually doing it.

Dad, thank you for always appreciating my oddly crafted gifts and for nurturing my creativity. Your dedication to doing your work well and your ability to appreciate every aspect of the world around you have profoundly influenced me. You've taught me the importance of commitment and passion in everything I do. Thank you for supporting me with a big heart and for always showing love for what I do.

My brother, thank you for being there whenever I needed you, for making fun of my creations (I know you were just a little jealous), and for trying to explain what I do to others. I know

"Design" hasn't always been easy to understand, but I hope this thesis makes things a little clearer.

Sarp, your enthusiasm and the brightness in your eyes every time I shared my work and anything else with you have always boosted my energy. Thank you for being my #1 fan, for offering your business perspective on my design passion, and for being there through every occassion. I'm lucky to have many more stories to share with you.

To my friends **Melis, Ecem, and Ece**—thank you for being a constant source of luck in my life. Despite the physical distance between us, you were always there to listen to my concerns, worries, and excitement. You may never fully know how much your sisterhood has brought light into my life, even in the darkest days of the Netherlands'.

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Last but not least, I extend my heartfelt gratitude to **IMMIB** for their scholarship, which made my studies abroad a reality. A sincere thank you to **Aadjan** for welcoming me into the Studiolab and providing a supportive environment that felt like an office, Jerry for his help for my prototypes, and to all the wonderful Studiolabbers who contributed to making my time there truly memorable. A special thanks to the **4TU Committee** for recognizing the significance of my work and selecting it for presentation at Dutch Design Week 2024. I am excited to share my research with a broader audience and look forward to the opportunities this will bring.

Through this project, I discovered an exciting and motivating intersection between technology, well-being, and play, and I want to thank all the other friends and everyone who supported me along the way.

With all this support, as I conclude my master's education and present this thesis, I do so with immense gratitude and excitement for the future. I hope this thesis offers valuable insights into the role of technology and play in learning, and fosters a deeper appreciation for their importance in life.

-kumsal.
August '24

GLOSSARY

Neurodiversity: The concept that neurological differences, such as autism, ADHD, and dyslexia, are natural variations of the human brain and should be respected as such, promoting inclusivity and acceptance.

Neurotypical: A term used to describe individuals whose brain functions align with the majority neurological patterns.

Neurodivergent: A term used for individuals whose brain functions differ from the typical population , encompassing a range of conditions such as Autism, ADHD, dyslexia, and more.

Special Education: Tailored educational programs designed to meet the unique needs of students with special needs.

Therapists: In the context of this report, therapists are caregivers within special education settings. They are sometimes referred to as teachers, as the school environment and children often phrase them this way. The term "therapist" encompasses various professions, including occupational therapy, physical education, and other specialized fields that support the developmental needs of neurodivergent children.

Fizzy: An interactive robotic ball concept initially designed to stimulate physical play and enhance the wellbeing of hospitalized children. It has since been adapted and further developed for various therapeutic and educational applications and used in this research within special education setups.

Ergotherapy (Occupational Therapy): Assist individuals who have physical, sensory, or cognitive conditions to improve their ability to perform everyday tasks.

Motor Skills: The ability to execute specific movements.

Social Skills: The abilities to interact effectively with others, including communication, empathy, cooperation, and conflict resolution.

Cognitive Skills: The mental abilities that enable a person to process information, reason, remember, and relate objects and ideas.

Vestibular Sense: The sense responsible for balance and spatial orientation. Important for maintaining posture, coordination and physical activities.

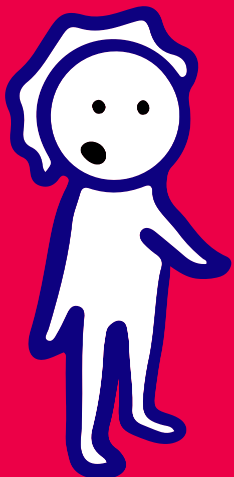
Proprioception: The body's ability to sense its position and movement allows to understand the positions in space without looking, essential for coordinated movement and physical activities.

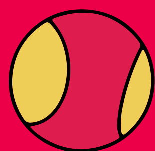
ASC (Autism Spectrum Condition): One of the most common diagnosises of neurodivergent individuals, a developmental condition characterized by differences in social interaction, communication, and restricted or repetitive behaviors. While widely referred to as a disorder, in this report, it is acknowledged as a condition, aligning with the perspective that neurodiversity should be recognized as part of the human variation rather than a disorder

Joint Attention: The shared focus of two individuals on an object or activity, which is fundamental to social interaction and communication.

Joint Engagement: The shared participation of two or more individuals in an activity, which is essential for taking part in activities and socialisation. Particularly challenging for children on the autism spectrum.

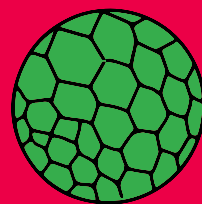
Also, why so many "Fizzy" 's in this report?





The Original Fizzy Concept

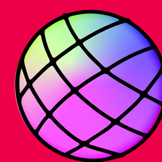
The original concept of Fizzy, designed in a PhD project, (Boon,2020) to stimulte physical play and wellbeing for hospitalized children



Fizzy that is being Developed for Home Rehab

The developing version of Fizzy, focusing on design and control of an intelligent version of it for rehabilitation and preventative healthcare, particularly for vulnerable populations such as patients with a history of stroke.

Referred as "Current Protoype of fizzy that is being developed"



Fizzy Prototype used in this Study

The prototype of Fizzy designed to be used in this study, special education school testings. Uses Sphero-bolt for the technology, has lights and more advanced movement capabilities than the other Fizzy's, it has a transIucent shell.

If not mentioned otherwise, all the Fizzy's refer to this version of Fizzy in this report

Fizzy Edu Concept as an outcome of this research

Fizzy EDU: A conceptualized and advanced version of Fizzy, incorporates the findings of the this study, specifically envisioning the use in special education settings to support the therapeutic and developmental needs of neurodivergent children.

Chapter 8,9 Referred As Fizzy "EDU"

EXECUTIVE SUMMARY

This project explores the potential of an interactive robotic ball, Fizzy, to enhance therapeutic activities and improve engagement among neurodivergent children and their therapists in special education settings.

Neurodivergent individuals, whose brain functions differ from the typical pattern, often require specialized education to address their unique physical, social, and cognitive needs. Special education is essential for skill development and wellbeing of these children.

Approaches for neurodivergent education often include individualized education plans, multisensory learning, and assistive technologies like social robots. While social robots have shown promise in this context, they also present challenges such as high costs and logistical difficulties. The literature review has highlighted the the need for personalized educational approaches, designing familiar technologies that have a meaning in children's lives, and the benefits of technology through multisensory encounters. Grounded in Activity Theory and the Qualities of Play framework, this research positions Fizzy as a tool that can mediate relationships and support skill development across different fields through its movements and sensory capabilities.

Integrating ethnographic research, research through design (RtD), and context mapping, the research was deeply rooted in empirical data and daily dynamics, resulting in the discovery of contextually relevant findings and opportunity points.

Through the observational study, it was noted that therapists play a critical role in developing various skills in these children through tailored tools, activities, and interventions.

However, children's engagement levels often pose a challenge, necessitating strategies that align therapists' extrinsic goals with children's intrinsic motivations for play. Tools like Fizzy have the potential to enhance therapeutic sessions by bridging the gap between those motivations and fostering a more engaging and effective learning environment. The pilot test of Fizzy demonstrated its ability to model behaviors and promote intrinsic motivation, which guided further research and school visit.

A Wizard of Oz testing in the second school visit, with a concept prototype of Fizzy, highlighted its role in mediating children's engagement with tasks and their therapists while also promoting skill development across physical, social, and cognitive domains. The library of behaviors documents how therapists employed Fizzy in their practices throughout the research and equips therapists and designers with empirical data for future studies, informing them about how Fizzy was tested, why and how it worked, and what was observed from the interaction in the child's perspective.

Following the testing and analysis of Fizzy's encounters, online co-creation sessions with therapists were conducted. These sessions facilitated ideation on how Fizzy could be integrated and controlled as an independent tool in therapeutic activities. This collaborative process led to the definition of design requirements for a comprehensive and adaptable service system concept—Fizzy EDU—consisting of a hub(house), ball, remote, and app.

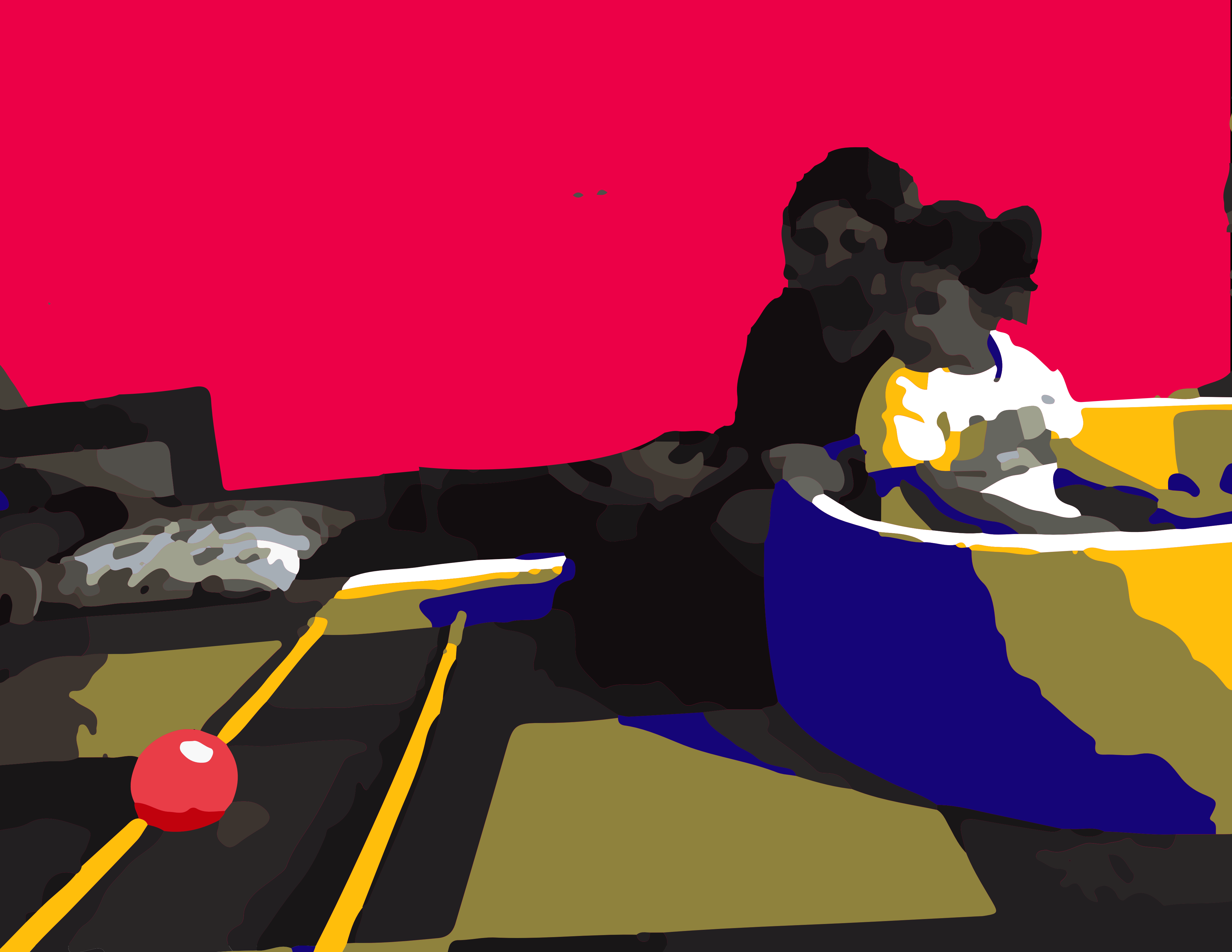
The evolution from the tested Fizzy prototype to the Fizzy EDU concept underscores the importance of developing technology that is adaptable and responsive to the specific needs of its users. Although these technologies set a high standard for functionality and practicality of employing Fizzy Edu as a desirable therapy tool, the actual implementation in

the near future may be constrained to simpler technologies due to practical limitations. Reflection on the desired values and currently achievable technological features of the current Fizzy model that is being developed by engineers and designers aimed to identify possible adaptations and how Fizzy might still provide the core therapeutic values within the realistic boundaries of available technology and to what extent. While with some adaptations the prototype of Fizzy can still support some of the therapeutic values, Fizzy EDU offers a more direct alignment with educational and therapeutic objectives. This adaptation and the new concept signifies the potential of Fizzy as a versatile and effective educational therapeutic tool in special education settings.

Immersing in real-world contexts and incorporating stakeholders' voices in the design process led to the development of relevant and desirable design recommendations for therapeutic applications.

01

INTRODUCTION



This research was started with an interest in the intersection between play, technology, and well being. Children grow up exploring the world and interacting with peers, family, and caregivers, learning the crucial skills needed for independent adulthood through these interactions. This may be more of a challenge to neurodivergent children with special needs, as the environment around them is not always best designed for their learning needs. (Alper et al., 2012). Neurodivergent children often face significant challenges in social interaction and inclusion within various settings. These children may struggle to form relationships with their peers and may experience feelings of exclusion in social environments due to their different social physical and cognitive abilities. (Sasson et al., 2017). Special Education is crucial for these children as the acquisitions that they learn during these practices directly impacts their overall wellbeing. The study aims to demonstrate how interactive interventions through the robotic ball foster engagement and the development of essential skills that empower neurodivergent children both in and beyond the classroom.

Observing the current technology used in special education schools, the wellbeing that activities in those environment bring, and the fundamental right of every child to play highlights the the framing of this study. (Figure 1)

"Play Is often talked about as if it were a relief from serious learning. But for children, play is serious learning"

-Fred Rogers.

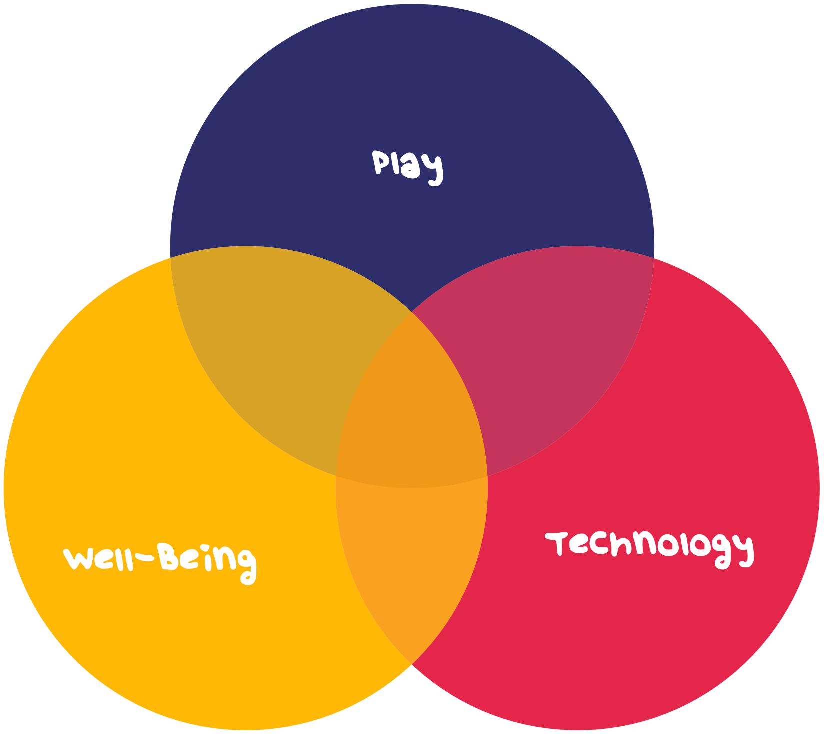


Figure 1: Framing of this study

1.1 Project Aim

This project aims to explore how embedding of Fizzy into therapeutic activities creates engaging learning experiences that promotes skill development and cooperation between children with diverse needs and their therapists. Fizzy's possible role as a mediating artifact is being explored to encourage therapists-children and peer to peer interactions. By promoting physical, social, and cognitive engagement, Fizzy aims to enable active task participation as well as collaborative play . Findings of the research aims to contribute to a deeper understanding of the role of technology in early childhood education of neurodivergent children and provide valuable insights for educators seeking to create engaging, fun and inclusive learning environments for children with diverse needs and abilities.

1.2 Background of the Research

Fizzy was initially designed by Boudewijn Boon (2020) to stimulate physical play and enhance the wellbeing of hospitalized children. Its development is currently being continued by Eda Karaosmanoğlu in collaboration with a research team in RWTH Aachen University in another PhD project, aiming to facilitate at-home motor rehabilitation for vulnerable populations, particularly patients with a history of stroke.

The current Fizzy prototype(Figure 2) is designed to be lightweight and robust, featuring an underactuated mechanism with a single motor and elastic components that ensure cost-efficiency and durability. It moves using a pendulum system, where the rolling direction is determined by the axis of the pendulum's turning. Fizzy incorporates only one sensor, an IMU, which aids in its movement and orientation and can respond to simple user inputs. Without extra sensors, Fizzy's interaction capacity is primarily limited to basic movement responses and preset movement patterns such as rolling in specified directions, wiggling in place, and adjusting its path in response to physical stimuli like taps or bumps.

Figure 2: Current Protoype of Fizzy That is being developed.

Fizzy's value propositions include its simplicity in appearance, technology, and interaction, making it an affordable and accessible tool. Although this simplicity limits Fizzy's directional agility, impacting its ability to provide precise directional control, Its design allows for easy adaptation to different populations, such as individuals with a low socioeconomic status, as it requires no prior knowledge to interact with and functions as a plug-and-play solution.

The versatility of Fizzy , demonstrates its potential across different therapeutic contexts. With the addition of extra sensors and add-ons, current capabilities can be significantly expanded, allowing Fizzy to offer more advanced interactions and respond to a wider range of inputs. Thus, the interactive ball has the potential to address some of the unique challenges such as; **lack of motivation, low attention span and skill development** faced by neurodivergent children and their therapists within a special education context.

However, this version of Fizzy was not used for this study due to practical reasons. The timing of the study and the ongoing development of the prototype meant there was no available prototype to test with. Additionally, the researcher had no prior knowledge of engineering and coding, which meant there was insufficient time and skills to adjust Fizzy's features to fit the special education dynamics and needs. Therefore, another prototype was built for this study, using the robot, Sphero, which was used in the very first development of Fizzy for hospitalized children. The control of the prototype was enabled by a mobile application operated by the researcher during activities.

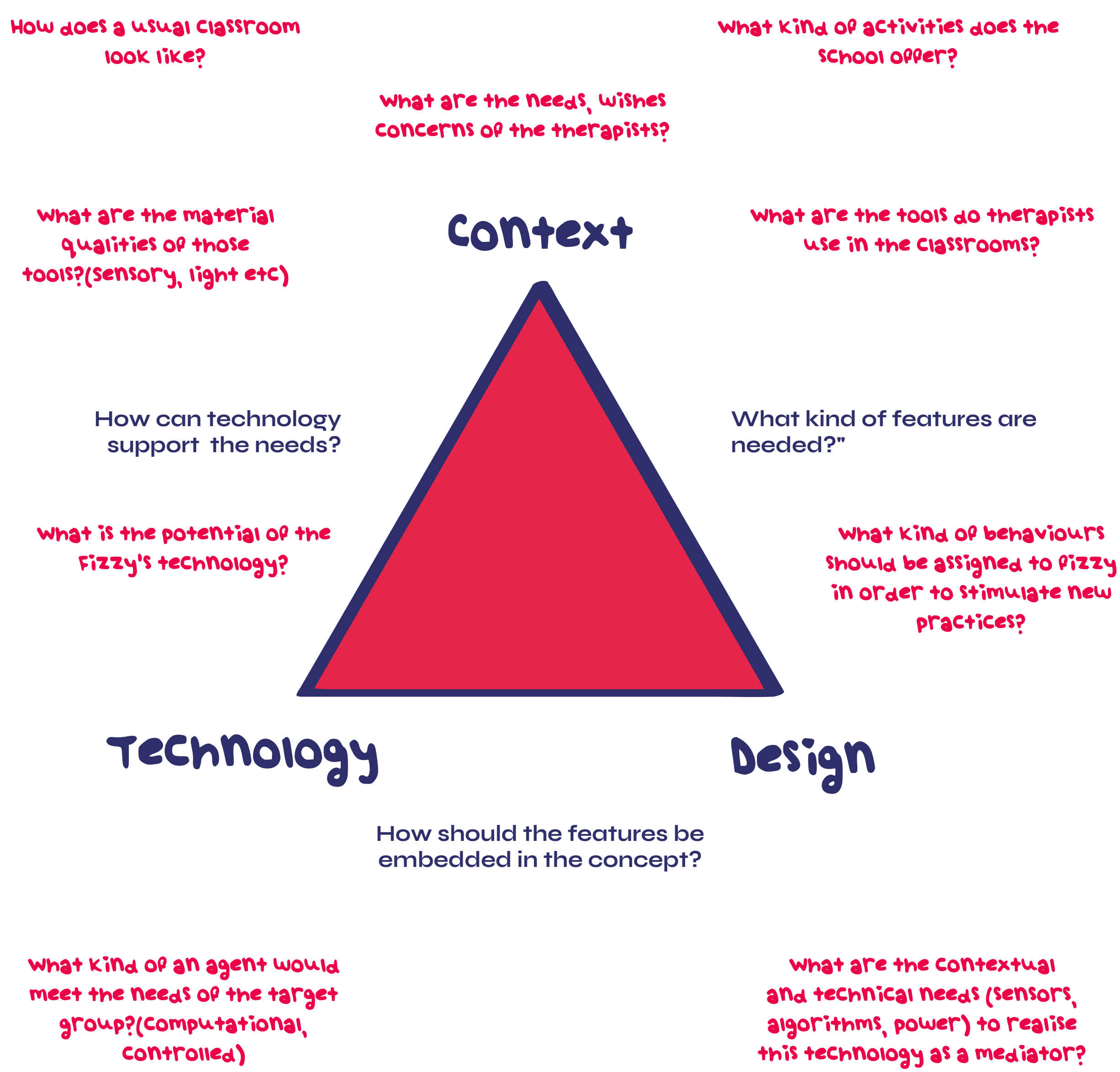
The details of the prototype used in this study can be found in Chapters 4.2 &6.2.

1.3 Project Scope and Context

The primary research question guiding this project is: ***How does the presence of Fizzy, as a mediating artifact, influence neurodivergent children's engagement with their therapists and the environment during therapeutic activities without directly imposing therapy (adult) goals?***

The question was addressed by considering three key areas depicted in the triangular diagram (Figure X): Context(social and physical), Technology, and Design. The central theme focuses on addressing the needs of neurodivergent children and how

Figure 3: Project Scope and Context



these needs can be met through technology and thoughtful design. This approach aimed to integrate social, physical, and technological factors to improve engagement and learning experiences in special education settings.

To understand each aspect, the project involved collaborations with special education schools, therapists, and research groups to gather insights and develop effective strategies for implementing Fizzy.

1.4. Definition of the problem

Neurodivergent children often face significant challenges in social interaction, communication, and skill development, which can hinder their integration into society and daily life. (Kircher-Morris, 2022, ; Vygotsky 1983, 102). Special education schools are uniquely positioned to address the unmet needs of neurodivergent children, employing various tools and methods. (Price, 2011) While efforts are made to develop skills necessary for neurodiverse children, if the skill-building process fails to capture their attention effectively and lacks engagement, it may make it challenging to achieve the desired outcomes. Therefore, the first and the crucial step is to use tools that serve for therapy goals but are enjoyable for children, ensuring their active participation in the learning process. However, current tools used in these settings often lack technological integration and interactivity. This gap in practicality and desirability can hinder the effectiveness of therapy and learning for neurodivergent children. Therefore, there is a need for solutions like Fizzy, which can introduce new practices and strategies for teachers to better support children with special needs while being a desirable plaything in children's world. The way to do that

Context and Stakeholders

The context of the project is defined as special education schools where access to neurodivergent children and therapists are available. This is where neurodivergent children get educational and therapeutic assistance when they get diagnosed. Before starting the project, multiple special education schools were contacted but later on it has been decided to continue with Parla Special Education School in Ankara, Turkey, as a main stakeholder. The school specializes in individualized and personalized education for children with special needs, serving over 150 students. With its team of 26 expert teachers, specializing in occupational therapy, physical education, music, ceramic and kitchen, and floor therapy; the school focuses on different goals for each child, offering both group and one-on-one individual classes based on the child's developmental conditions. The students' diagnoses range from high and low-functioning Autism, Down Syndrome, and Intellectual Disabilities. Three studies in total were completed with Parla Special Education School:

1)An initial visit to observe current classroom dynamics and getting to know practices that they use for sessions, as well as introducing the project. [Chapter 5]

2)A second visit for Wizard of Oz testing of the prototype with therapists during their regular sessions.[Chapter 6]

3)An online co-creation workshop with the same therapists to discuss the results of the analysis and brainstorm possible control mechanisms for Fizzy if it were to become a marketable product. [Chapter 7]

Additionally, for a pilot study, Samen Spelen, a research group based in Utrecht, Netherlands dedicated to promoting inclusive outdoor play, was contacted. Samen Spelen involves therapists, children (with and without disabilities), parents, and other stakeholders in their activities. The therapists from the research group took part in the pilot testing and contributed to the study with their insights on the first version of the prototype before the actual testing happened at the Parla Special Education School.

1.5 Target Group

The idea of researching the value of interaction and engagement stemmed from exploring the needs of neurodivergent children. Children with special needs might need more assistance when it comes to learning, communication, mobility, social interactions, and forming relationships.(Wyeth et al., 2023). While the primary target group for this research encompasses neurodivergent children, Autism spectrum disorder is the most frequently associated form of neurodiversity; even though it is not the sole form of it (MEd, 2021). However, a significant proportion of individuals at the collaborating school also exhibit characteristics of Autism Spectrum Condition (ASC/ASD). Consequently, children diagnosed with ASC served as the primary observation group for this study and catalyzed the project's initial focus on utilizing Fizzy to stimulate engagement —a critical area of support among neurodivergent individuals, especially those who are diagnosed with ASC.

Overall, the study acknowledges the **diverse nature of neurodiversity in special education classroom settings, where children with various diagnoses often learn together.**

CHAPTER TAKEAWAYS

Neurodivergent children face significant challenges in social interaction and inclusion due to their unique physical, social, and cognitive abilities, making special education crucial for their wellbeing. This project investigates the potential of an interactive robotic ball named Fizzy, to enhance therapeutic activities and improve engagement among neurodivergent children and their therapist in special education settings. It also seeks to explore how teacher-child and child-child relationships evolve through the introduction of such technology, since current tools used in these settings often lack technological integration and interactivity.

02

LITERATURE RESEARCH

2.1 Neurodiversity and Being Neurodivergent

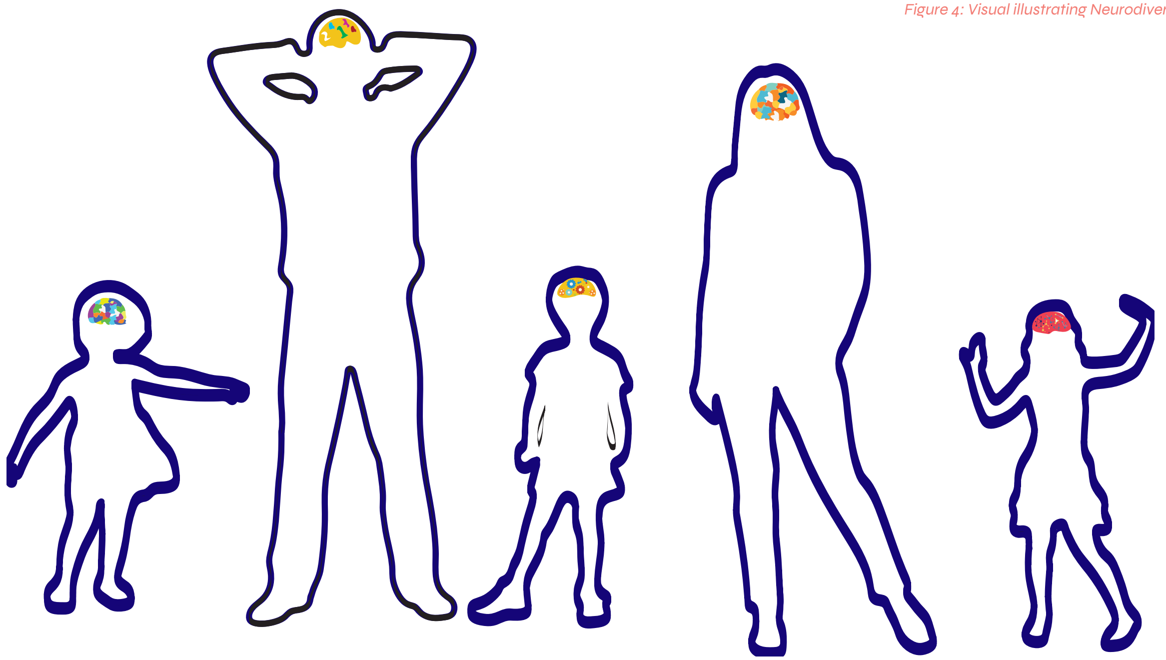
Neurodiversity can be explained by the observed differences in cognitive, emotional, and sensory functioning that deviate from what is typical for most of the general population (Rosqvist et al., 2020). People whose brain differences affect how their brain works are called "Neurodivergent" whereas those whose functions align with the majority are referred to as "Neurotypical". Nick Walker distinguishes these terms by:

> **"Neurotypicality is the way-of-being from which neuro-divergent people diverge."**
>
> Nick Walker (2014)

Neurodivergence results in distinct strengths and challenges compared to those without these differences (Why Do We Use Neurodiverse or Neurodivergent?, n.d.). An estimated 15%–22% of people on the globe are considered to be neurodivergent in some way. (Doyle, 2020) Neurodivergence encompasses various neurominority conditions, such as autism spectrum, attention deficit disorders, down syndrome, epilepsy dyslexia, dyspraxia, dyscalculia (Brînzea, 2019)

Although the target group of the research includes many different neurodivergent children throughout the process of visit to the special education, as mentioned before, children with autism spectrum condition outnumbered the other diagnoses. This might be because most people diagnosed with autism also have other co-occurring diagnoses, such as intellectual disability, language difficulties, hyperactivity, anxiety, and so on (Lai et al., 2019). Therefore, the importance of providing a more detailed explanation of Autism Spectrum Condition has been recognized to make it easier for readers to understand findings.

Figure 4: Visual illustrating Neurodiversity



2.1.1 Autism Spectrum Condition

Autism Spectrum condition (ASC) is a neurological and developmental condition that may affect the way individuals interact with others, how they communicate, behave and learn. There is typically nothing different in their physical appearance that distinguishes them from others (What Is Autism Spectrum Disorder? | CDC, 2022). Because autism is a spectrum disorder, each person's symptoms are different from each other, it is characterized by repetitive behaviors, restricted interests and deficiencies in social communication (Hodges et al., 2020). They can have difficulty focusing on a task or switching between tasks, as well as different sensitivities to certain stimulus. Since autism is a lifelong condition, an autistic person's requirements, abilities, and difficulties might change over time. Following a diagnosis, parents and other caregivers start the difficult process of choosing interventions and collaborating with therapists to create and carry out programs that will improve their child's functional ability, academic performance, behavior, language, and social skills (Ennis-Cole, 2019). As individuals move through different phases of life, they could require various kinds of assistance. Early therapy and intervention can have a significant impact on an autistic individual's skills and results in the future (What Is Autism? | Autism Speaks, n.d.).

> **"There is no one type of autism, but many."**
>
> Stephan Shore

2.1.2 Joint Attention and Joint Engagement

Joint attention and joint engagement are crucial aspects of social interaction and communication. Children with autism often display lower levels of joint attention and joint engagement, which can significantly limit their opportunities for learning and social development. (Keen, 2009).

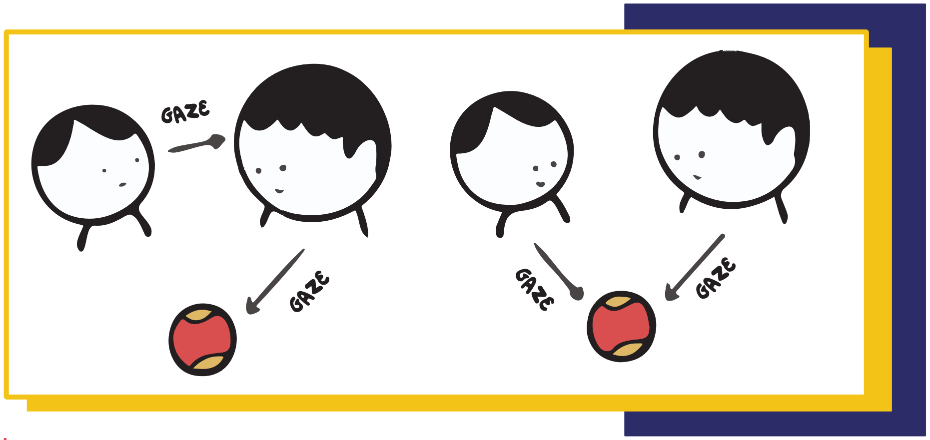


Figure 5: Illustration of Joint Attention

Joint attention refers to the ability to coordinate attention with another person, such as by following their gaze or pointing gestures to share experiences or focus on an object or event. (Figure 5) Joint engagement involves the active, coordinated participation of two or more individuals in a shared activity or experience (Keen, 2009).

Caregivers often use reinforcers to enhance these skills. For example, in one observed one-on-one class, an autistic child showed an unusual interest in a specific book and struggled to focus on tasks, repeatedly asking for the book every 2-3 minutes. The child would only answer questions when given chips, an intrusive reinforcer that interrupted the activity flow. *To make the child speak, a chip break was needed.*

2.2 Pathology Paradigm, Neurodiversity Paradigm and Neurodiversity Movement

Nick Walker (2014), a scholar in neurodiversity, introduced the terms pathology paradigm and neurodiversity paradigm to describe contrasting approaches to variations in psychological and behavioral functioning. The pathology paradigm focuses on deficiencies, disorders, and differences, often used with concepts of health. In contrast, the neurodiversity paradigm suggests that neurodiversity is natural and valuable. It critiques the characterization of this diversity as disordered, highlighting how such categorizations are shaped by societal power dynamics and inequalities (Walker, 2013; Walker, 2014; Walker, 2021; Chapman, 2019). This perspective acknowledges that even groups of neurotypical individuals are neurodiverse, as no two individuals possess identical minds or brains (Dwyer, 2021).

For a long time, the pathology paradigm has been to conceptualize neurodevelopmental differences through the lens of the medical model, which frames them as impairments or deficits that necessitate remediation (Granger et al., 2023). However, the neurodiversity paradigm has challenged this perspective, arguing that neurological differences should be recognized as natural variations in human cognition and behaviour.

According to Walker (2014), the neurodiversity paradigm provides a philosophical foundation for the activism of the Neurodiversity Movement, but it is important to distinguish these concepts as they are not synonymous. Some individuals involved in developing inclusive education strategies based on the neurodiversity paradigm may not identify as social justice activists or part of the Neurodiversity Movement.

The neurodiversity movement aims to challenge the assumption that certain conditions, such as autism, are inherently disabling (Rosqvist et al., 2020b). Instead, it seeks to "problematize neurotypical domination" and show that the **disabling aspects of these conditions arise from neurodivergent people's interaction with a society that does not accommodate their distinct ways of interacting with the world, and may even oppose them actively.**

2.3 Navigating Neurodivergent Education: Current Practices, Challenges, and Technological Innovations *with Multisensory Learning and Social Robots*

The dynamics of special education schools and practices that caregivers use for the different conditions and needs for Neurodivergent individuals is a critical consideration in understanding the current landscape and future directions of this field. The social environment is the fundamental of any educational setting. The interactions that take place between the student, their peers, academic and professional staff have a significant impact on the learning process. (Hamilton & Petty, 2023). In light of the theories from the neurodiversity paradigm and movement, as well as Hamilton and Petty's (2023) observations, **the goal of education should not be to "fix" neurodivergent students but rather to create inclusive environments that accommodate and nurture their unique strengths and needs.**

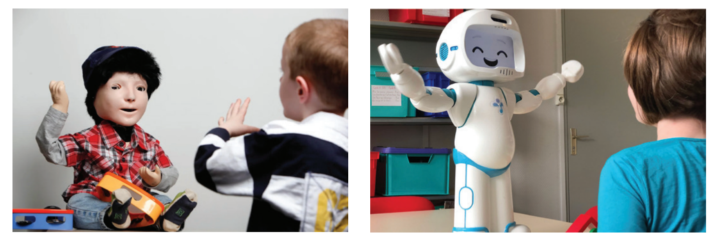
Current practices in special education often involve individualized education plans (IEPs) tailored to each student's specific needs. These plans are developed collaboratively by teachers, therapists, parents, and the students themselves, ensuring that the educational strategies employed are personalized and effective (Morin, 2024). The integration of technology has become a well-recognized approach to aiding young children with special needs. (Wyeth, Kervin, Danby, Day, & Darmansjah, 2023) One important consideration of the technology is the need for multisensory teaching approaches that cater to the diverse learning preferences of neurodiverse students (Puccini et al., 2013). Multisensory learning involves engaging multiple senses simultaneously to enhance the learning experience. This approach can help neurodivergent students better process and retain information. Multisensory learning may involve incorporating **visual, auditory, and kinesthetic elements into lesson plans**, as well as providing flexibility in the ways students can demonstrate their understanding. This type of learning can "trick" the brain into holding more information by using multiple modalities (visual, auditory, and kinesthetic inputs) (Miller, 2001).

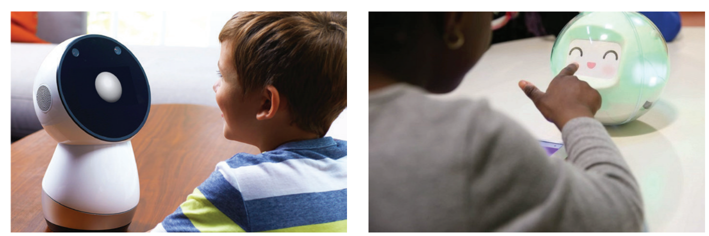
2.3.1 Assistive Technologies and Socially Assistive Robots

Assistive technologies provide alternative stimulation methodologies that complement the residual sensory channels. (Brayda et al., 2015) Assistive technology (AT) is defined as any item, equipment, or system, whether commercially bought, modified, or customized, that is used to enhance, maintain, or improve the functional abilities of a child with a special condition (IDEA, 2004). In the initial stages of early childhood education and care (ECEC) settings, assistive technology is employed with the objective of enhancing learning, behavior, attention and communication in children. (Parette & Stoner, 2007).

Among the suggested technologies, social robots have received a lot of interest, with a major emphasis on intervention techniques (Cabibihan et al., 2013). Socially assistive robots are designed to offer motivation, guidance, and support, facilitating the advancement of individuals through the provision of appropriate emotional, cognitive, and social cues. (Overview | Socially Assistive Robotics, n.d.) They have the ability to aid in therapeutic interventions, enhancing engagement and learning outcomes for neurodivergent children (Cabibihan et al., 2013). The use of social robots, including anthropomorphic robots like NAO, Milo, Kaspar, QT and others like Jibo, Leka, etc., (Figure 6) has been proposed as an efficient solution in special education settings. These robots are capable of interacting with children, stimulating their curiosity, and grabbing their attention efficiently due to their enhanced functionalities (Ueyama, 2015b; Cordis, 2018). Research has shown that children with autism experience social robot therapy more positively than therapy from health care professionals.

Figure 6:Social Robots (left to right) "NAO, Milo, Kaspar, QT, Jibo, Leka"





The reason for this preference may be that humans, due to their unpredictable nature, can evoke emotional responses in children, while robots' repeatability, predictability, and flexibility may make children experience less anxiety and be more willing to engage in learning activities. (Lytridis et al., 2018).

As mentioned in CybSPEED projects report on PEdagogical Rehabilitation in Special EDucation (2018), robots can alleviate some of the workload on teachers of children with special needs by motivating children, and enhancing the learning processes.

Although these robots are increasingly being integrated into various domains, including therapy, education, and health assistance, due to their interactive nature and ability to provide personalized support, there are significant challenges in implementing these practices consistently. These challenges include limited resources, varying levels of training among staff, time constraints, and the need for ongoing professional development to keep pace with emerging best practices and technological advancements. Despite the legal requirements for assistive technology under the Individuals with Disabilities Education Act (IDEA), the current financial climate and the high costs and logistical challenges associated with these advanced technologies often limit their accessibility. This prevents schools from acquiring technology specifically designed for neurodivergent children (Center for Parent Information and Resources, 2017).

Instead, schools might classify technology intended for mainstream classrooms as assistive technology, which fails to address the specific needs of neurodivergent students (Puccini et al., 2013). Therefore, educational technology for classrooms should be designed to be flexible, not only because of the mainstream inclusion class dynamics but also due to the differences of each neurodivergent child. It should be customizable to different needs, as it may be the only technology available to groups that have different characteristics. This disparity underscores the need for developing cost-effective and scalable solutions to ensure that all neurodivergent children can benefit from these innovative tools.

In addition to those technologies, mobile educational apps offer personal use alternatives. These apps integrate multiple modalities and are portable, facilitating multisensory learning experiences across diverse settings, including outside the classrooms (Suriya & Arumugam 2020). However, the predominant focus on digital solutions overlooks the holistic tool ecosystems of neurodivergent children, alongside these technologies, they often integrate non-digital props, toys, and stuffed animals into their daily interactions (Alper et al., 2012). According to research, a **robot's physical morphology has a substantial impact on children's expectations and worries about social robots** (Collyer-Hoar et al., 2018). These implications concern unexpected outcomes that can result from mismatches between a robot's morphology and the context of interaction. This oversight highlights the need for design practices that encompass a broader spectrum of assistive technologies, including both digital and non-digital aids that would create a sense of familiarity for children.

*In summary, the current practices and challenges in the education of neurodivergent children highlight the need for **accessible technology, familiarity and multisensory** learning approaches that can be tailored to the needs of neurodivergent children by caregivers.*

Since the research activities in this study are conducted in Turkey, it is essential to provide background information on the special education landscape in the country;

2.3.2 Special Education Context In Turkey

In Turkey, the education system for children with special needs encompasses various types of educational settings and support mechanisms aiming to provide the best possible educational outcomes for neurodivergent children, helping them to reach their full potential. The landscape involves both the integration into mainstream schools and special education schools. When a child with special needs is referred to a school with a medical report, experts at the school develop Individualized Education Plans (IEPs) to outline specific learning goals and the support services required. These plans may involve modifications to the curriculum, specialized instruction, and other accommodations. The choice between mainstream schools and special education options depends on the individual needs of the children and the resources available.

Mainstream Education

Turkey strives to integrate children with special needs into mainstream education as much as possible. This integration can occur in two main ways. Some mainstream schools have inclusion classes where neurodivergent children attend regular schools alongside their neurotypical peers, but in separate classes. In other cases, those children are integrated into the same classes as their neurotypical peers. The goal is to create inclusive environments where neurodivergent children can learn alongside neurotypical children, providing accessible facilities, training teachers in inclusive practices, and fostering a supportive school culture.

However, most of the mainstream schools struggle to provide adequate support for diverse learning styles and social needs, leading to a prioritization of academic performance over comprehensive educational outcomes. Because of the challenges in fully integrating neurodivergent children into mainstream education alongside neurotypical children,the focus often shifts towards attaining passing grades rather than achieving broader developmental or educational goals. As a result, children and their parents view the primary objective of attending mainstream schools as meeting minimal academic standards, rather than fully supporting holistic development. Consequently, they often seek additional support from specialized education schools.

Special Education Schools

In addition to efforts at mainstream integration, Turkey also has special education schools for children who have conditions that affect their learning. These schools are financially supported by the government, providing eight hours of individual and four hours of group classes per month in either private special education schools or rehabilitation centers. Early intervention in special education is considered the most effective way to help neurodivergent children progress in various skills. There are special education teachers, speech therapists, occupational therapists, and psychologists in those schools who tailor the structure of the class based on children's needs.

"The most effective method for ASC is special education "

- Education Coordinator, Parla Special Education School

2.4 Knowledge Gaps and Conclusions

While the advancements in educational practices, technologies and interventions for neurodivergent children hold promise in enhancing educational experiences for neurodivergent children, there are several knowledge gaps and areas that require further exploration. The literature review has highlighted the characteristics of neurodiversity, emphasizing the need for inclusive environments, highlighting the effects of personalized educational approaches and benefits of technology through multisensory encounters and technologies tailored to meet the needs of neurodivergent individuals. Therefore, this study focuses on 3 main points and investigates these points by utilizing Fizzy as a research tool:

2.4.1 Adaptable Interventions Aligned with Neurodiversity Paradigm

Current theories and interventions emphasize the need for education that is not fixed but adaptable to the diverse needs of neurodivergent individuals. The neurodiversity paradigm advocates for recognizing and accommodating the unique strengths and challenges of each child, rather than trying to "fix" them. This underscores the necessity for educational tools and interventions that are not only flexible but also customizable to meet the varying requirements of each child. Such tools should allow for adjustments and modifications that caregivers can manage based on different children and sessions, ensuring interventions are directly relevant and beneficial.

2.4.2 Affordability and Accessibility of Tools for Neurodivergent People

A significant barrier in the implementation of assistive technologies is their high cost, which restricts accessibility in educational settings due to financial concerns faced by schools and caregivers (Puccini et al., 2013). Most social robots used in research are notably expensive, limiting their practical application in everyday educational settings. Fizzy addresses this issue by being designed as a low-cost device that incorporates essential digital functionalities without the need for expensive, high-tech components. Furthermore, the ability to add on extra sensors and components as needed allows for incremental investments over time, making it easier for schools and parents to manage costs while still providing comprehensive support for the child's development. This feature ensures that Fizzy remains an accessible and scalable solution.

2.4.3 Designing Familiar and Relatable Technologies:

There is a noticeable lack of research on designing social robotic technologies that children can easily relate to, using objects they encounter daily, such as toys and playthings.(Alper et al., 2012) Most social robots used for research with neurodivergent children are anthropomorphic, which, while engaging, may not always be familiar, something looking like human but not a real one. (Vagnetti et al., 2024) As described by Kim et al. (2021), relevant affordances of social robots were found to provoke task-related actions from children. Fizzy, on the other hand, resembles a ball—a common and familiar object in children's play, providing familiar tactile and sensory experiences similar to conventional playthings, while integrating essential digital functions tailored to the context of special education . This familiarity enhances predictability and comfort, making it easier for children to engage with the device. Additionally, most robots are used for social and cognitive skills while lacking support for physically active tasks, despite the fact that neurodivergent children often have co-occurring conditions that necessitate physical education as well as social interventions. The integration of technology into physical education has proven to be a motivating factor for students (Suriya & Arumugam, 2020). Fizzy's ability to model physical behaviors through interactive movement is a significant benefit that Fizzy offers in that context. Its movement capabilities allow it to model physical activities, such as navigating parkours, without being intrusive to the actual tasks children need to perform while its multisensory features allows engagement of multiple senses simultaneously to enhance cognitive and social learning and interaction.

In summary, Fizzy aims to addresses these critical gaps by offering by aligning with the neurodiversity paradigm, ensuring accessibility, andadaptability and relatedness.

CHAPTER TAKEAWAYS

Neurodivergent" refers to individuals whose brain functions differ from the typical pattern, necessitating specialized education for their development. This includes individualized education plans, multisensory learning approaches, and assistive technologies like social robots. Social robots have shown promise in special education, but also brings barriers like high costs and logistical challenges. Key gaps include the need for adaptable interventions that can support diverse nature of individuals, affordability of tools, and designs that are familiar to children. Fizzy has the potential to address these gaps by being an adaptable, affordable, and familiar educational tool that promotes engaging learning experiences and enhances the development of neurodivergent children.

03

THEORETICAL FRAMEWORK

3.1 Activity Theory as a Design Perspective

Activity Theory (AT) (Leontiev 1977; Kaptelinin and Nardi 2006) provides an important framework for the insights and data gathered in this research. It contextualizes human activity as a complex system of interconnected elements, rather than isolating individuals or behaviors. The theory of instrumental act indicates that **activities are driven by goals and mediated by various tools, both physical and psychological, (such as language) and those play an important role in shaping the relationship between humans and their environment** (Vygotsky, 1982a). It views the use of technology to accomplish meaningful objectives for both individuals and groups as an essential element within a broader, complex and mediated system of interactions between people, technology, and their environment, rather than as distinct from other types of human-technology relationships.

This means that there is a connection between human action to human goals embedded in the physical and social environment. This interconnection between subjects, objects, and tools in previous object with intent studies with Fizzy is framed by Rozendaal et al. (2019). as follows:

> **"Humans hardly ever act directly in the world. Instead, we rely on artifacts that mediate the relationship"**

3.1.1 Zone of Proximal Development (ZPD)

A key concept within Activity Theory is the Zone of Proximal Development (ZPD), which refers to the difference between what a learner can do without help and that we can do with the help of an adult, a friend, technology, or what Vygotsky called the "more knowledgeable other". The ZPD highlights the potential for development through social interaction and collaboration. (1978) The world presents different goals and objectives, both social and physical, and by engaging in this reality, learners construct knowledge and competencies, in other words, we simply learn by being in the world. By actively engaging in these domains, individuals develop mental frames and skills necessary for navigating the world.

> **"What a child can do in cooperation today, he can do alone tomorrow"**
>
> -Vygotsky

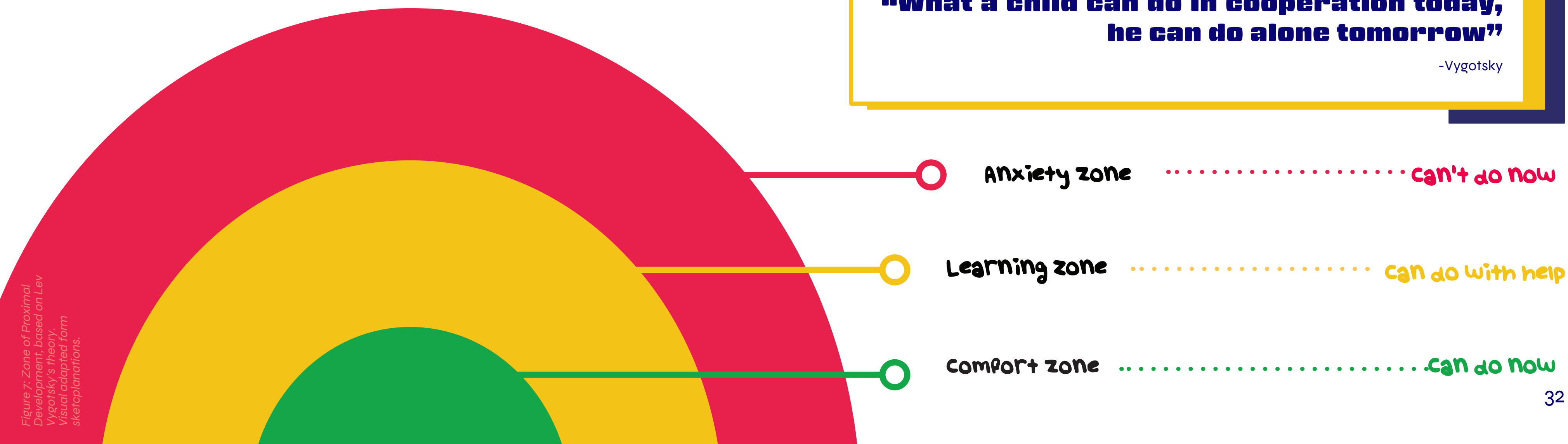


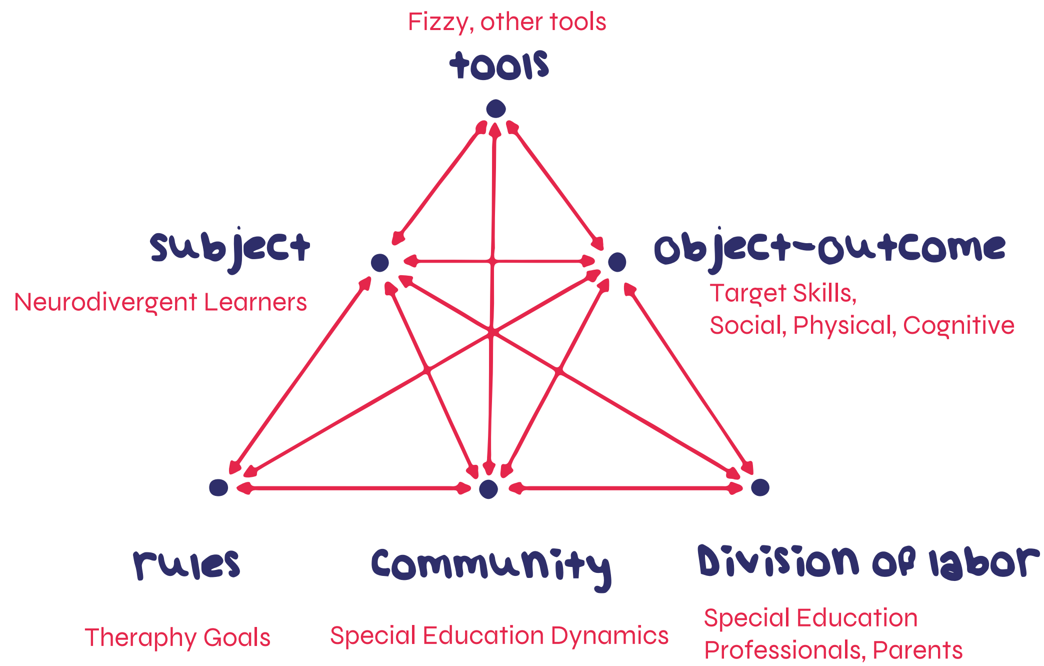
Figure 7: Zone of Proximal Development, based on Lev Vygotsky's theory. Visual adapted form sketchplanations.

3.1.2 Relevance of AT for Conceptualizing learning through artifacts

The doing of activities within a rich social matrix of people and artifacts is essential for learning. Learning in the world includes various domains—social, motor, sensory, and cognitive which are also highly relevant to the context of this study and therapy goals that are being used in the special education classrooms.

According to the theory, **objects in the world do not exist independently of other objects; thus, subject-object interactions are embedded in entire contexts or environments.**

Figure 8: Activity System Model by Engeström(1987), adapted from "A Systematic Review on Robot-Assisted Special Education from the Activity Theory Perspective " by Tlili et al. (2020)



While Fizzy may not be more knowledgeable "cognitively" than a human being, its playful attributes and technological capabilities make it an effective "more knowledgeable other" within the context of learning. Fizzy is intended to immerse children in rich contextual interactions with therapists as well as other objects. By participating in activities involving Fizzy, children would be exposed to blend of tasks, that enhance their cognitive, physical and social engagement skills within their ZPD. This aligns with the principles of Activity Theory, recognizing **the significance of mediated, contextual learning experiences.** The Activity System Model by Engeström (1987) supports multi-stakeholder data analysis and uses the "collective activity system" concept as the fundamental unit of analysis in a visual way. (Figure 8) This model from an educational lens, helps to analyze teacher approaches (Karasavvidis, 2009) and interaction towards technology (Rozario et al., 2015). It highlights the complex interaction of elements affecting how digital technology might serve children with special needs in early childhood education.(Wyeth, Kervin, Danby, Day, & Darmansjah, 2023). For these research all the variables in the context are correlated with the model as seen in Figure 8.

3.2 Qualities Of Play

Play is a fundamental aspect of childhood development, serving as a powerful tool for learning, socialization, and emotional expression. In the context of special education, the therapeutic value of play becomes even more fundamental as it can be leveraged to address the unique needs of students with various developmental and cognitive conditions. (Vygotsky, 1967) According to Gielen's framework on the Lenses on the Qualities of Play (2023), the Play Phases and the Developmental Stages provide valuable insights into the meaningful interactions facilitated by Fizzy. These play frameworks help to understand how children engage with and derive meaning from their play experiences with Fizzy.

3.2.1 Play Phases

Play Phases describes how children's playful interactions with objects evolve through distinct stages: exploration, functional play, variation, and integration. These phases represent a sequential progression from initial contact with an object to more complex and integrated forms of play. It is important to mention that the shift between phases does not have to be in the same play activity but can happen overtime. 4 phases can be explained as follows;

Exploration: What is it? Children initially discover an object's basic characteristics and functionalities.

Functional play: What does it do? They use their motor and sensory skills to understand how the object works.

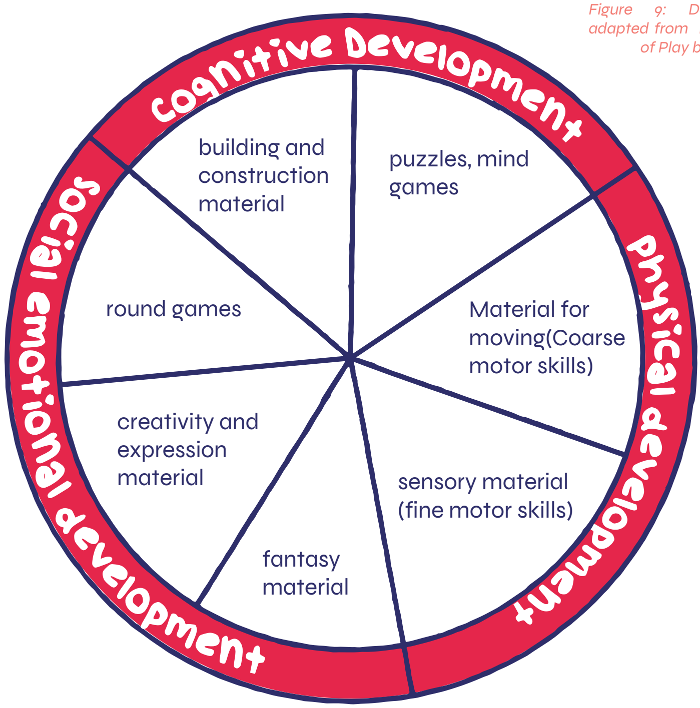
Variation: What can I do with it? Children experiment with different ways to interact with the object and achieve various outcomes.

Integration: How should I employ its capabilities? They integrate the object into more complex play scenarios involving imagination and social interaction.

3.2.2 Developmental Stages

To support children's play effectively, it's crucial to consider the interconnected development areas such as sensorial and motor skills (physical development), cognitive abilities, and social-emotional skills. Playthings should align with children's developmental stages, offering challenges appropriate to their abilities. When they are mismatched with children's developmental levels, challenges may become overwhelming in one area while underwhelming in others. When play is absent or limited, the development of executive function and prosocial behavior can be disrupted, leading to the risk of toxic stress and adverse outcomes. For therapeutic educational activities, play becomes an even more important avenue for addressing these developmental challenges. (Yogman et al., 2018)

Figure 9: Developmental stages, adapted from Lenses on the Qualities of Play by Mathieu Gielen, (2023)



3.2.3 Relevance of Qualities of Play in Shaping Playful Therapeutic Experiences

Mathieu Gielen's framework outlines the progression of play behavior through exploration, functional play, variation, and integration phases, each crucial for children's developmental stages across physical, cognitive, and social-emotional domains. The theory of Lenses on the qualities highlights two main relevance to this research: Firstly, the importance of appropriate play activities to emphasize the diverse developmental needs of children, which is especially crucial for tailoring activities to the unique needs of neurodivergent children. Fizzy can addresses this requirement through customizable features that allow caregivers to tailor interactions based on individual preferences and developmental abilities, as outlined in Chapter 8 and Knowledge Gap 2.4.1

Secondly, Fizzy'ss interactive features encourage children to engage in collaborative meaning-making during the exploration phase, fostering interaction with their therapists and promoting engagement and communication skills.

Throughout the functional, variation, and integration phases, children and therapists experiment with Fizzy's multisensory interactions, which include movements and sensory feedback. These interactions enhance both cognitive and physical development through activities that involve problem-solving and creativity.

In play, children naturally practice and extend their skills across these domains simultaneously.

The concept of Fizzy for special Education use ensures that it can dynamically align with the evolving developmental stages of each child through its adaptability, while also promoting the progression of play. Caregivers can promote healthy child development by employing playful learning experiences in the therapeutic activities. (Yogman et al., 2018). This approach focuses on fostering freedom of exploration, smooth transitions between phases, and motivational aspects that drive children's engagement and learning, thereby fostering meaningful and effective learning experiences in therapy settings.

CHAPTER TAKEAWAYS

By understanding the interconnectedness of human activities and the role of tools in mediating these activities, Fizzy can be positioned as a therapy tool that mediates different relationships while supporting the cognitive, social, and physical development of neurodivergent children. Activity Theory and the Qualities of Play framework guide the research on how Fizzy can best serve these functions, providing playful experiences that stimulate development across multiple domains. These principles ensure that the design of Fizzy for the special education context effectively meets the diverse needs of its users.

04

METHODOLOGY

The methodology of this study adopts an integrative approach, drawing upon the principles of research through design, context mapping techniques, and ethnographic research. Together, these methodologies facilitated a comprehensive understanding of dynamics between the neurodivergent children, therapists and Fizzy together with other therapeutic tools in special education setups, guiding to development of concepts that are engaging, and contextually relevant.

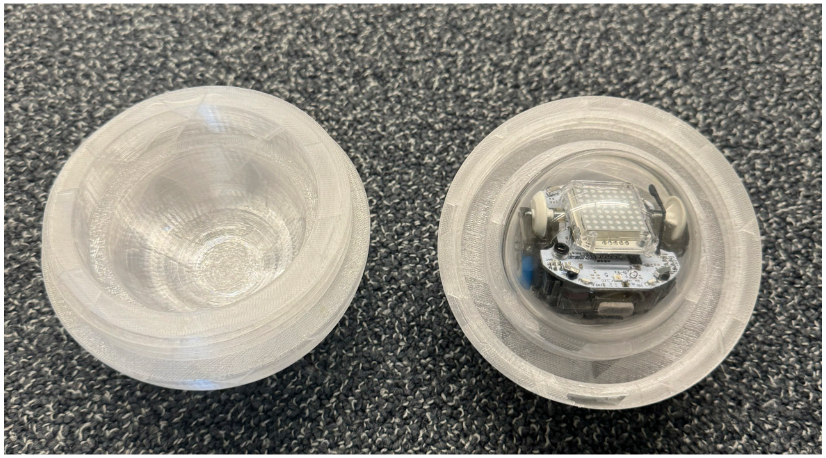
4.1 Ethnographic Research

The methodology incorporates an ethnographic approach, which involves the immersive study of people and their behaviors within their natural settings (Schwandt, 2007). This approach was employed to gain a profound understanding of the school dynamics, environments, routines, and behaviors of neurodivergent children and their therapists. This strategy is particularly important because deep engagement is essential for understanding what makes this population different from typically developing children. It requires additional efforts in reviewing literature and collaborating with experts (Alper et al., 2012). The information gathered from observational research is documented in the form of 'field notes', which involves what the researcher actually sees and hears while they are in the field in order to produce meaning and understanding of the context (Schwandt, 2007). These insights were crucial in informing the design iterations of Fizzy, ensuring it was tailored based on empirical data of its users through field studies. Details about how this method was utilized can be explored in Chapter 5,6.

4.2 Research Through Design

Research through design (RtD) is a key component of the methodology, as it highlights the ways in which design actions play a formative role in the generation of knowledge (Stappers & Giaccardi, 2014). This approach acknowledges designing the right thing before being concerned with designing the thing right. Bringing physical prototype to the context of the study, whether it is conceptual that has only the limited elements available for use still brings significant value to the discussion as their tangible qualities help people think about their current experiences as a starting point as well as speculating on the future scenarios of the use of the product that may not currently available in the current version. The RtD process ensured that the design concepts and recommendations for Fizzy evolved in response to tangible user interactions. In this study, RtD involved cycles of designing, prototyping, testing, and refining Fizzy through different prototypes and can be found under the Chapter 6.

Figure 10: The prototype of Fizzy that is used in this study



4.2.1 The prototype

In this study, Fizzy was powered by Sphero Bolt(Figure 10), a programmable robotic ball equipped with a variety of features such as LED lights, sensors, and Bluetooth connectivity. It can be programmed and controlled via a mobile application, allowing for a range of interactive and engaging activities. Leveraging Sphero Bolt's capabilities, the Fizzy prototype was controlled by the researcher using this mobile application, aiming to provide an effective and engaging therapeutic tool.

4.3 Context Mapping Studies

Contextmapping is a user-centered research method that focuses on understanding users' environments, emotions, and needs in different levels (Visser et al., 2005). In this study, contextmapping was used to delve deeper into the insights gathered and collaboratively develop solutions that address the children's and therapists' needs. As the method advocates, users were viewed as experts of their own experiences and generative techniques such as co creation were used to uncover tacit and latent knowledge not accessible through traditional methods. (Figure 11) How this method was employed with its details can be found in Chapter 7.

4.3.1 Ethical Considerations

The study complied with ethical guidelines for research involving children, including anonymized quotes, pictures and drawings based on the sessions. Informed consent was obtained from parents or guardians through consent forms. Due to the children's literacy challenges and neurodivergent conditions, consent from the children was obtained verbally by a therapist who explained the research to them in a manner that minimized distress. Participants' confidentiality and anonymity were maintained throughout the study by anonymizing data for analysis and ensuring personal research data were destroyed after the study concluded.

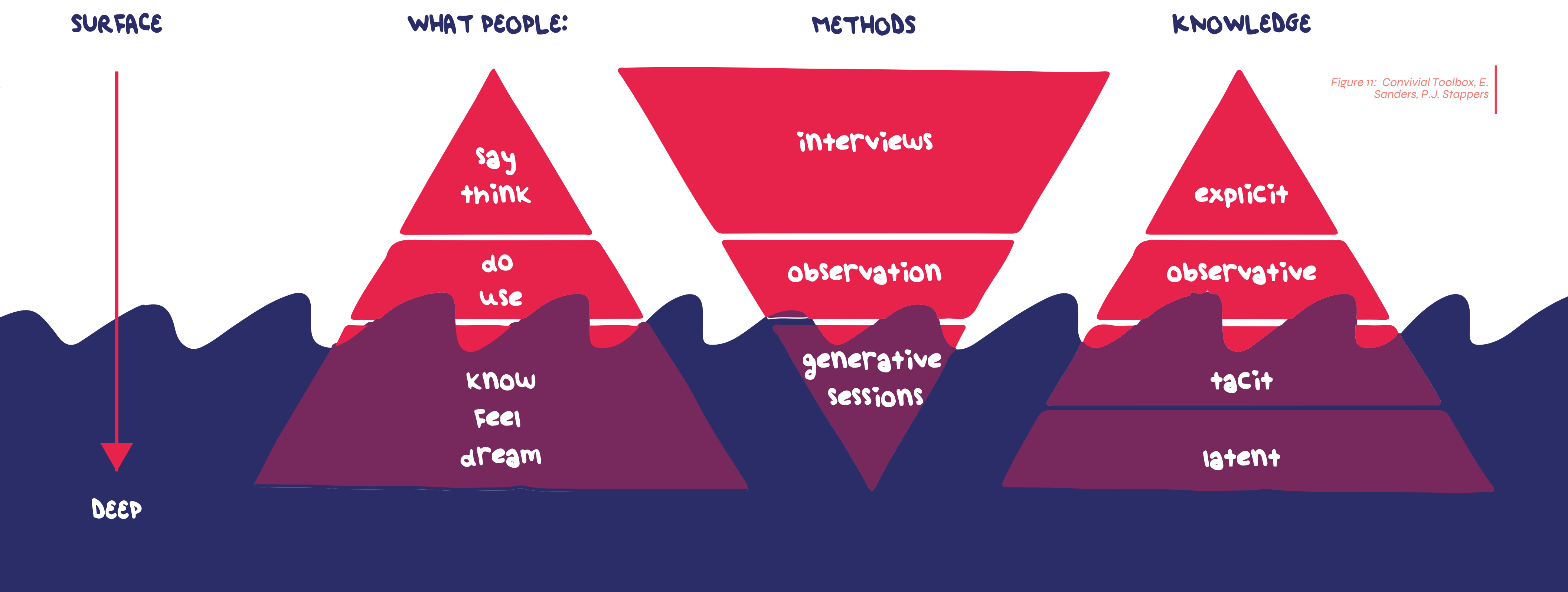
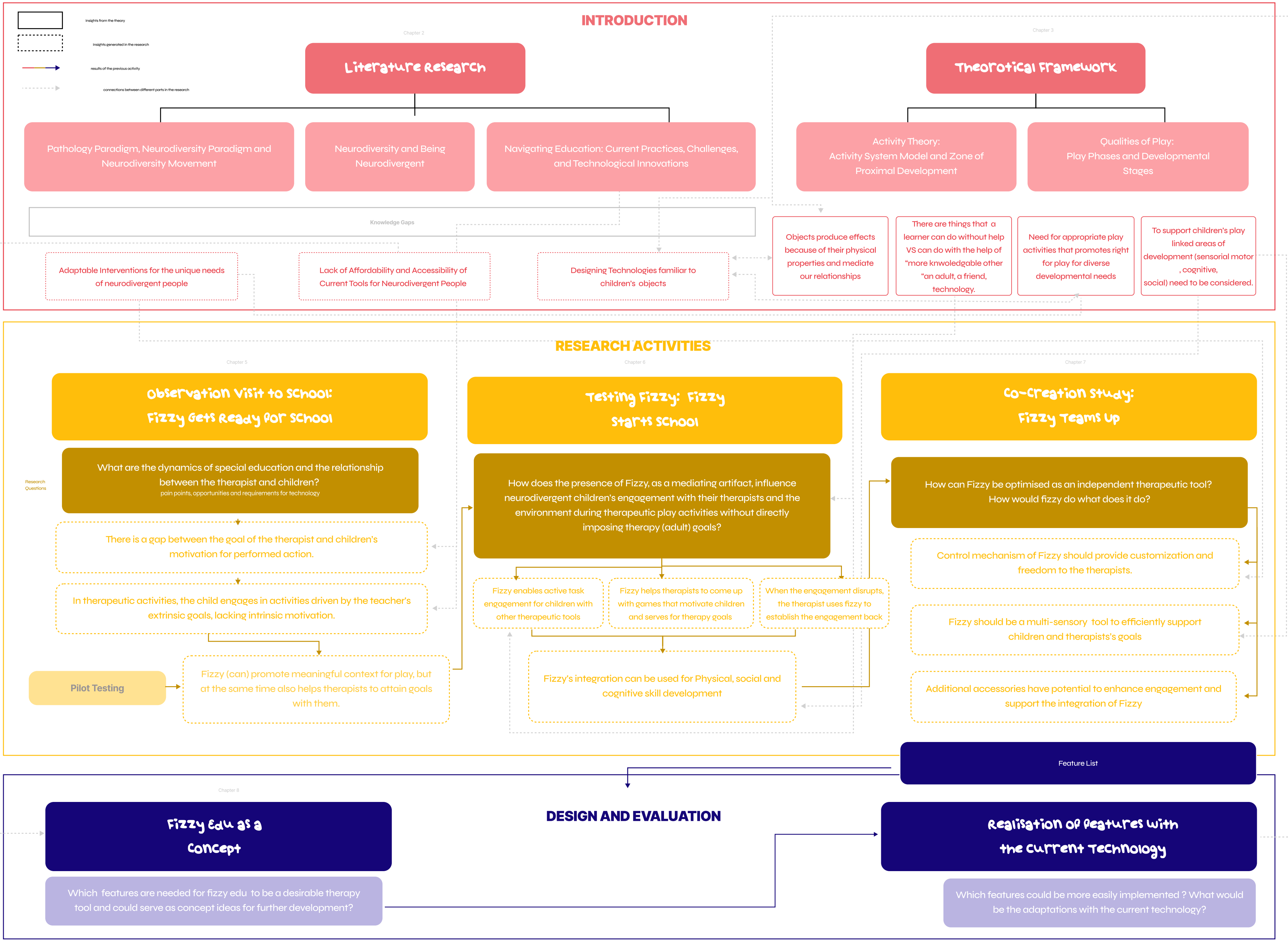


Figure 11: Convivial Toolbox, E. Sanders, P.J. Stappers

Figure 12: The Project Framework and how different activities relates to eachother



All interactions with children were supervised by qualified professionals. The researcher's role was limited to observation and controlling the robotic ball Fizzy, under the guidance of therapists.

The stakeholders of this research do not have direct access to the raw research data but the anonymized outcomes and findings.

4.4 Project Framework-Thesis Setup

The setup of this thesis can best be described schematically, as shown in Figure 12. This framework connects the different activities and insights gathered throughout the research, illustrating how they correlate with each other. It provides a structured overview of the interrelationships between the various components of the study, highlighting the research questions, key findings and their implications for the final proposed concept Fizzy Edu together with the reflection on the current technology.

CHAPTER TAKEAWAYS

By integrating ethnographic research, research through design (RtD), and context mapping, the project aimed to be deeply rooted in empirical data and daily dynamics of the special eduction. Immersing in real-world contexts and incorporating stakeholders' voices in the design process ultimately led to the development of relevant and desirable design recommendations for therapeutic applications.

05

FIZZY GETS TO KNOW ITS FRIENDS

5.1 Objective:

During the discovery phase, the primary objective was to visit special education school(s) and get to know the dynamics of the environment and stakeholders through observations. This involved closely examining classroom dynamics, interactions among students and educators, as well as various activities taking place. Informal conversations and observations are utilized to gather qualitative data, supported by background research on the neurodiversity and integration of technology and play within special education settings. Ultimately, the aim of the discovery was to identify dynamics, pain points, opportunities and requirements for effectively incorporating technology and play into special education environments.

5.2. Method

On the first day, the researcher was introduced to teachers and the education coordinator by the principal. The schedule of 3 days was planned to join the related classes that has the project's target group of students, neurodivergent children in preschool and early education ages(3-10). Over the three days, the researcher attended 17 classes: **8 physical education, 6 occupational therapy, 2 one-on-one, and 1 cooking class.** The researcher maintained a non-intrusive presence to minimize disruption to the classroom environment.

As a passive observer, the researcher documented observations through field notes, videos, audio recordings, and photographs. These recordings were reviewed to gain insights into the interactions between children and therapists, focusing on **verbal, physical, and gestural** attributes. The pain points of children and the goals and strategies of therapists for tackling those were analyzed and clustered to understand the dynamics of special education.

Ethical considerations were addressed by obtaining parental consent (See Appendix 3) and ensuring the confidentiality of all recorded materials.

5.3. Findings

The observations provided insights into the goals of teachers and therapists in addressing the pain points of children in the context of special education. These insights are presented in the subsequent subsections.

5.3.1 Role of Teachers and therapists in child's progress: Elaboration on Teacher's and Therapist's Goals

Teachers and therapists play a crucial role in the development of neurodivergent children by focusing on challenges faced by neurodivergent children, such as fostering essential skills for sensory, motor, social, and cognitive development, as well as implementing effective behavior management techniques crucial for the children's well-being.

Activities tailored to address these challenges significantly impact daily life, as illustrated in Figure 13.

The goals of teachers and therapists are multi-layered, aiming for comprehensive skill development to enhance children's overall readiness for different encounters. For example, a teacher may aim to work on fine motor skills by asking the child to put small balls onto a sharp surface, while its generalization in life would enable the child to hold a pencil correctly at school.

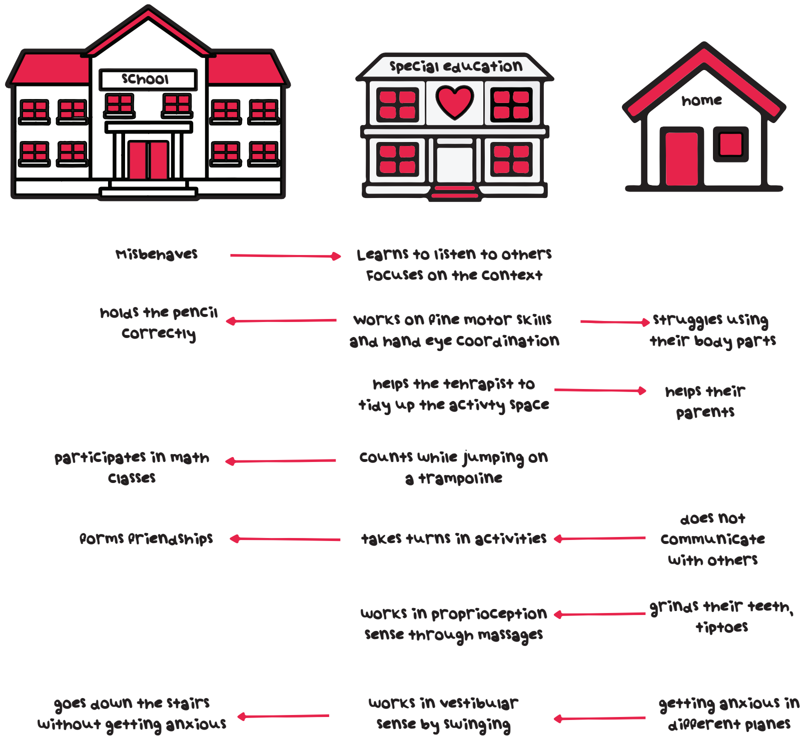


Figure 13: Illustration of how different activities in different environments interralete with eachother for child's

5.3.2 Pain Points of Children

Children with special needs, exhibit a wide range of strengths and weaknesses, some children demonstrate proficiency in receptive language skills and following instructions, others might excel in expressive language or face difficulties with verbal communication, making each child unique in their abilities and challenges. During the visit, various needs of children at different levels were observed, including sensory and motor difficulties, communication and social interaction challenges, as well as behavioral and emotional issues. There are four recurring pain point themes that educators are aiming to work on:

Sensory Processing Development

Sensory support is a crucial aspect of special education. Children with special needs often encounter sensory challenges, such as unusual interests or sensitivities to certain stimuli. Neurological factors affect how sensory information is processed and integrated in the brain, impacting a child's ability to respond to external stimuli effectively.

Figure 14: 8 sensory systems, visual adapted by https://www.sensoryfriendly.net

In addition to the widely acknowledged "5 senses" (taste, touch, hearing, sight, and smell), neurodivergent individuals may also exhibit hyper- or hypo-reactivity to proprioceptive, vestibular, and interoceptive senses, which affect body awareness, balance, and internal body states (e.g., hunger, thirst). (Figure 14)

Therapists use various tools and activities to address these sensory needs (Figure 15). For example, weight vests, textured materials, and massaging tools are used for children lacking proprioception.This sense helps them perceive their body part's positions relative to each other and the environment. .When the input is low, children might seek sensory input in unconventional ways, such as licking objects, tiptoeing or grinding their teeth. Therapists address these needs by enabling children to feel their muscles, joints, and body parts to provide effective sensory integration therapy, aiming to reduce these behaviors.

Figure 15: Tools used by therapists during sessions;Massaging tool with foam,disco lights, swing, weight vest

To address the vestibular sense, occupational therapists employ tools that provide unfamiliar planes of movement like cocoon-like swings, climbing walls, or trampolines that modify balance and gravity, helping children maintain posture, coordination, and stability.

Sometimes, sensory tools are used to keep the child engaged and focused. For instance, educators might turn on disco lights to calm a child while swinging or use bubbles to re-engage a disconnected child.

Physical Skills Development

Many children require both physical and cognitive support, especially those managing multiple conditions like physical impairments alongside neurodevelopmental challenges. Neurodivergent children, especially those on the autism spectrum, often face difficulties with eye contact and hand-eye coordination. Some children also struggle with balance, body movements, motor skills and coordination.

To address physical challenges, the school employs various tools and activities, such as parkours with hoops, discs, balls, and cones, trampolines, and treadmills. (Figure 16). These interventions enhance hand-eye coordination, reflexes, fine and gross motor skills, balance, and the ability to follow multi-step instructions.

Figure 16: Activities and tools used ifor physical development in the sessions

Each activity is adjusted to meet individual needs, supporting physical development and motor skills. For example, during group parkour activities, children may perform tasks differently based on their abilities, with some jumping over obstacles from a height and others requiring ground-level jumps.

Social Emotional Skills Development

Understanding social cues is essential for navigating and thriving in human social interactions. Neurodivergent children commonly encounter challenges in sustaining attention within specific contexts, engaging in tasks and conversations and regulating their emotions and behavior in competitive situations. (Hodges et al., 2020). They often struggle in coordinating their attention between people and objects(Joint attention), making it difficult for them to participate in shared activities. (Joint engagement,) These struggles frequently result in social withdrawal and loneliness from peers (Molnar-Szakacs et al., 2020).

Success in social interactions is not solely defined by task completion but also by the development of social skills such as considering others' needs, taking turns, waiting for others, and maintaining context during interactions. Activities in sessions are designed to demonstrate and reinforce these skills with questions like "Whose turn is it?" and "Who wants to be next?" Educators also suggest alternative activities before fulfilling the child's request to teach patience, cooperation, empathy, and conflict resolution. Requests for reassurance and questions about tasks are common, reflecting children's need for support and clarification.

Cognitive Skills Development

Cognitive development in neurodivergent children often presents challenges in reasoning, following instructions, understanding tasks, correlating information, and decision-making. These difficulties can significantly impact their ability to engage effectively in both academic and social tasks.

Educators focus on improving cognitive abilities such as contextual comprehension and the ability to correlate sentences. For instance, when children struggle with forming meaningful sentences, educators use scripts and script fading to teach conversation skills, reducing the pressure to think of original thoughts and aiding in starting or continuing conversations. (Birkan, 2011) Similarly, when a child struggles to follow a physical activity, therapists demonstrate the task themselves, providing visual guidance and reinforcement.

During multi-step activities, educators use a combination of main tools and supporting tools to foster cognitive development. For example, in parkour activities, a teacher might instruct a child on which color to jump onto next or which ball to take. This requires the child to stay focused, perceive the given information, and execute the action accordingly. Such activities enhance physical coordination, cognitive processing, attention, and the ability to follow multi-step instructions.

Figure 17: Children Demonstrating Interest in Taking Turns and Raising Their Hands to be selected.

5.4 Discussion & Conclusion

Neurotypical people might not have to put extra effort on practicing skills that are mentioned in the findings as they simultaneously occur during social setups, but neurodivergent individuals have to practice them to build social competence (Ennis-Cole, 2019). The findings highlight the critical role of skill generalization for neurodivergent children to integrate effectively into society.

Despite various tools and activities used to teach these skills, children's engagement levels often fall short, making it challenging for educators to maintain motivation.

Figure 18: A dialogue observed between the therapist and the child during one of the sessions.

Figure 19 : Toys brought to sessions by children

To address this, educators use strategies such as supportive multisensory materials and incorporating children's preferences into sessions. **Children may, for example, find what the therapists's build as an activity boring in some cases but participate to be able to do something they enjoy later.** Some children bring toys to sessions, asking therapists to incorporate them into activities or insist on simply playing with them instead of following the therapists' tasks (Figure 18,19).

Figure 20 : Multiple tools used by therapists to reach to a goal

Figure 21: The current dynamics observed in the setting, .

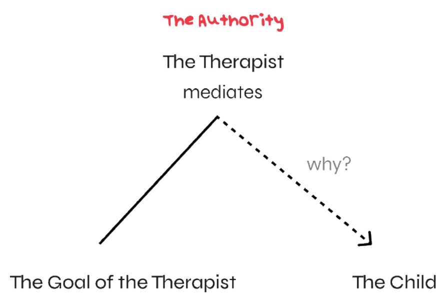
Figure 22:The involvement of the child starts with the direction of therapist towards to activity.

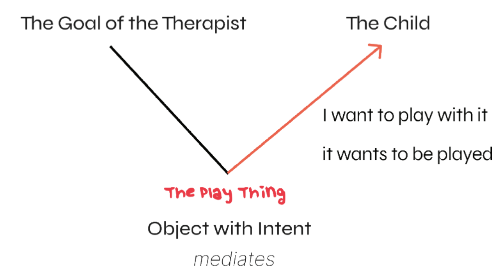
In therapeutic activities, the child engages in activities driven by the teacher's extrinsic goals, lacking intrinsic motivation.

A significant gap exists between the therapists' goals and the children's motivation. Sometimes children show no interest in the chosen object and activity, therapists communicate their goals through tools and additional objects to make activities "fun" for children, to keep children engaged while achieving therapeutic goals. For example, a therapist might use a massaging tool alongside lights to provide sensory input for a child lacking proprioception. The light keeps the child calm and engaged with the massaging activity. (Figure 20).

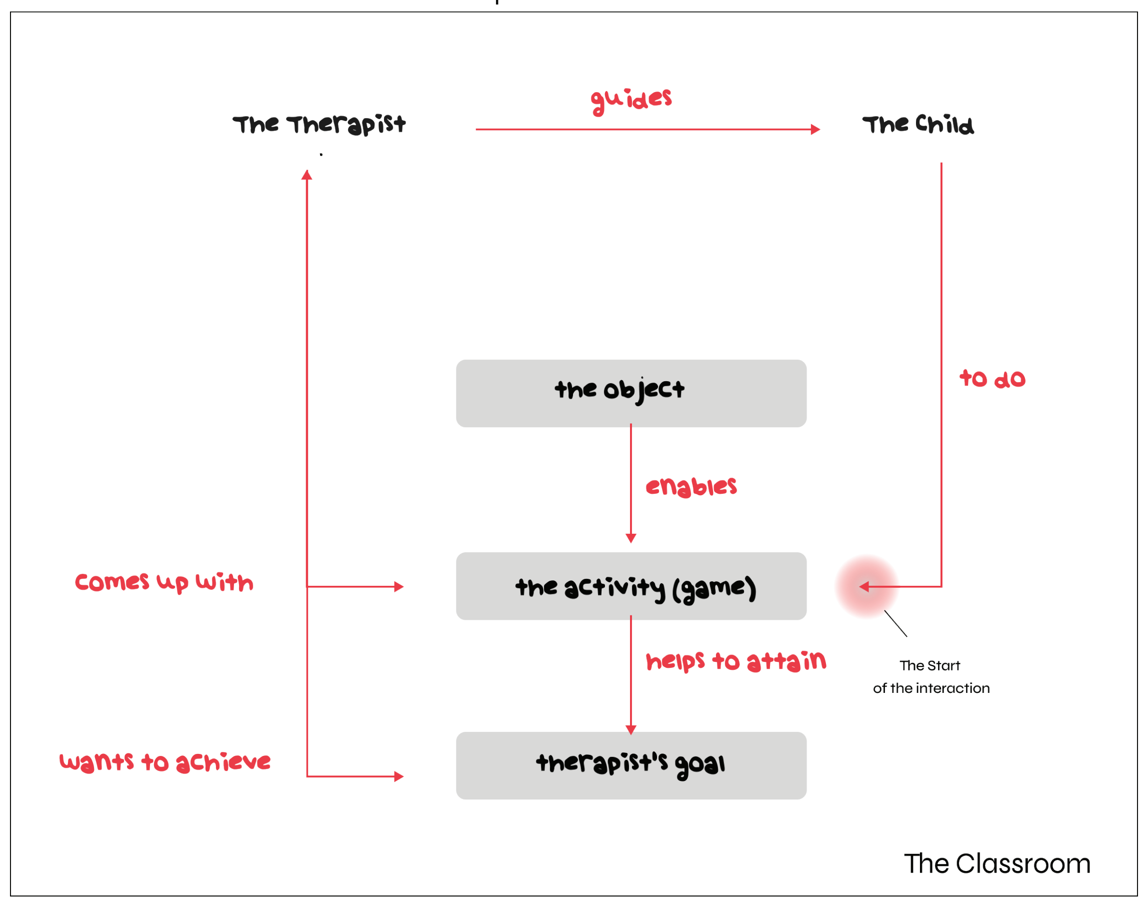
The therapist has an extrinsic motivation to facilitate the activity and achieve their goals, while the child would engage more easily if there is an intrinsic motivation to play and interact with the activities and others. **Aligning these motivations by incorporating elements that resonate with the child's interests can facilitate meaningful engagement and promote effective therapeutic sessions.**

In therapy, artifacts mediate the interaction between therapists' goals and children's engagement. (Figure 22)





Therapeutic Activities



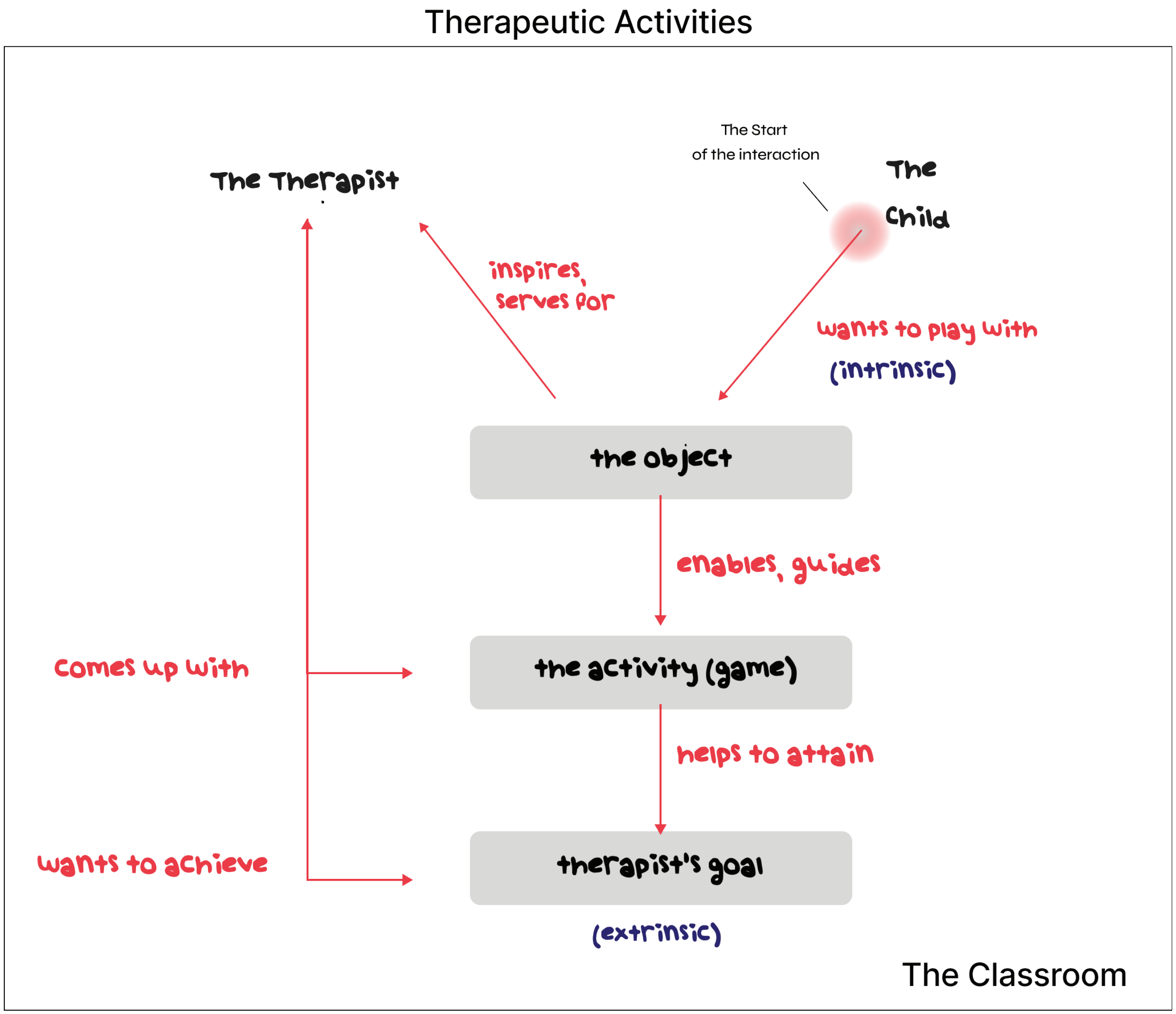
When these artifacts lack meaning for the children, maintaining their attention becomes challenging. (Figure 21)

The mismatch between extrinsic motivations of therapists and intrinsic motivations of children highlights the potential for innovative solutions. This sparked the research opportunity and underscored the potential of Fizzy in this context.

Fizzy promotes meaningful context for play, but at the same time also helps therapists to attain goals with children.

When a child intrinsically wants to interact with an object, it fosters a more engaging environment and effective session flow. Fizzy can serve as both an educational tool/assistant for therapists and an engaging plaything for children, bridging the motivational gap. (Figure 22)

Figure 23: The potential of fizzy serving for therapist's oals while provoking intrinsic motivation for children. The interaction can start with showing interest to fizzy.



5.5 Pilot Test: Samen Spelen? First exposure of Fizzy.

5.5.1 Objective

To gather data and feedback on Fizzy's interaction qualities and understand the stimuli it provides for children to refine its use, a pilot study was conducted in a playground before proceeding to school settings. The study aimed to provide preliminary insights on exploring the potential of Fizzy as a tool to stimulate intrinsic motivation and create a meaningful context for play for children, which was identified as a gap in therapy sessions

In the playgorund, group of researchers are working on inclusive outdoor play together with students from ergotherapy, physiotherapy, and orthopedics. Fizzy was brought there to observe children's reactions towards it and understand research group's viewpoints on integrating such tools into therapy.

5.5.2 Method

The first exposure of Fizzy, using a concept prototype, took place in the Living Lab playground (Figure 24), which offers diverse play environments. Initially, there was a presentation round where researchers presented their works on inclusive play, followed by the testing phase. Neurotypical children across various age groups were observed interacting with Fizzy during the testing phase.

Figure 24 : Living Lab playground in Utrecht that gathers students and researchers.

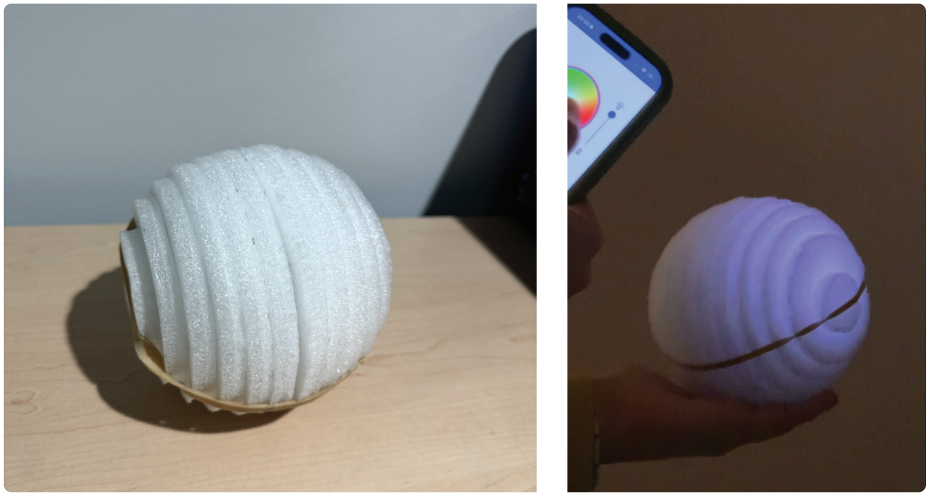


Figure 25 : Low fidelity prototype of fizzy for the pilot testing

The Prototype

The prototype of Fizzy used in the playground was low fidelity, constructed from polyethylene foam slices glued together to form a ball shape. (Figure 25). Fizzy was controlled via a smartphone.

The Procedure:

The testing lasted for 20 minutes. Fizzy operated in three preplanned modes during the evaluation:

Mode 1: Bumping into children

Mode 2: Moving around when unobserved

Mode 3: Escaping when approached

After the testing, semi-structured interviews were conducted with the research group to understand their reactions towards Fizzy.

5.5.3 Findings

Findings from the playground pilot test revealed several observed characteristics of Fizzy's interactions, as seen in Figure 26, including *Eye Gazing (Tracking), Following Fizzy (with their own will), Running after Fizzy, Trying to catch Fizzy, Helping Fizzy, and Different Children interested in the same object.*

Children aged 1-4 exhibited keen eye gazing, attentively tracking Fizzy's movements, and actively chose to follow Fizzy, indicating intrinsic interest. One toddler, who initially resisted imitating their mother, followed Fizzy independently, highlighting Fizzy's potential to influence behavior based on intrinsic interest.

Figure 26 : Observed interactions from theplayground testing

Action of Fizzy	Action of Children	Skill	Value
Rolling around freely	Not very interested	Social	-
Rolling around close to children	Eye Gaze	Social	Join Attention
	Following Fizzy	Social	Staying in the context
	Talking out loud what fizzy is doing	Cognitive	Verbalizing
	Showing Fizzy to others	Social	Joint Attention
Bumping into children	Eye Gaze&Observing	Socio-Cognitive	Understanding intentions, Social Perception
	Laughing	Social	Social Bonding, Communication
Escaping from Children	Catching Fizzy	Cognitive	Visual Perception and Attention, Prediction and Anticipation
	Following Fizzy	Cognitive	Curiosity,Coordination,Integration of Sensory Information
Getting Stuck	Offering Help	Social-Cognitive	social interaction, cooperation, empathy
	Kicking fizzy	Cognitive+Motor	Observation, Assessment, Planning and Decision-Making, Physical
	Following fizzy with others	Social	Joint Engagement, coordinate attention between oneself, another person, and an object or event.

When Fizzy rolled away (Mode 3), it led to playful pursuits, such as running after and attempting to catch it. Older children demonstrated fluency in transitioning between play phases, they verbalized their observations and asked questions about Fizzy, reflecting cognitive engagement. When fizzy was stuck one girl asked their therapists if they should "help" it to keep going. After some time, children expressed a desire to interact with it differently, such as throwing or kicking it, fitting into Gielen's (2023) variation phase as they were already trying to find the limitations and capabilities of the object.

Although some children were not engaging with fizzy directly, they were following what fizzy was doing, highlighting shared interest and potential collaborative play scenarios.(Figure 27).

Figure 27: Different Children showing interest in Fizzy's behaviours.

In the semi structured interviews, therapists noted that Fizzy could benefit children who struggle to socialize, especially neurodivergent children, by sparking initial interest. An ergo-therapist emphasized the need for flexibility in engaging neurodivergent children, stating , "Children with special needs depend more on others or other things to engage since they are usually on their heads." suggesting that Fizzy could serve as a trigger for the engagement with its playful nature.

5.5.4 Discussion & Conclusion

While the visit to the school highlighted the gap between the goal of the therapist and children's motivation for performed actions, the pilot study revealed the potential of Fizzy to address this issue by mediating interactions. By stimulating intrinsic motivation, Fizzy can promote children's engagement in therapeutic activities. This aligns with activity theory's emphasis on **artifacts as mediators of human actions and relationships** (Leontiev 1977; Kaptelinin and Nardi 2006).

To test if fizzy mediates therapist's goal to children without being directive , the following research question was formulated to measure the effect:

Research Question

How does the presence of Fizzy, as a mediating artifact, influence neurodivergent children's engagement with their therapists and the environment during therapeutic play activities without directly imposing adult goals?

This research question served for the purpose of the second visit to the school, and can be found in the next section.

CHAPTER TAKEAWAYS

Neurodivergent children face sensory, physical, social, and cognitive challenges, requiring individualized approaches to support their development. Therapists play a critical role in developing various skills with tailored tools, activities and interventions. However, children's engagement levels often pose a challenge, necessitating strategies that align therapists' extrinsic goals with children's intrinsic motivations for play. Tools like Fizzy have the potential to enhance therapeutic sessions by bridging the gap between those motivations, fostering a more engaging and effective learning environment. The pilot test of Fizzy demonstrated its ability to model behaviors highlighting its potential as a mediating artifact. These findings guided the second school visit, detailed in the next section.

06

FIZZY STARTS SCHOOL

Figure 28: Child holding Fizzy after it rolls away during an occupational therapy session.

6.1 Objective:

The primary focus of the second visit to the school is to investigate the impact of Fizzy, on enhancing engagement and interaction during therapeutic sessions.

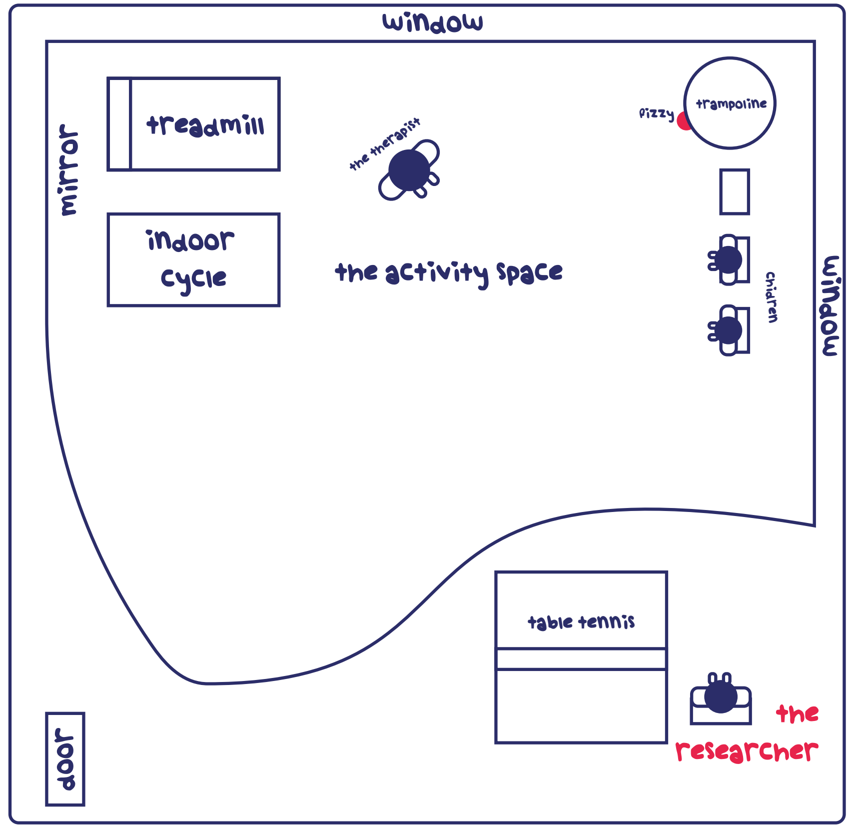
Specifically, the study aimed to explore how Fizzy's presence and behaviours facilitates meaningful context for play for children while promoting skill development across social, cognitive, sensory, and motor domains, which is the main focus of special education educators.

In light of the research question mentioned in the previous chapter, this second study aimed the test the following hypothesis to provide qualitative insights into the complex field of child-robot and human-robot interaction within special education:

Hypothesis

The presence of Fizzy contributes to the engagement between the child and the therapist .

Figure 29 : Setup of the testing



6.2 Method

Drawing inspiration from various Human-Robot Interaction studies as well as considering the current technical capabilities of Fizzy, wizard of oz testing method was used in the study. Fizzy was being controlled by the researcher via a mobile application. The researcher was situated at a distance from the activity area, allowing them to control Fizzy's movements based on the interactions occurring in the context without disrupting the usual activity flow.(Figure 29)

To empirically answer the research question and test the hypothesis Fizzy was tested with a total of 13 children across 10 sessions including 5 occupational therapy and 5 sports classes.

Ethical considerations were carefully addressed throughout the testing process. As with the initial observations, consent was obtained from the parents (see Appendix 3), and the confidentiality of all recorded materials was ensured.

6.2.1 Materials and Tools

The primary tool used in this study was Fizzy with a translucent shell (Figure 30). The shell consists of two parts, with the halves of the sphere assembled together using a threaded mechanism, keeping Sphero Bolt embedded.. This design choice ensures the safe protection of the technology inside and makes it difficult for children to open the shell. The aim was to present Fizzy as an interactive toy rather than a robotic device. Fizzy was used in various interactive activities aimed at enhancing cognitive, social, and motor skills by using movement, lights and different speeds. The control of the prototype was enabled by a mobile application by the researcher.

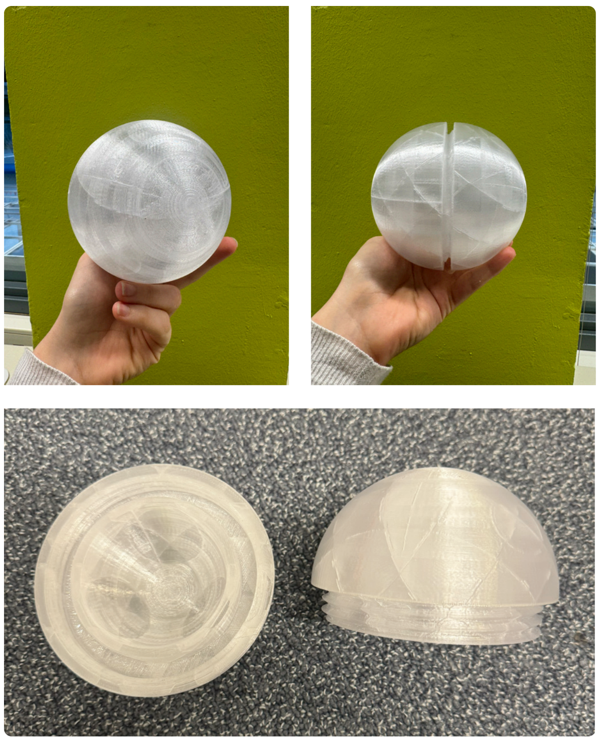


Figure 30: The prototype of Fizzy used in the testing.

Given the unpredictable dynamics of children's actions, several shells were brought to the context in case something would go wrong. Although these additional shells did not have as strong a closing mechanism as the first one, they had different characteristics, such as varying light emission and size.(see Appendix 5)

To facilitate documentation, the researcher used observation sheets (see Figure 31) to record contextual dynamics and interactions involving the child, Fizzy, therapist and the designer through a graphical model. These sheets included a place for notes on important session interactions prompted by a list of questions, and semi-structured questions to ask for therapists.

On the other side of the sheet, there were questions aimed to capture insights into the activities' interactions and effectiveness;

Child Number:
Age:
Diagnosis:
Class:
Date:
Consent:
Which Prototype:
Mode of Fizzy:
Exploration:What is it?
Functional Play:What does it do
Variation: What can I do with it?
Integration:Fluency

Mode: Bump into children
Mode:Go around when no one is watching
Mode: Escape when approached
Mode:

Activity:

Eye Gazing(Tracking)
Following Fizzy(with their own will)
Running after Fizzy
Trying to catch Fizzy
Helping Fizzy
Different Children interested in the same object

The therapist has an extrinsic motivation with the activty and the child has an instrintic motivation with the activity. How do extrinsic and the instrinsic come together?It is a very dynamic situation. I will explore how how is this negotiated.

Figure 31 : Observation sheets of the researcher for the testing

- How does the therapist modulate the environment to motivate the child for the activity?

- What does the teacher do with Fizzy or want to do with Fizzy? Why is this activity important (therapeutically)?

- What does Fizzy do?

- How does the child react to in response to fizzy's actions?

- How does fizzy work, when does it work, and when does it not?

6.2.2 Data Analysis Methods

After completing the testing phase video recordings, voice recordings, pictures, and observation sheets were analyzed. The analysis was structured around key components of the activity system(Engeström, 2000) adapted to suit the specific focus and data collected.

Personal information of children was anonymized by assigning numbers to each individual and session, as shown in Figure 32.

Child's Number	Session	Code of the Observation
C1	Sports	S.1.C.1
C2, C3	Sports	S.2.C.2.3
C4	ErgoTherapy	E.1.C.4
C5	Sports	S.3.C.5
C6,C7	Sports	S.4.C.6.7
C8	ErgoTherapy	E.2.C.8
C9	ErgoTherapy	E.3.C.9
C10	ErgoTherapy	E.4.C.10
C11,C12	Sports	S.5.C.11.12
C13	ErgoTherapy	E.5.C13

Figure 32: Anonymisation process of the data

To analyze the effect of fizzy with respect to the activity theory and interaction design practices, various parameters capturing what happens in the context were defined. To understand the context as a dynamic and ever-changing system, perspectives of the therapists and children, as well as the physical and social context, were compiled into an excel sheet. A total of 73 interaction snippets were captured across all sessions. This approach enabled the researcher to analyze data from multiple perspectives, defining robot interactions that initiate, mediate, adapt, and alter the physical and social meaning of therapeutic activities. Figure 33 shows a part of the data sheet used to record elements of the child-robot and therapist's interactions (For data from all 11 sessions, please refer to Appendix 4.).

After the comprehensive analysis of 73 interaction snippets happened in the context from 11 sessions, recurring physical actions and reactions of Fizzy were defined a as interaction patterns and characterized by Fizzy's movements. An interaction pattern incorporates the physical action and social behavior of Fizzy, how the subjects (i.e., therapist, children) react to these, the context characteristics, and the therapeutic benefit of the activity indicating the situated nature of HRI.

To understand the table and the purpose of each cell please refer to Appendix 4 for the detailed guide on how to read the data.

Out of these 73 interaction snippets, repeated interactions were merged, resulting in a total of 27 recurring interaction patterns. Some part of the table can be seen in Figure 34, for the full table please refer to appendix 2.

Following the mapping of interaction patterns, a library of behaviors was created. This library consisted of a set of illustrated and explanatory cards. Each card featured visual illustrations and detailed explanations of specific behaviors and interaction patterns observed during the study to translate complex analysis into clear, visual outcomes.

Figure 33 : Screenshot of w Data analysis table to record different interactions

	Fizzy		Therapist		Child(ren)		Context		Objective(Therapeutic Goal)
Sessions	**Physical Action**	**Social Behaviour**	**Says**	**Does**	**Says**	**Does**	**Physical Activity**	**Social**	**Performance Measures**
S.2.C.2.3	Goes in a defined route	Does the activity correctly and	“Fizzy now you have watched them(kids’s names), you know how to do the parkour. Do it like how they did it		“Yeees! You won!”	Eye Gaze, follows where fizzy goes. Smiles, celebrates when it scores and claps to the teacher.	Going in between cones and scoring a goal	It is happening after children completed the parkour without fizzy once each.	Modeling Kinesthetic Behaviours, Active Task Engagement
S.2.C.2.3	Rolls towards,around the child and pause		“See it does what I say, you can also give commands and see if it does what you say.”	Watches children and fizzy from a distance	“Come fiz!” “Fiz go”	Sit on the ground and gives commands to Fizzy, laugh		two children	
S.2.C.2.3	Goes to its place in the classroom, turns its lights off and stays still	Waiting for the child’s turn to perform	“Now everyone should wait in their place”;”Well done to all 3 of you, now its [Child 1]’s turn” “Yes see fizzy is watching and waiting us so well now”		“Fizzy is watching us w-right?”	Does the parkour		two children	Turn Taking
S.2.C.2.3	Comes to the eye sight, stops Rolls in its own axis;right and left	Getting Excited, Celebrating an achievement	“Fizzy is so happy that you did it”			Celebrates an achievement and looks at fizzy if it gives reaction		two children	
S.2.C.2.3	Rolls around without an identifiable pattern	Chasing;Tagging				Run after fizzy, try to catch it, crawls	Chasing fizzy and trying to catch it	two children, all the obstaces are removed	In motion Together, Joint Attention;Joint Engagement;Basic Movement Skills;Gross motor Skills
S.2.C.2.3	Rolls around; not reactive to commands	Disobedient	“Fizzy, I told you to wait, go back!”		"It does not wait! "	Complains about fizzy to the therapist			Attention Span; Fair Treatment
S.2.C.2.3	Leaves the activity area				“Fiz will go to its mom”	Watches the ball as it goes	Goes to an area where it is no longer visible to the subjects		Pretended Play;Role Playing
E.1.C.4	Rolls towards,around the child and pause	Follows the instructions			“Ball come on come”				
E.1.C.4	Rolls back to the subject when being kicked	**Used as a ball that “wants to be played with”**	N/A	N/A	“Let’s go”	Kicks the ball			

Figure 34: Interaction Patterns created from recurring interactions

	Interaction Patterns	When	Therapeutic Meaning	Perceived Meaning by Children
I.D.1	**Comes from an invisible area dedicated to it towards the activity area**	Initial ıntroduction, mediating the therapist and the child	Eye Gaze; Joint Attention; Mediating the Activity	Inital Introduction "It came"
I.D.2	**Rolls towards, around the child and pause**	Initial introduction or when the chld rejects to collaborate;	Initial ıntroduction	"What is that?" "It moves" "A ball" "wooow"
I.D.3	**Roll Towards(to teacher)**	The therapists calls Fizzy	Doing Instructions;Positive Reinforcer	Fizzy is listening to the introductions . “Come fiz!” “Fiz go”
I.D.4	**Goes in a defined route(in front of the child)**	Modelling an activity	Visual Reinforcer;In motion together;Modelling Kinesthetic Behaviours;Motor Skills	Follows fizzy's route,When Fizzy does it wrong says"it did it wrong" and laughs at it
I.D.5	**Goes to its place in the classroom, turns its lights off and stays still**	It is turn for the child to perform tasks, does not respond to what the child says	Turn Taking; Pretended Play(characterising the ball);	“Fizzy is watching us w-right?”; "Fizzy wait for me"; "Fizzy will you also do the parkour?" ; "Do it Fizzy, Do it Fizzy" ;
I.D.6	**Rolls around without an identifiable pattern**	In sport and ergotheraphy session	Free Play;Hand Eye coordination; In motion Together, Joint Attention;Joint Engagement;Basic Movement Skills;Gross motor Skills	"I will catch you fizzy" "It is fast"

6.3 Findings

Using a scripted method to analyze interactions with Fizzy revealed a collective way of understanding the world that connects different people and objects meaningfully. Across various sessions, Fizzy engaged children at different interaction levels, facilitating the learning and practicing of various skills. This analysis served as a foundational step towards understanding the research question.

A model was created to illustrate the different relationships between the main actors: the therapist, the child(ren), and Fizzy. These relationships are essential to uncovering Fizzy's potential within different therapeutic interactions. (Figure 35)

Fizzy acted as a dynamic participant in the setting. Its presence was mediated by therapists, sometimes guiding activities, sometimes being part of the activity, and at other times acting as a social actor like another student. Fizzy's role was versatile, changed in activeness over time in the context.

The relationship between the therapist and fizzy were defined as "Task" as most of the time the therapist assigned tasks to Fizzy, directing its actions. (left part of the model). Children interacted with Fizzy as a toy, making the interaction playful and engaging. (bottom part). Meanwhile, the relationship between the therapist and the child was centred on engagement, fostering a collaborative and interactive environment (right part of the model).

At the core of this triangular relationship lies the activity itself, dynamically shaped by the interplay of tasks, games, and engagement, demonstrating **how Fizzy, as a tool, mediates and enriches the therapeutic process.** This dynamic interplay can be broken down into three distinct relationships within the model, each highlighting a unique aspect of Fizzy's role and its impact on the therapeutic setting;

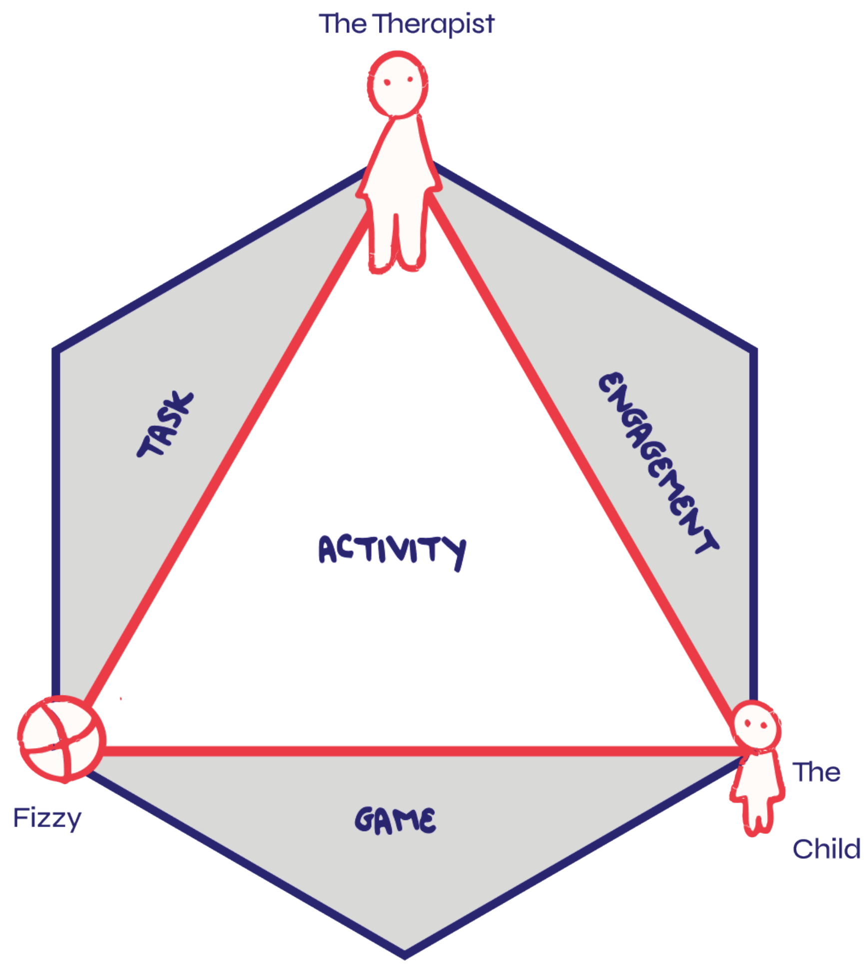


Figure 35 : The model depicting different meanings of the realitonships between actors.

1) Re-establishing Engagement: When the engagement disrupts, the therapist uses fizzy to establish the engagement back

Disruptions in engagement can happen any time of the session as sometimes children struggle to regulate their feelings and focus, requiring therapists to employ strategies to re-establish focus and participation. Fizzy observed to be an effective tool that therapists could utilize to regain children's attention and bring them back into the therapeutic context. (Figure36, 37,38)

However, it is important to note that there was a significantly smaller number of children who still had difficulty following the context, regardless of Fizzy's presence.

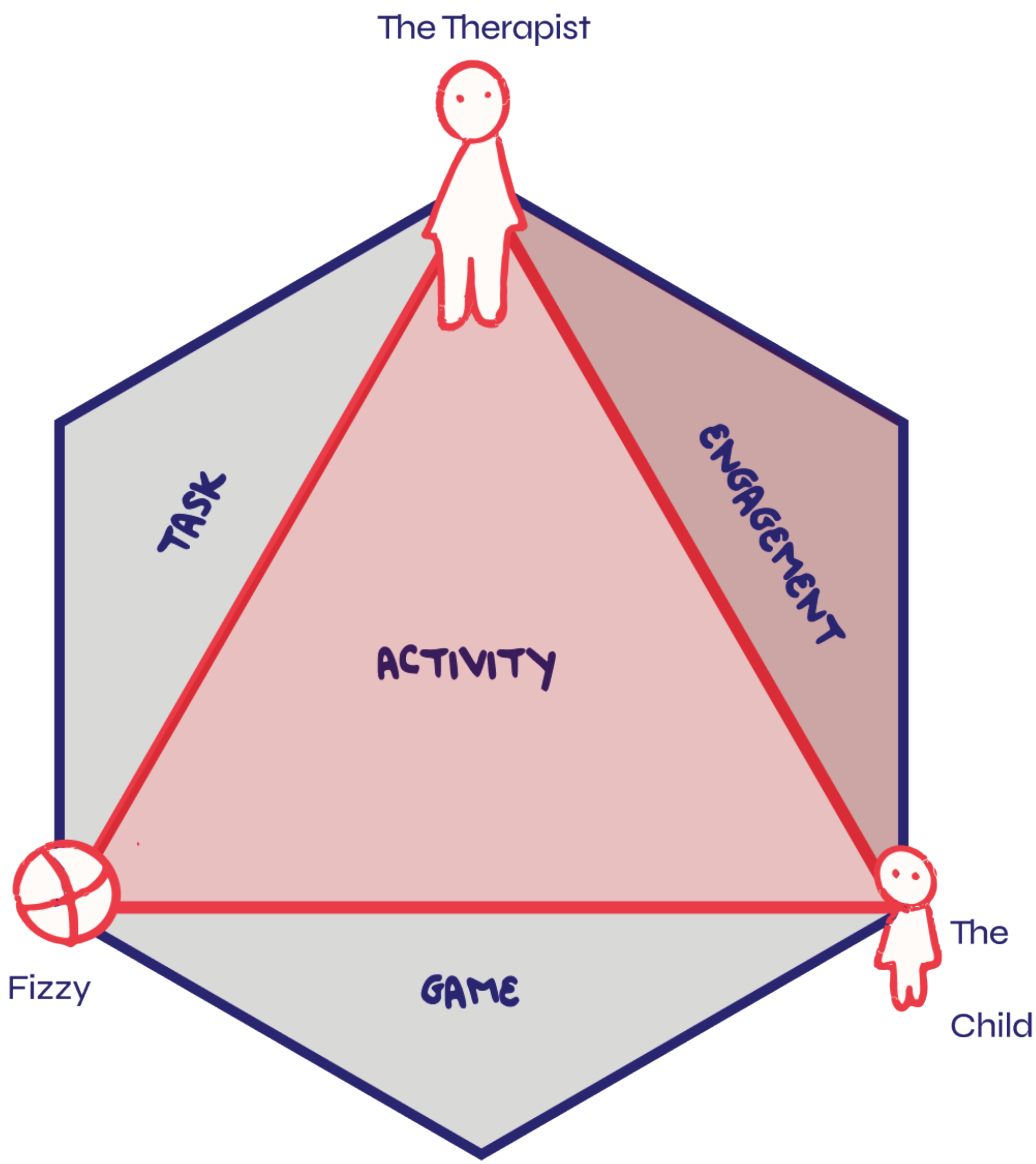


Figure 36 : The model illustaring how therapists use fizzy to establish engagement

Starting Sessions:

Starting Sessions: When children resisted collaboration at the beginning of sessions, Fizzy mediated engagement by rolling into view to capture attention. For example, a child upset about not playing with their car had their attention captured by Fizzy rolling into sight. The therapist then introduced Fizzy, allowing for some explorative play where the child and therapist together gave commands and observed its behaviors, setting the foundation for structured activities and collaborative meaning-making.(Figure 37) Fizzy's Responsiveness helped to create games that supported cognitive therapy goals later as both therapists and children could input commands to alter Fizzy's behavior. This dynamic interaction facilitated children's expressive communication with their therapists and supported turn-taking while guiding Fizzy.

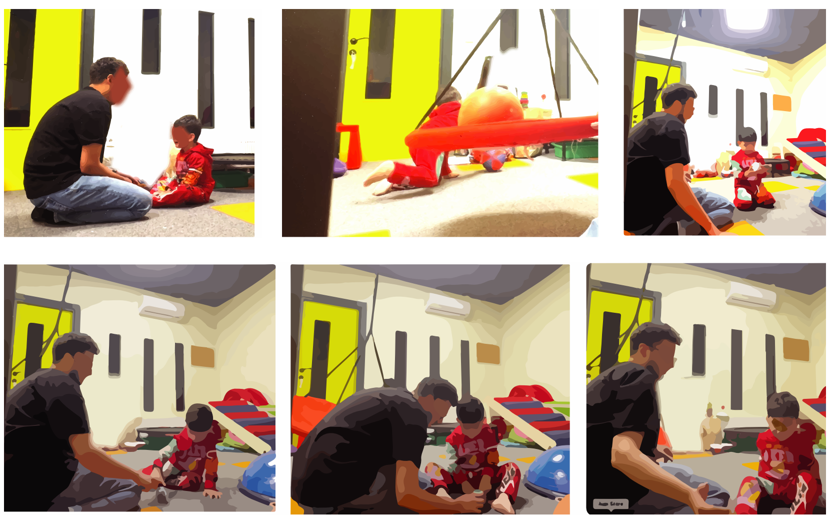


Figure 37: An encounter from the testing: right to left: the child cries and does not want to start the session, he gets curious about fizzy, the tehrapist and child gives commands to fizzy and explore its behaviours

During Sessions:

When the child's engagement with the ongoing activity is disrupted due to distractions such as a low attention span, (which is a common characteristic observed in many neurodivergent children) Fizzy's assistance motivated children to maintain focus. For example Figure 38 represents an encounter within a physical education class, a child with ASC and hyperactivity completed a parkour course significantly faster when Fizzy was introduced. Without Fizzy's presence, he was constantly distracted with other objects and executing tasks reluctantly and incorrectly. When the therapist introduced Fizzy, saying, "Now Fizzy will show you," the child's interest was captured. He completed the course focused, following Fizzy's movements. **This highlighted Fizzy's effectiveness in maintaining focus and guiding the child through tasks.**

Figure 38 : Child distracted during activities introduced to fizzy to show them how to do the parkour

2)Supporting Therapy Goals through Play: Fizzy helps therapists to come up with games that motivate children and serves for therapy goals

This type of use of fizzy was observed when both the therapist and the child are familiar with what fizzy does after an initial introduction with fizzy. Therapists recognized Fizzy tool and suggested activities to support motor, cognitive, and social skills, utilizing the ball's features with or without other therapeutic tools. (Figure 39)

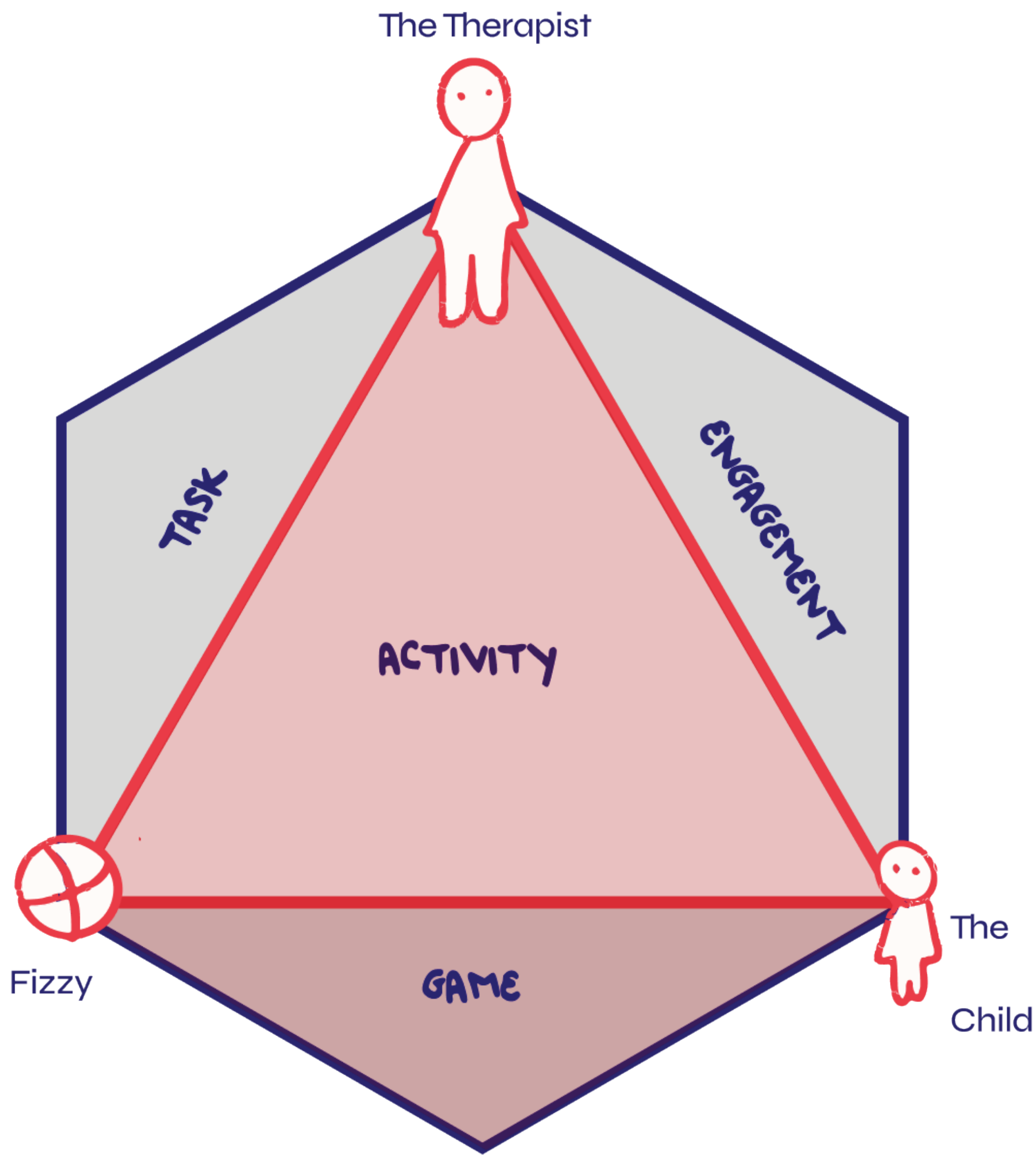


Figure 39 : The model illustaring how fizzy helps therapists to build variety of activities that are perceived as games from children's side.

Building Games with other tools:

Fizzy sparked imagination and creativity among teachers and therapists, who integrated it spontaneously into various activities with other therapeutic tools.(Figure 40) For example, therapists used Fizzy to guide multistep activities essential for cognitive development, gave commands to Fizzy, or had children move based on Fizzy's colors. These scenarios showcased Fizzy's adaptability and versatility, enhancing interactivity and engagement in sessions that would otherwise lack interactivity with traditional tools alone.

Figure 40: Different ways therapists incorporated fizzy into activities

Free Play

Therapists sometimes allowed Fizzy to define the flow of the activity using its movement capabilities. Children would run after Fizzy or have Fizzy follow them, encouraging them to catch it before it reached a designated area. This approach promoted motor skills, hand-eye coordination, and physical play. Unlike usual turn-taking activities, letting Fizzy "be" promoted collaborative skill building through social play and fostered joint engagement. (Figure 41)

Figure 41: Children try to catch Fizzy before it goes to its "home".

3)Facilitating Active Task Engagement: Fizzy enables active task engagement for children with other therapeutic tools

Fizzy's integration not only within the activity but also within the activity space helps maintain children's participation in tasks, making the therapeutic process more effective and interactive. (Figure 42)

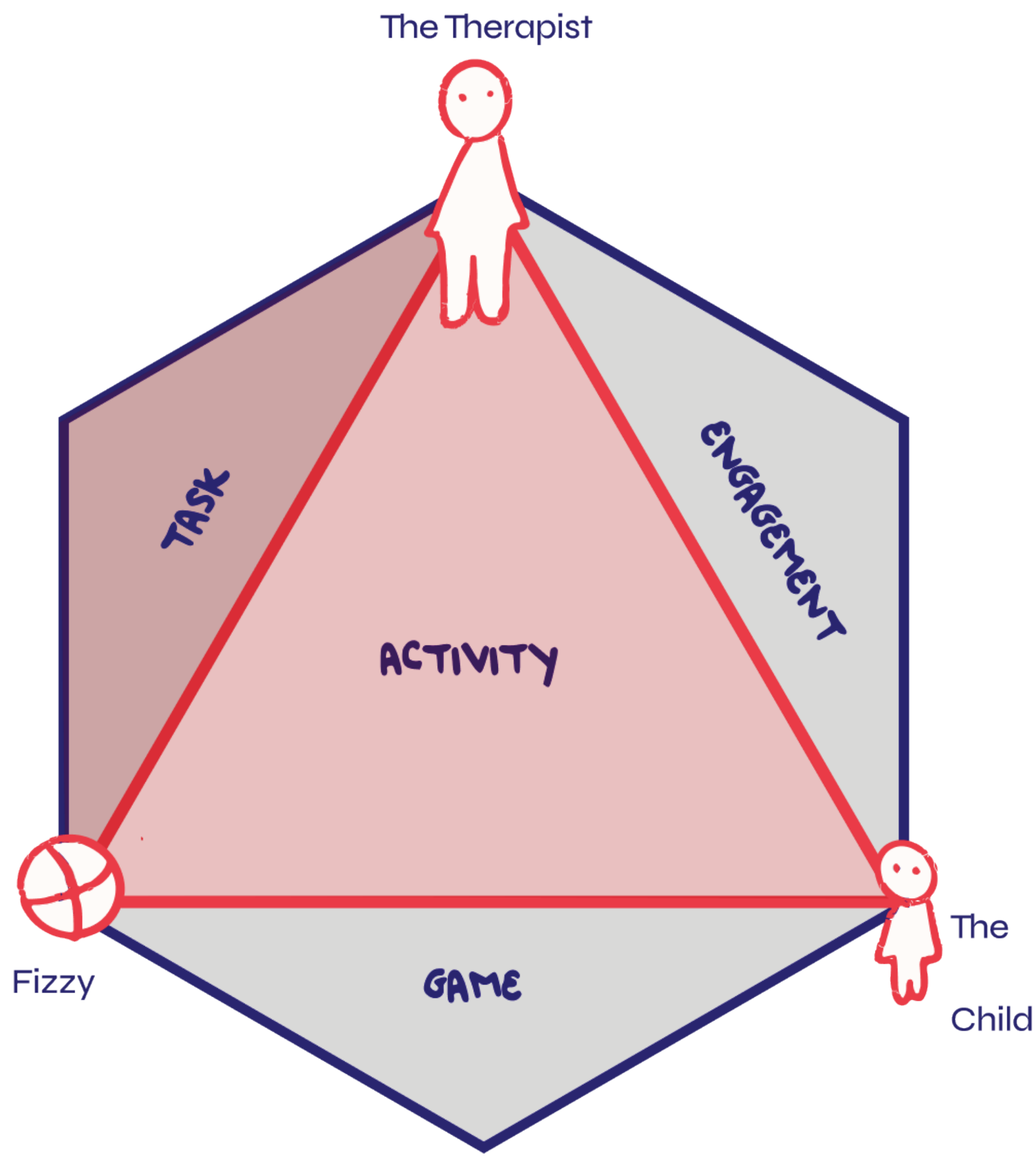


Figure 42 : The model illustaring how fizzy promotes active task engagement for children by being part of the activity and guiding tasks.

Guiding Multi-Step Tasks:

Therapists used Fizzy to provide structured guidance, aiding the child in multistep activities by being one of the steps itself. Fizzy not only guided the children in the current task but also influenced how the child should interact with other therapeutic objects next. For instance, Fizzy's color changes indicated which hoop to jump through or which ball to take next, reinforcing focus and motor skills. (Figure 43)

Figure 43: Different ways tfizzy guides multistep tasks. What ball to take, which hoop to jump, which pompom to blow

Social Actor:

Fizzy's role extended beyond its physical interactions. Even without actively participating, it motivated children in active task participation and behavior modeling by simply being present as a social actor. For example, therapists positioned Fizzy visibly but away from the activity space, telling children "Fizzy is waiting for its turn nicely". Children acknowledged Fizzy during tasks, asking, **"Fizzy, are you watching me?"** or requesting, **"Fizzy, wait for me here,"** emphasizing its role as an observer and motivator. They waited next to Fizzy for their turn, reinforcing the behavior modeling aspect.

Figure 44: Fizzy placed near the seating are to signal appropriote waiting behaviour

Figure 45: Fizzy goes to its dedicated area at the same time with children as requested by the therapist.:

Fizzy also followed what the therapists says along with others, promoting classroom rules. *Therapists, when giving commands, like "everyone go and wait in your place untill I set up the next activity"* expected fizzy to follow them as well to model following order. (Figure 45)

Fizzy's presence has not only influenced children's physical engagement with tasks but also shaped their social behaviors within the therapy environment.

The researcher and therapists decided on a specific location for Fizzy prior to the session beginning At the times when the activity was over, by going "

to a dedicated area, Fizzy signaled the end of the activity. Childrenreferred to this as Fizzy's "home," using expressions like **"Go home ball,"** "Fizzy is going to its mum," and "Bye bye Fizzy," helping them attribute a personality to Fizzy. (Figure 46)

In moments of achievement, **children often immediately turned to Fizzy for acknowledgement.** In response, Fizzy wiggled (Interaction Pattern 17), which therapists and children interpreted as celebrating the child's success. This created a positive feedback loop, with some children expressing affection to its response by caressing Fizzy. (Figure X). These interactions illustrate how Fizzy's presence has not only influenced children's physical engagement with tasks but also shaped their social behaviors within the therapy environment.

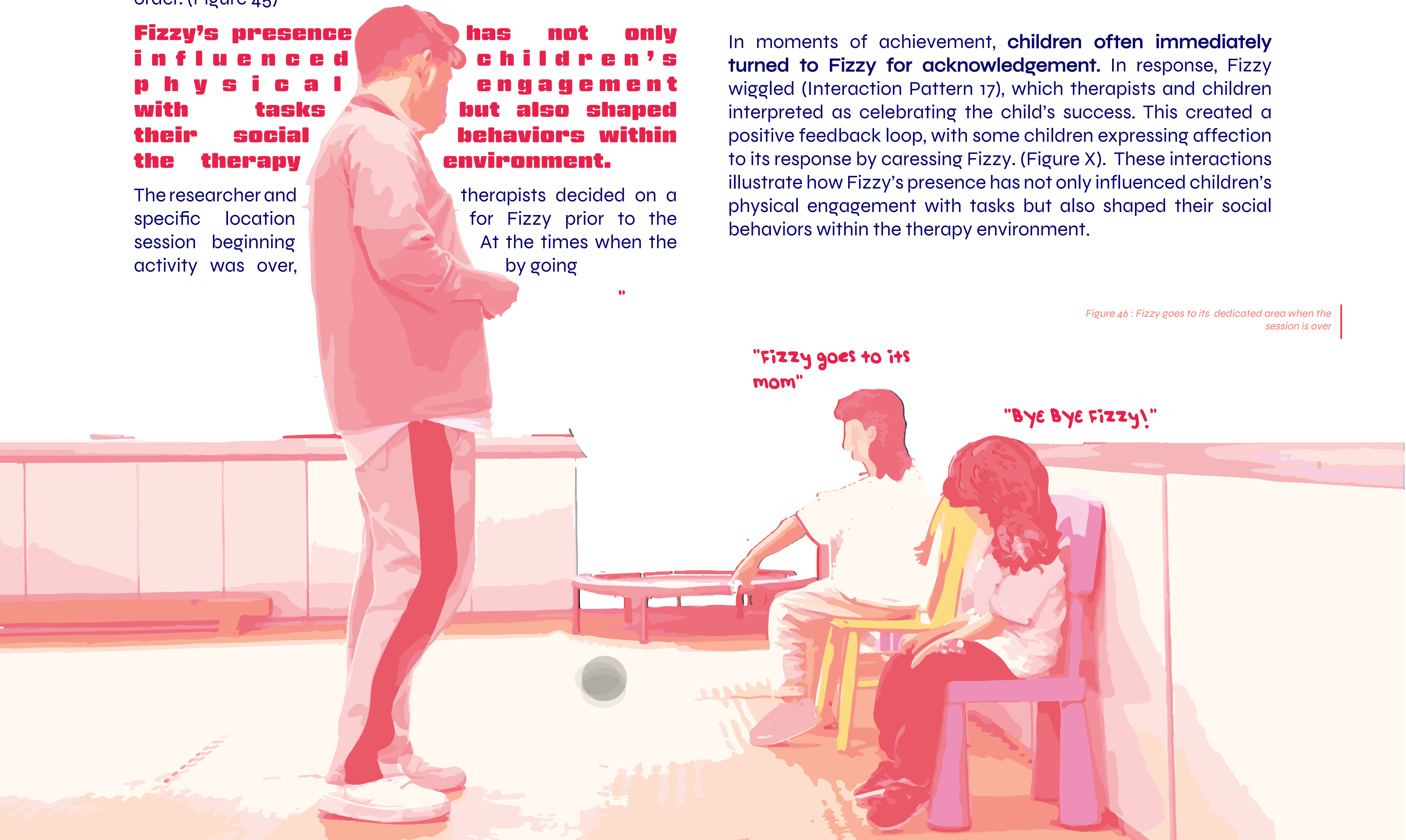


Figure 46 : Fizzy goes to its dedicated area when the session is over

6.4 Discussion & Conclusion

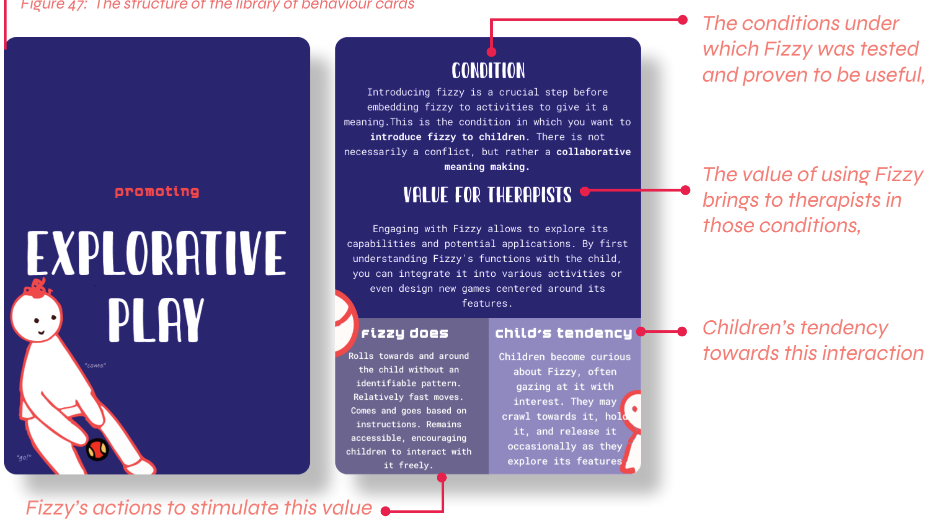
By examining how Fizzy's actions were perceived and responded to by children and therapists thorugh interaction patterns, valuable insights into the dynamics of social interaction within the therapeutic context were gained. This analysis confirmed the initial hypothesis and explained **WHICH interaction patterns of fizzy enabled WHICH therapeutic goals and HOW are they perceived by children.**

A library of behaviors, consisting of a card set for Fizzy, was developed to provide a detailed and structured analysis of findings. (Figure 48) This comprehensive guide demonstrates various ways to integrate Fizzy into therapeutic contexts, highlighting the meaning associated with Fizzy's interactions. It provides clear examples to help therapists effectively interpret and apply the study's findings in therapeutic educational settings.

What does Fizzy do? A comprehensive

Each card consists of 4 parts, providing insights into:

Figure 47: The structure of the library of behaviour cards



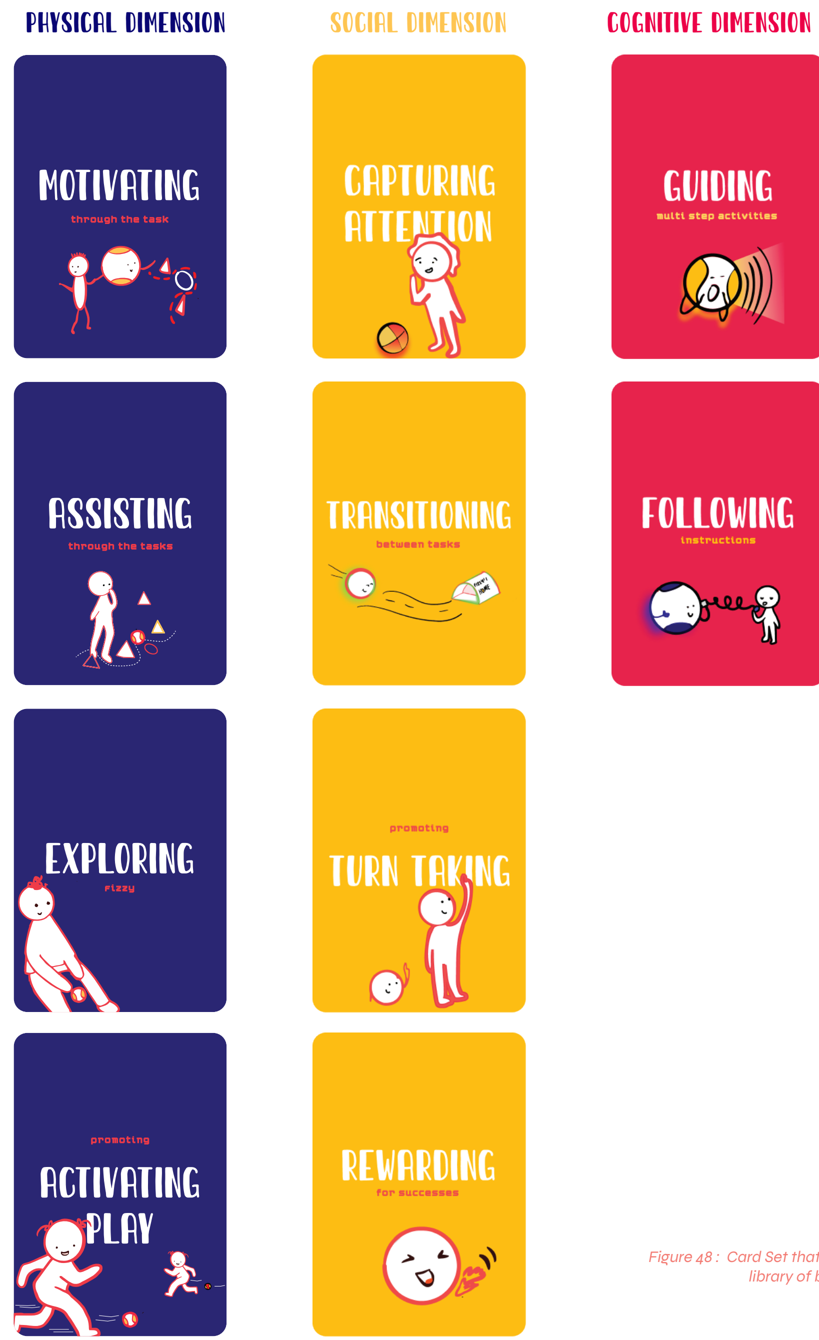


Figure 48 : Card Set that illustrates library of behaviours

6.4.1 Library of Behaviours

Fizzy's integration into activities was particularly effective in facilitating engagement across three main domains:

Physical Dimension

In the physical domain, Fizzy encouraged children to engage in physical activities by making the activities more appealing or by providing step-by-step guidance in complex tasks. It was helpful in encouraging gross motor skills, hand-eye coordination, and physical play. These types of activities help children develop coordination and physical fitness, but also being able to follow instructions and focus; which are essential components for their overall development. (Figure 49) In this domain, Fizzy contributed by:

Exploring Fizzy: Fizzy's introduction to children promotes curiosity and exploration, helping them to discover its functions, which can then be integrated into various activities.

Motivating through the task : When children lose interest or become distracted, Fizzy re-engages them by drawing attention back to the activity and reminding them of the rules.

Assisting through the task: Fizzy provides structured support during tasks, helping children stay focused and complete activities correctly.

Activating Play: Fizzy acts as a dynamic play partner, enabling activities that encourage movement and collaborative play, enhancing motor skills and coordination.

Social Dimension

Fizzy was perceived as a social actor within the therapy setting, whose presence changed the way children interact with others and the environment. Fizzy was used to promote classroom rules, reinforcing positive behaviors by acknowledging children's successes or simply being present while others performed. Children spontaneously communicated with Fizzy, shared their experiences, and engaged in cooperative play. (Figure 50) In the social domain, Fizzy contributed by:

Capturing Attention: Fizzy captures children's attention during moments of disengagement with the therapists, fostering shared focus and calming them.

Rewarding the child : Fizzy provides the acknowledgement that children seek after completing tasks, which therapists use to reinforce a sense of achievement and motivate continued engagement.

Transitioning between tasks: By returning to its designated area at the end of activities, Fizzy models social behavior and promotes classroom order.

Promoting Turn-Taking: Fizzy models patience and cooperation by waiting its turn, helping children learn and follow social rules.

Cognitive Dimension

Therapists incorporated Fizzy into structured activities to add an interactive layer to multi step tasks, enabling children to develop planning and sequencing skills, and practice processing multiple pieces of information simultaneously. Semiotic meanings of things, receptive and expressive language activities were made possible through Fizzy's integration into tasks, signaling what to do next". (Figure 51) In this domain, Fizzy contributed by:

Guiding multi-step activities: With its multimodalities such as lights and movement, Fizzy guides multi-step activities, helping children engage in cognitively active tasks by following its cues and interpreting its actions.

Following Instructions: Fizzy supports task engagement by responding to children's and therapists' instructions, reinforcing learning through interactive play.

Figure 49 : Card Set that illustrates the value Fizzy brought to activities in physical dimensions

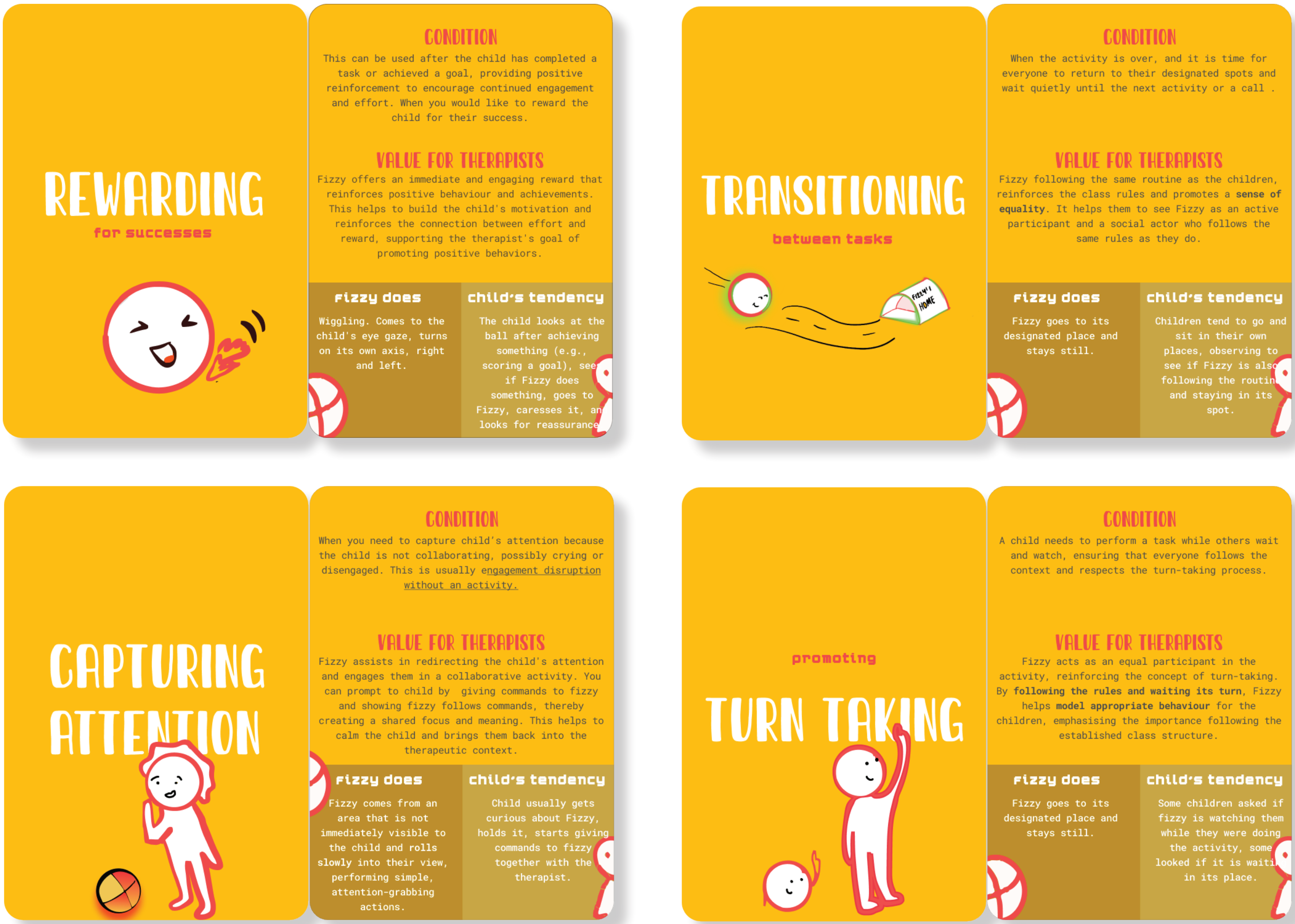
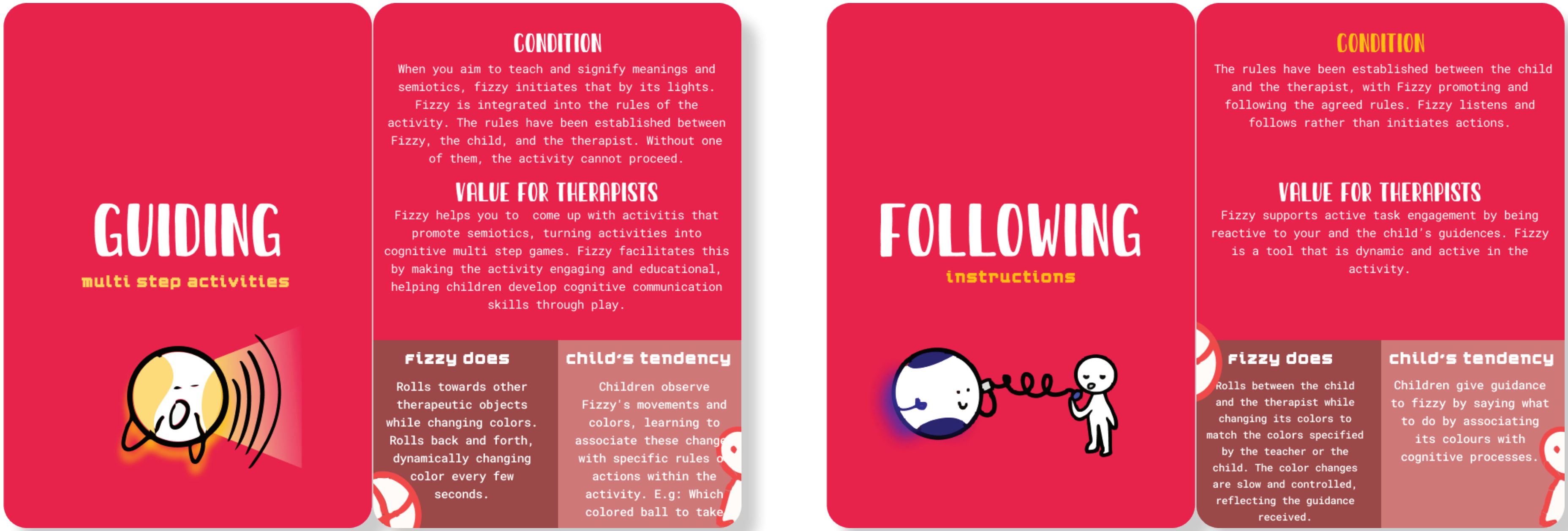


Figure 50 : Card Set that illustrates the value Fizzy brought to activities in social dimensions

Figure 51: Card Set that illustrates the value Fizzy brought to activities in Cognitive Dimensions



Analyzing interactions with Fizzy provided valuable insights into its mediating impact on both the environment and people. In light of the different values that Fizzy brings into therapy sessions, it is safe to say that **Fizzy not only supported engagement and skill development but also influenced the rules and dynamics between the therapist, children, other therapy tools and the therapeutic environment.**

This highlights how Fizzy's integration into therapeutic activities has created rich, supportive learning environments that affect a broad context encompassing physical, social, and cognitive domains. The set also guides the ideation process on how Fizzy could evolve into a marketable, practical product for therapy sessions, which will be further discussed in the next chapter.

CHAPTER TAKEAWAYS

The interactions with fizzy illustrated how Fizzy's presence has not only mediated children's engagement with tasks and their therapists but also promoted skill development in physcial, social and cognitive domains. The library of behaviors documents how therapists employed Fizzy in their practices throughout the research and equips therapists and designers with empirical data for future studies, informing them about how Fizzy was tested, why and how it worked, and what was observed from the interaction in the child's world.

07

FIZZY TEAMS UP

7.1 Objective

The primary objective of this phase is to evolve Fizzy from a manually controlled prototype, tested using The Wizard of Oz method, to an independently functional product concept that therapists can use effectively in therapy sessions.

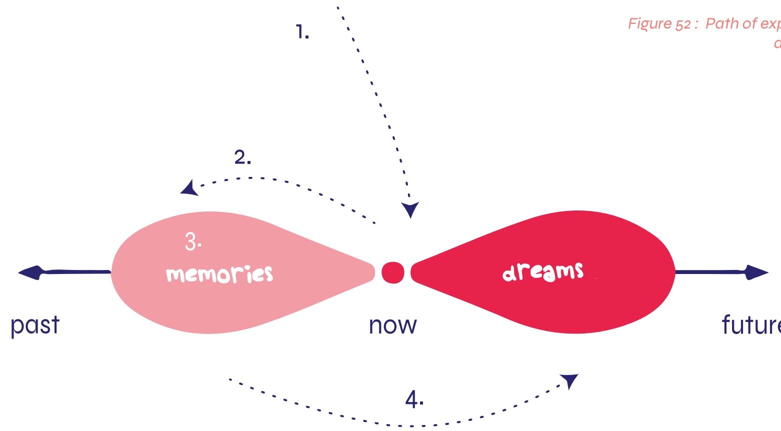
Through active involvement of the target group in research and design activities, the goal was to derive insights from therapists about the essential features and most effective methods for controlling Fizzy. This approach emphasizes the value of such co design processes, suggesting that it leads to innovations that are more likely to be adopted and sustained in practice because they directly address the users' real-world experiences and constraints, as outlined by Sanders & Stappers (2012).

7.2 Method

To achieve this objective, an online co-creation session was conducted with 3 therapists who had previously participated in testing Fizzy. These include 2 occupational (ergo) therapists, 1 physical education teacher. The co-creation study took place in Microsoft Teams and Zoom, together with Figma's FigJam feature, to create interactive activities that therapists would be able to ideate on the given findings and speculate on how they would like to embed and control Fizzy in their usual therapeutic activities.

The session involved three main parts, employing the Path of Expression (Figure 52) method by Sander&Stappers (2012) to guide therapists through a structured process. This method starts by focusing on the present moment, then shifts to recollecting past experiences to uncover underlying layers of meaning, and finally envisions future possibilities. In other words, it connects participants' current experiences with their memories and dreams, facilitating deeper insights and innovative thinking, uncovering tacit and latent knowledge about interactions with Fizzy for effective control mechanism interventions.

Figure 52 : Path of expression by Sander and Stappers (2012)



This method was employed by first introducing the library of behaviours derived from previous testing sessions with videos to remind participants of experiences. This was followed by interactive activities, where therapists could ideate and draw on how they would like to embed and control Fizzy in 5 previously selected therapeutic activities. Finally, a collage activity was used to help envision and speculate on future possibilities for Fizzy's control mechanisms. Data collection methods for the co-creation workshop included audio recordings, written notes, and visual documentation of the therapists' interactions and discussions, which later translated into statement cards and clusters and supergroups.

Co-Creating with Experts, workshop on feature development of Fizzy.

To encourage collaborative exploration and decision-making regarding the design of Fizzy as a useful therapeutic tool, the workshop was structured around five key scenarios listed below;

1)As an ergo/physio therapist I want to get childrens' attention back when the child is not collaborating with me

2)As an ergo/physio therapist I want to use fizzy to guide the activity when I want to work on multistep directions

3)As an ergo/physio therapist, I want to create a game with fizzy that encourages motor skills and social play.

4)As an ergo/physio therapist, I want the child to stay in context by modeling the activity with fizzy when the child's attention is distracted and provide feedback(reward/improvement) through fizzy.

5)As an ergo/physio therapist, I want to reinforce classroom rules and social behavior by using fizzy

These scenarios reflect common therapeutic goals and challenges identified throughout the research and the workshop was structured into **three main parts to facilitate this exploration.**

1)Stimulating the situation.

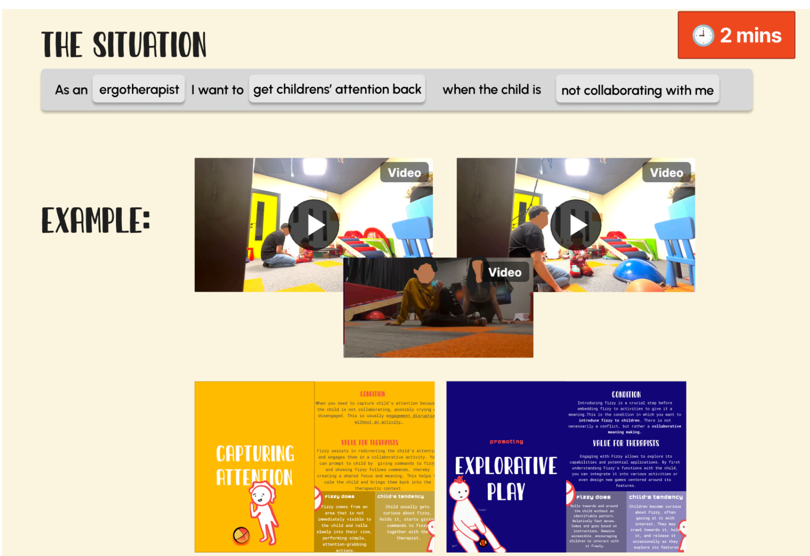


Figure 53: The first activvity of the co-creation session

Therapists viewed and discussed video examples of past sessions, utilized by the statements mentioned above that sums up the given situations . (Figrue 53)

This activity helped therapists visualize and evaluate various therapeutic interactions that they and their colleagues encountered. This exposure was deliberately selected because it allowed them to gain insights into diverse therapeutic interactions and scenarios beyond their direct experience.

2) What should fizzy do in this situation & How should it do what it does

Figure 54 : Second activity of the c o-creation session

In the second part, the aim was to get their ideas on "what should fizzy do" in a given situation. Therapists engaged in interactive simulations using a simplified representation of the session context. By rearranging elements like Fizzy, therapists, and children on a canvas and drawing on it, they explored potential actions and functions for Fizzy, and reflected on how they would like to enable this interaction with what kind of control mechanism.s. . (Figure 54)

Following that, therapists were asked "how should fizzy do what they want it to do". In other words, What kind of things would they like to control and what kind of things would they like fizzy to do? Guided discussions helped therapists explore how varying Fizzy's speed, feedback, trajectory, and control mechanisms might improve its therapeutic effectiveness.

3)Collage activity-What would your envisioned control mechanism look like?

Figure 55: The last activity of the co-creation session

After completing above-mentioned steps for 5 scenarios, participants created collages to visualize their ideas for controlling Fizzy, using provided images depicting child-therapist interactions, words, different remote controls of several technological devices (both manual and app-based), wearables, toys, cartoon characters. This activity aimed to help participants to translate what they had previously thought while discussing the scenarios into more concrete ideas about Fizzy's control and integration into therapy sessions.

Data Analysis Methods of the workshop outcomes

After the co-creation study was conducted, the insights gathered from all three sessions were analysed. Key expressions, concerns, and suggestions from therapists during sessions were captured in 167 statement cards. These cards were then organized into 21 thematic clusters to identify common themes and insights. Finally, these clusters were grouped into six super groups, which outlines the primary discussion topics and expectations regarding the functionalities, control mechanisms, and interaction dynamics. (Figure 56) (The structure of the statement cards and super groups can be seen in Appendix 6)

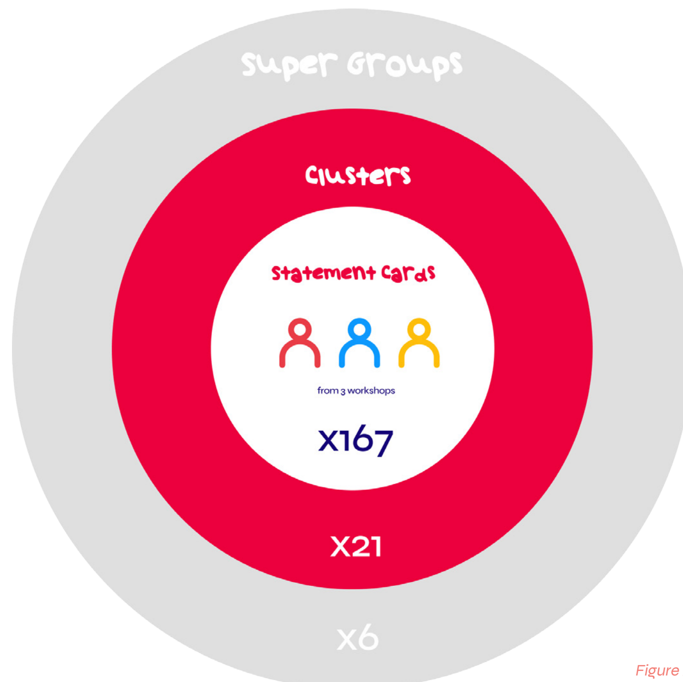


Figure 56 : A figure illustrating Data Analysis outcomes

7.3 Findings

There are several patterns discussed during the workshops that sum up the therapists' perceptions and expectations of Fizzy if it were to be a product sold in the market and used in their classes.

(Figure 57)

"Fizzy is like a happy smurf, its joyful by its nature and it is motivating"

-Therapist 3

Behavioral Modeling and Guidance

- Fizzy models a social behaviour like waiting, taking turns by being a friend
- Fizzy provides motivating guidence by going in front of the child
- Fizzy can create a condition that guides the activity

Control Mechanisms

- Fizzy's should be controlled by a remote that fits into hands of the therapist
- Fizzy's movement should be controlled by the therapist
- For advance controls and personalization of features, there can be an app
- Colours can be controlled by the therapist
- With buttons certain things can be enabled
  - Movement
  - Sound
  - Vibration
  - Lights

Therapist-Child Interaction Dynamics

- The child should know fizzy is controlled by the therapist
- The therapist should be visible to the child during all session
- Fizzy's functions should be adaptable & controllable for different needs, not every child is the same.

Occasional Features and Additional Accessories

- Fizzy comes from a suprising place when there is a need for it
- Fizzy should grab the attention as it comes by light&sound
- There can be a dedicated place for fizzy like a house or waiting area

Sensory Feedback and Interaction

- There can be Positive Feedback: Sounds&lights&movement for Rewarding the child
- There can be Negative Feedbacks and Sounds for Improvement
- Fizzy can react to touch by vibration or lights
- Fizzy can be controlled by voice control

Environmental Awareness and Autonomy

- Fizzy can recognize the environment and calibrate within the class on its own
- Fizzy can sense the movement of the child
- Fizzy can have an autonomous movement in which it rolls around

Figure 57: Findings from the Co-creation Session1

1)Control Mechanisms

"I would like to position Fizzy somewhere in the class and then with my hand in the back I'd like to control it with the directional pad in a way that the child cannot see my hands."

In the workshop, therapists consistently emphasized the need for flexible control options for Fizzy. They suggested using remote controls with preset buttons for instant interventions and a mobile app for more advanced, personalized controls. The remote would allow therapists to adjust movement, direction, speed, color, vibration, and sound settings in real-time. The app would enable them to personalize, add, remove, or change the type of expressions that the remote would execute before sessions, catering to each child's unique needs. This dual control system ensures Fizzy can be tailored to each therapy session, enhancing its effectiveness and adaptability. This requirement was also reflected in the therapists' collages.(Figure 58)

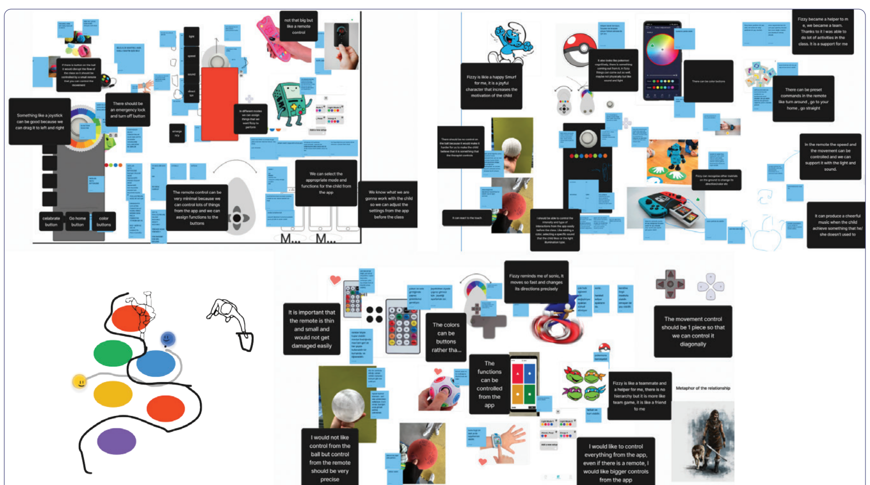
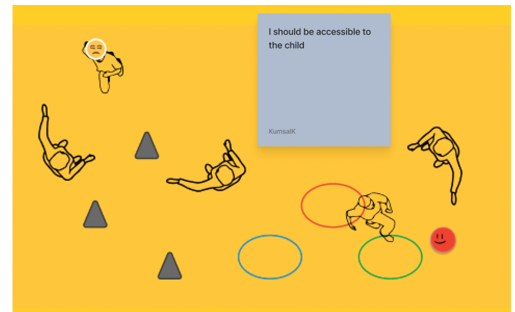


Figure 58: The collages of therapists

2)Therapist-Child Interaction Dynamics

"The child should know that the ball is under the control of the therapist so that he would direct the attention not only to the ball but also to the therapist."

Figure 59: The placement of the therapists-



Central to the therapists' feedback was the dynamic between Fizzy's actions and its role in facilitating therapist-child interaction. One therapist noted, "Every time Fizzy progresses, children should progress with it. The child should also be able to see you, your gestures and hand movements. No one should be left behind." This feedback emphasizes the significance of utilizing Fizzy not only as a tool for play but also **as a medium to enhance the therapeutic relationship.** (Figure 59,60)

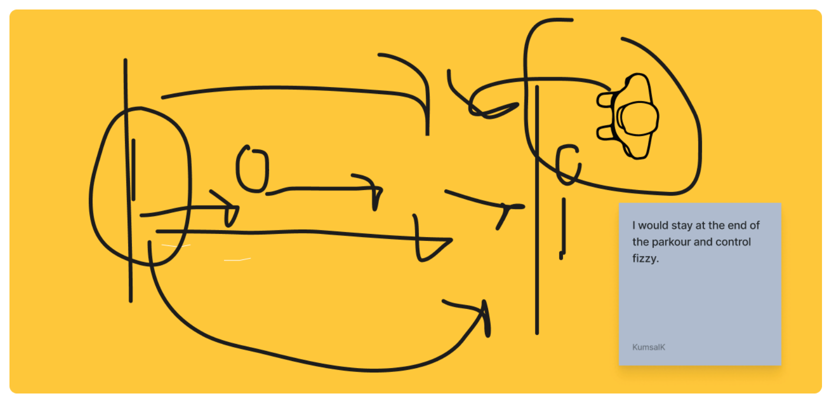


Figure 60: Therapist's representaion of how would they place themselves while controlling fizzy

3)Environmental Awareness and Autonomy

“If Fizzy recognizes its environment, it can light blue in the first circle, yellow in the second circle, jump in another one, allowing us to simply verify if the movements are correct. But we can also do those with the remote control.”

Therapists expressed interest in Fizzy’s ability to autonomously navigate and interact within its environment. They envisioned scenarios where Fizzy could recognize and adapt to different classroom settings or materials to change its behaviors, such as automatically changing colors when crossing a certain part of the classroom or automatically vibrating while being held. (Figure 61) Autonomous reactions to stimuli were seen as beneficial for skill development activities like parkour, allowing therapists to focus on assessing the child’s abilities rather than managing Fizzy’s actions. However, concerns were raised about relying solely on sensors due to the dynamic classroom environment. Therapists recommended a balanced approach, combining autonomous functions with manual controls to adapt to different therapeutic contexts, ensuring Fizzy remains practical and effective.

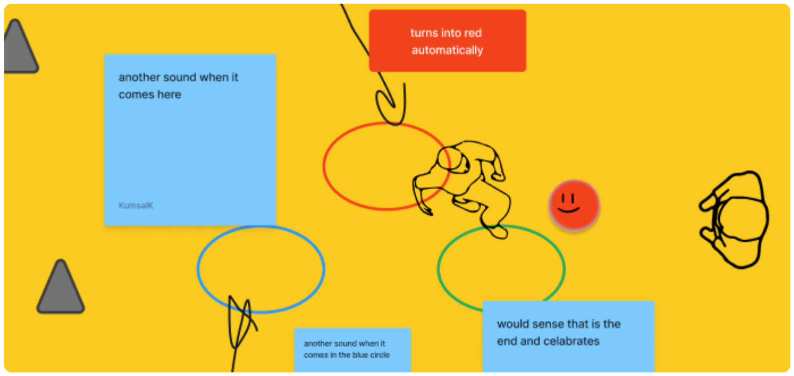


Figure 61: A drawing from the session iprepresnting Fizzy’s ability to recognize the environment

4)Sensory Feedback and Interaction

“It would be very beneficial to have sensory feedback as a reward when you press something. It can react not only to positive things but also to negative situations, depending on the child’s sensitivity. “

Therapists believed that providing multiple sensory inputs for children would enhance Fizzy’s effectiveness for capturing attention, maintaining focus, and reinforcing positive behaviors. They envisioned feedback modalities for achievements or areas for improvement through **movement, light, or sound patterns.** Currently using massaging tools for sensory input, therapists also saw potential in Fizzy providing **varied vibrations** as current tools lack variety in patterns. They proposed that feedback could be triggered by a button on the remote control, with the type of feedback personalized and selected through an app’s library of behaviours. Personalized feedback modes, such as celebrating achievements with lights or performing laps around the child, were suggested to cater to individual needs and sensitivities. (Figure 62)

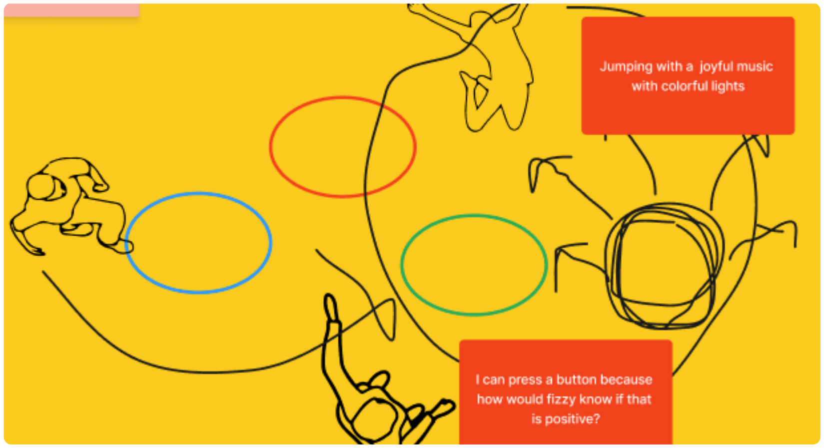


Figure 62: A drawing from the session representing an envisioned scenario for Fizzy’s celabration expression

5)Behavioral Modeling and Guidance

“It is great to reach the target under the guidance of fizzy. Fizzy is very important because it is already a motivating tool and the biggest problem is the lack of motivation in our activities”

“ Fizzy can model class rules and appropriate behaviour.”

Therapists emphasized Fizzy’s role in modeling social behaviors and guiding physical activities, envisioning it stimulating behaviors like **taking turns, following rules, and encouraging specific actions.** They suggested controlling Fizzy with a small remote featuring buttons for colors and movement directions for quick access to various activities. In terms of cognitive capabilities, therapists valued Fizzy’s guidance in multi-step activities, attributing meaning to its actions to prompt the next steps, such as Fizzy rolling around objects indicating where to go next. Therapist 1 highlighted **Fizzy’s ability to make repetitive exercises enjoyable and enhance gross motor skills.**

Fizzy was also found to be useful as a social actor even when not physically active. **Even its idle state brought meaning to the context, such as waiting in order.** Therapist 1 also noted, *“During parkour preparations, children often struggle with waiting. Using Fizzy as an example, we can encourage them to wait patiently, just like it does.”* These insights from both workshops and testing sessions demonstrate that therapists are prepared to utilize not only Fizzy’s physical capabilities to increase children’s motivation and engagement but also its social potential, such as modelling turn-taking and waiting.

6)Additional Accessories

“There might be a home button on the remote control for situations such as “you go to your place and fizzy go home” it can come from and go to its area every time the button is pressed”

During the workshop, therapists discussed the value of having a dedicated space in the classroom for Fizzy, such as a **“house” or a waiting area,** and expressions while entering and leaving these spaces, particularly for social purposes. **Upon being called by the therapist, Fizzy would emerge from this area and return there once the activities are concluded.** Therapists suggested different locations for Fizzy during activities and when it was not in use, enhancing its involvement in the classroom environment.

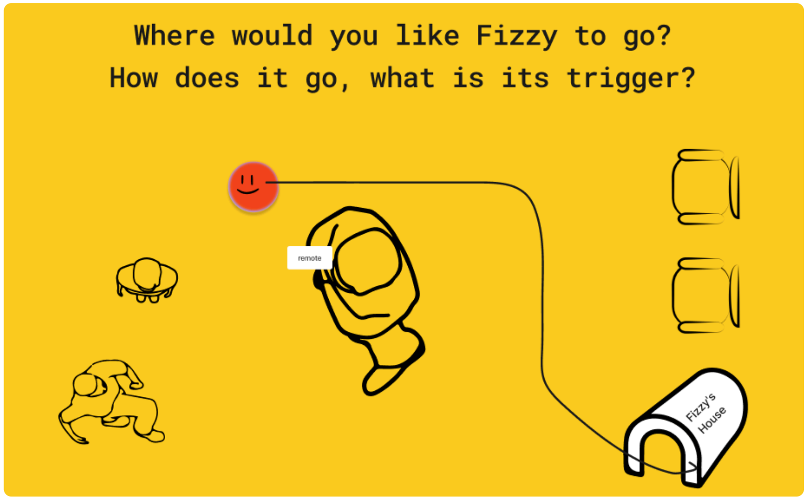
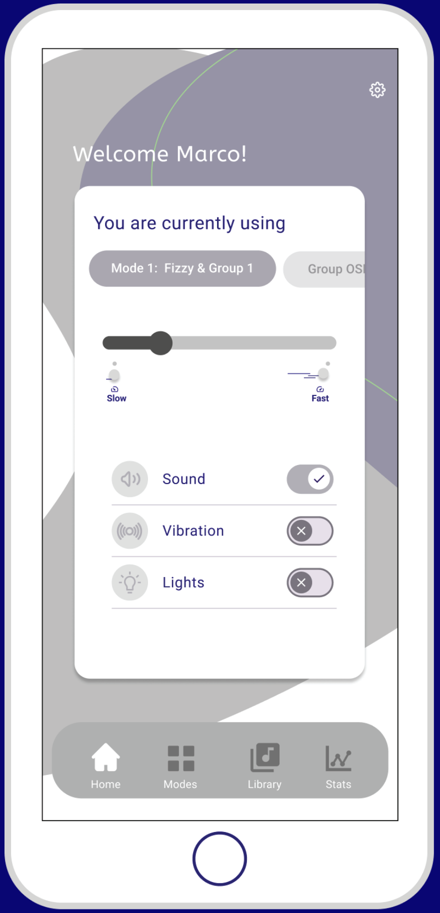


Figure 62: An illustartion from the session illlustrating where would they like fizzy to go when an activity is

Therapist 3 mentioned, **"There may be a different place at the end and beginning of the lesson; a permanent house in one corner versus an area where it waits alongside children during activities."** referred as a **"waiting spot for Fizzy, so they wait together."** A flexible and easily movable designated place for Fizzy was suggested to accommodate the varying needs of neurodivergent children as some of them would be distracted by it. These discussions demonstrated Fizzy's potential as an active participant in the social setting.

Figure 63: Conceptual Wireframes as an outcome of the workshop



+

Advanced Controls

Before the sessions starts

In the Context

During the sessions

7.4 Discussion Conclusion

Each of the previously mentioned super groups reflects the diverse ways therapists envision Fizzy contributing to therapeutic sessions, from direct control mechanisms to nuanced behavioral modeling and environmental interaction. A key finding was the usefulness of a small remote control, allowing therapists to employ Fizzy's capabilities without disrupting the flow of the session. However, the diverse needs of neurodivergent children and the dynamics of special education sessions highlighted the necessity for advanced control mechanisms.

Therapists expressed the desire to customize Fizzy's functions for different children, such as adjusting the intensity of stimuli or specifying the type of expression or movement Fizzy would perform in class. To address these needs, a concept for a mobile app and a remote control was developed as a starting point, as seen in Figure 63.

This need for customization aligns with the broad nature of neurodiversity, recognizing that even children with the same diagnosis have very diverse needs. As Kaptelinin and Nardi (2007) noted, when designing systems to afford developmentally sophisticated activities, **it is crucial to consider the specific level of individual development since each individual's zone of proximal development is different. Caregivers, who understand these nuances best, play a crucial role in addressing these individual requirements.**

CHAPTER TAKEAWAYS

The online co-creation sessions allowed therapists to ideate and specify how they would integrate and control Fizzy as an independent tool in their therapeutic activities. This involvement provided valuable insights into the desired features and control mechanisms for Fizzy. Consequently, the design requirements for a comprehensive and adaptable service system were defined, consisting of a house, ball, remote, and app. This integrated system is envisioned to enhance engagement, motivation, and skill development in neurodivergent children during therapeutic sessions. By incorporating flexible control mechanisms, multi-sensory features, and additional accessories, Fizzy's potential as a versatile and effective tool in special education settings can be realized.

08

FIZZY BECOMES FIZZY EDU AS A CONCEPT

8.1 Fizzy EDU as a concept

The purpose of this chapter is to introduce Fizzy Edu, an educational therapy tool concept that emerges from in-depth research addressing the specialized needs of neurodivergent children and the therapeutic strategies utilized by professionals in this field. Figure 64 is illustartes the system.

Fizzy Edu embodies a system equipped with a network of devices that incorporates various sensors and features that actively engage children in a range of therapeutic activities. Fizzy EDU is an adapted and conceptualized version of the original Fizzy, specifically for educational settings. (Figure 64) Central to this system is the interactive ball that not only facilitates engagement but also serves as an active participant within the classroom environment. Additionally, the system includes:

- A hub (house) where the ball comes and goes, reinforcing its role as a consistent social actor in classroom settings.Also works as a chraging station

- A remote control, enabling therapists to direct, integrate and manage Fizzy's actions effectively during sessions.

- An app that allows for the customization and selection of stimuli, tailored to meet the diverse and evolving needs of neurodivergent children, ensuring that each child's individual requirements are met through customized interactions.

The overarching goal of Fizzy Edu is to significantly enhance therapeutic engagement, supporting the development of social, cognitive, and motor skills in neurodivergent children through interactive and adaptive means.

Figure 63: The concept model for Fizzy Edu system, the hub, the remote

Figure 64: Figure explaning the features, control mechanisms and required etchnology for the suggested system

Conceptual Basis

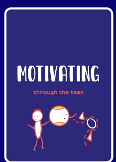
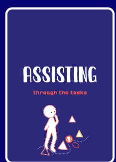
The design of Fizzy's functions was informed by analyzing a card set that represents a library of behaviors. These cards are primarily value-based, highlighting the therapeutic benefits Fizzy can bring to educational settings rather than specifying technical features. They provide therapists with a starting point for incorporating Fizzy into their sessions, demonstrating the potential activities Fizzy can facilitate.

To transform these value-based insights into practical features , the cards were grouped based on the actions they prescribed for Fizzy as seen in Figure 64. This methodical grouping was crucial in identifying the most effective actions and features that allow Fizzy to support therapeutic activities effectively, ensuring that each design feature is both purposeful and practical. For each grouping, the main and customizable features were detailed, along with the necessary physical mediums of interaction controls and sensors required to facilitate these actions.

Specific behaviors and needs that were frequently highlighted in the card sets influenced design decisions that were taken into account.

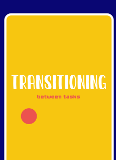
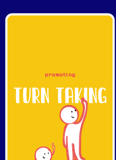
Value	Behaviour	Main Features	Customisable Features	Physical Control	Sensor

 	• First Comes from the hub towards the remote and then remote control	• **Sensing the Location of the Remote:** Allows Fizzy to find and move towards the remote.
		• **Directional Movement:** Enables Fizzy to move in various directions controlled by the remote.
		• **Haptic Feedback:** Fizzy vibrates when held, or a button is pressed providing sensory feedback to the child.
			• **Preset Expressions**
			Fizzy can display different expressions by (joyful, neutral, etc.)
			  • **Light Effects**
			  Various LED light patterns and colors.
			  • **Sound Effects**
			  Plays different sounds or music.
			• **Vibration**
			Adjust intensity and pattern of vibrations.
			• **Speed**
			Adjust the movement speed of Fizzy.
				• **Remote**
				  • **Directional Button:** To control the direction in which Fizzy moves.
				  • **House Button:** To call Fizzy from the hub
				  • **Vibration Button:** To activate/ deactivate vibration.
				• **App:**
				  • **Light Effects Control:** Allows customisation of LED light patterns.
				  • **Sound Effects Control:** Enables selection and adjustment of sounds.
				  • **Vibration Settings:** Adjusts the intensity and patterns of vibration.
					• **Proximity Sensor:** Detects the remote's location to guide Fizzy towards it.
					• **Haptic Sensor:** Detects when Fizzy is being held or interacted with. A small vibration motor can be activated when Fizzy is held, offering tactile feedback
					• **Motion sensor:** Detects and controls the movement, ensuring precise navigation of Fizzy within the therapeutic space.

 	• Changescolours and rolling between objects based on the pressed buttons	• **Colour Change:** Allows Fizzy to change colors based on the pressed button.
		• **Directional Movement:** Enables Fizzy to move in specified directions controlled by the remote.
			• **Sound Effects:** Play a small sound every time the color changes.	• **Remote**
				  • **Colour Buttons:** Changes color.
				  • **Directional Control Buttons:** To control the direction in which Fizzy moves.
				• **App :** To adjust the type of effects (e.g., light, sound, vibration, speed, and preset expressions).
					• **Motion Sensor:** Monitors Fizzy's movement, ensuring that it is moving as directed by the control buttons. This sensor is essential for implementing precise directional movements and adjusting Fizzy's speed or stopping it as needed.
					• **Color Sensor:** Detects the current color of Fizzy, verify if the intended color is being displayed and can be used in feedback loops to correct any discrepancies.

	• Changes its direction every 30 seconds.
	• Stops when being held.
	• Continues to roll around when released.
		• Preset Autonomous Movement
		• Responsiveness to touch (stops when being held)
			• Preset expressions(Joyful, neutral)
			  • Light Effects
			  • Sound Effects
			• Speed
				• **Remote**
				  • **Directional Button:** To control the direction in which Fizzy moves.
				  • **Preset Roll Around Button:** To activate the autonomous roll-around mode.
				• **App :** To adjust the type of effects (e.g., light, sound, vibration, speed, and preset expressions).
					• **Touch Sensor:** Detects when Fizzy is being held. A capacitive touch sensor can be embedded in Fizzy's surface to detect when a child is holding it.
					• **Proximity Sensor:** Senses nearby objects and ensure Fizzy changes direction before hitting obstacles. Ultrasonic or infrared sensors can be used to detect proximity and navigate autonomously.
					• **Inertial Measurement Unit (IMU):** Tracks Fizzy's movement and orientation. An IMU can provide data on Fizzy's acceleration, rotation, and direction changes.

	• Gives an animated response when the expression button is pressed.	• **Movement Animation:** Allows Fizzy to execute various animated movements.
		• **Light Effect:** Utilizes LED lights for visual feedback during interaction.
		• **Sound Effect:** Integrates audio feedback to enhance interaction.
		• **Haptic Feedback:** Fizzy vibrates when held, or a button is pressed providing sensory feedback to the child.
			• **Preset Expressions**
			Fizzy can display different expressions (joyful, neutral, etc.) to reflect various states or reactions.
			  • **Light Effects**
			  Various LED light patterns and colors.
			  • **Sound Effects**
			  Plays different sounds or music.
			• **Vibration**
			Adjust intensity and pattern of vibrations.
			• **Speed**
			Adjust the movement speed of Fizzy.
				• **Remote**
				  • **Expression Button:** Triggers Fizzy's animated response (reward), utilizing preset expressions, lights, sounds, and vibrations.
				• **App :** To adjust the type of effects(e.g., expression type, light effects, sound effects).
					• **Sound Module and Speakers:** Integrated to provide dynamic sound effects.
					• **RGB LEDs and LED Drivers:** Allows for custom light displays that can be synchronised with movements and sounds.
					• **Control:** Both the sound module and the LED drivers can be integrated with a central microcontroller within Fizzy. This microcontroller would receive signals from the remote control or mobile app, dictating when to activate sound and light effects.

 	• Goes to its hub when a button is pressed	• **Automated Return to Hub:** Fizzy locates and navigates back to its hub when the session ends or it's time to switch activities, signaling a clear end to the current task.
		• **Light Management on Arrival:** Upon arriving at the hub, Fizzy automatically turns off its lights or changes them to signify the end of activity participation.
		• **Directional Movement:** Enables Fizzy to move in various directions controlled by the remote.
			• **Customizable Features**
			  • **Adjustable Light Effects at Hub:**
			    • Can be set to dim or turn off entirely once Fizzy reaches the hub. (or dimming to 50%, changing colors). This can visually signal the end of an activity or a period of waiting.
			  • **Sound Cues:**
			    • Different sounds can play when Fizzy begins its return to the hub, arrives, or while stationed there. Sounds can be a beep before moving, or a melody upon arrival to the hub.
				• **Remote:**
				  • **Home Button:** Controls Fizzy to move to and from its hub.
				• **App:**
				  • **Light and Sound Settings for Hub:** Allows for the customization of the auditory and visual signals associated with Fizzy's return to the hub and waiting periods.
					• **Navigation Sensor:** GPS or RF-based navigation system to autonomously find the path back to the hub without manual guidance, ensuring accurate and reliable returns.
					• **Audio Module:** Integrated audio system to play designated sounds based on the activity's conclusion or during the wait period.
					• **LEDs and Light Controllers:** Advanced light control systems to adjust Fizzy's illumination according to its status—active, returning, or inactive in the hub.

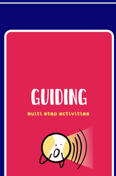
 	• Changes colours and rolls between objects based on the pressed buttons	• **Colour Change:** Allows Fizzy to change colors based on the pressed button.
		• **Directional Movement:** Enables Fizzy to move in specified directions controlled by the remote.
			• **Sound Effects:** Play a small sound every time the color changes.	• **Remote**
				  • **Colour Buttons:** Used to change Fizzy's color.
				  • **Directional Control Buttons:** Used to control the direction in which Fizzy moves.
				• **App**
				  • To adjust the type of effects (e.g., light, sound, vibration, speed, and preset expressions).
					• **Motion Sensor:** Monitors Fizzy's movement, ensuring that it is moving as directed by the control buttons. This sensor is essential for implementing precise directional movements and adjusting Fizzy's speed or stopping it as needed.
					• **Color Sensor:** Detects the current color of Fizzy, verify if the intended color is being displayed and can be used in feedback loops to correct any discrepancies.

Figure 63: The concept model for Fizzy Edu system, the hub, the remote

System Architecture Overview

To give an overview of all the defined features of Fizzy Edu gathered by the above mentioned grouping and technology overview, the system architecture illustrates the decision-making process and interaction flow within the Fizzy EDU system. (Figure 65) This flowchart helps clarify how features are integrated and function in real-world application scenarios, which will be further explained in the next section as key features..

The flowchart uses shapes and colors to represent different types of actions and decisions within the Fizzy EDU system architecture.

Shapes:

Ellipses : (Start/End): Represents the starting and end point of the flowchart.

Rectangles (Actions/Processes): Indicates specific actions or processes that Fizzy performs.

Diamonds (Decisions): Represent decision points where the flow can branch based on a yes/no question.

Colors:

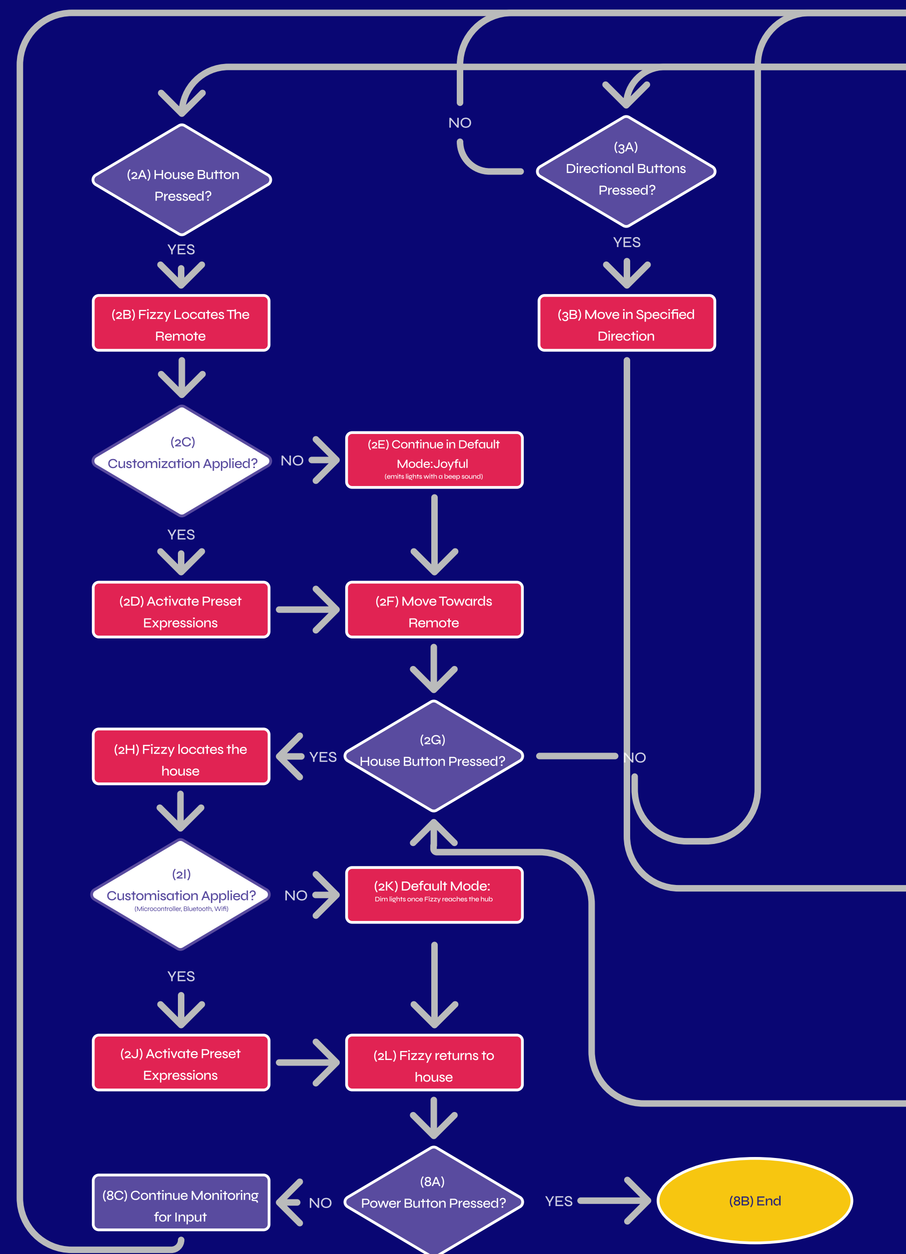
Yellow: Used for the start and end points.

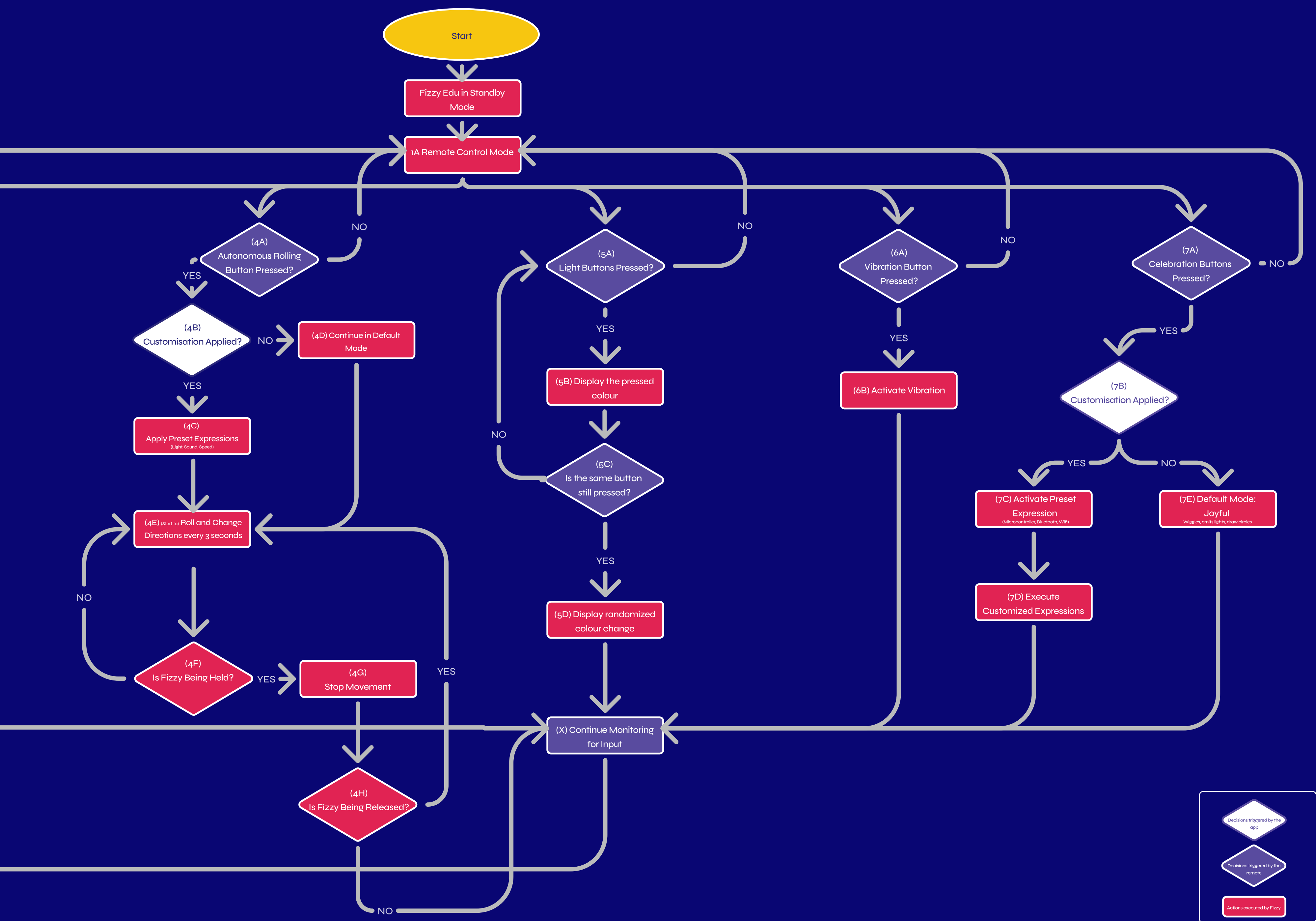
Blue: Decision points where input comes from the remote.

Red: Represents specific actions or processes that Fizzy executes in response to inputs or decisions. These are the operational steps that Fizzy undertakes.

White: Used for decision points involving customization through an app, indicating a conditional check that may alter the following actions based on whether customization has been applied.

Figure 65: The System Architecture illustarting how the features can be triggered by the remote and the app.





Start
Fizzy Edu in Standby Mode
1A Remote Control Mode
(4A) Autonomous Rolling Button Pressed?
NO
YES
(4B) Customisation Applied?
NO
(4D) Continue in Default Mode
YES
(4C) Apply Preset Expressions
(Light, Sound, Speed)
(4E) (Start to) Roll and Change Directions every 3 seconds
NO
(4F) Is Fizzy Being Held?
YES
(4G) Stop Movement
YES
(4H) Is Fizzy Being Released?
NO
(5A) Light Buttons Pressed?
NO
YES
(5B) Display the pressed colour
NO
(5C) Is the same button still pressed?
YES
(5D) Display randomized colour change
(X) Continue Monitoring for Input
(6A) Vibration Button Pressed?
NO
YES
(6B) Activate Vibration
(7A) Celebration Buttons Pressed?
NO
YES
(7B) Customisation Applied?
YES
NO
(7C) Activate Preset Expression
(Microcontroller, Bluetooth, Wifi)
(7E) Default Mode: Joyful
Wiggles, emits lights, draw circles
(7D) Execute Customized Expressions
Decisions triggered by the app
Decisions triggered by the remote
Actions executed by Fizzy

8.2 Key Features of Fizzy EDU

The subsequent section will explore features in detail, demonstrating how they contribute to making Fizzy EDU a dynamic and adaptable tool in special education environments.

8.2.1 Control and Customization

Remote Control

Real-time adjustments to Fizzy's behavior are facilitated by the remote, allowing therapists to accommodate the unique needs of each child and the unpredictable dynamics of therapy sessions. This control mechanism helps in seamlessly integrating Fizzy into various activities without disrupting the flow of the session. The remote includes buttons for movement, preset expressions such as celebration, and interactions such as autonomous rolling, providing comprehensive control from Step 1A onwards in the general control flow.

App Integration

The mobile app offers a platform for therapists to configure Fizzy's settings, tailoring its operations to specific therapeutic activities and individual needs, including selecting the intensity and types of stimuli (Light, Vibration, Sound). Therapists can possibly create settings that cater to the varying needs of different sessions and save them as presets.

8.2.2 Navigation and Movement

Precise Directional Movement

Controlled via the remote (Step 3B), Fizzy's precise directional movement allows it to navigate between objects or around the therapy area. It is crucial for tasks that require the child to follow, such as parkour. By assisting and motivating, Fizzy helps children to understand the task sequence

Locating Hub and Remote

Fizzy can autonomously locate and navigate back to its hub when the house button is pressed. (Steps 2A and 2G) This feature is useful for signaling the end of sessions or switching activities, providing a clear conclusion to the current task and promoting classroom rules by demonstrating appropriate waiting behavior. This hub is also a charging station for Fizzy. Having a dedicated place highlights its belonging and active participation in the classroom not just as a tool but also as a social actor. The hub also works as a charging unit for Fizzy.

Speed Control

Enables the speed of Fizzy's movement to be adjusted to match the pace required for therapeutic activities, ensuring it aligns with the child's motor skill level.

8.2.3 MultiSensory Expressions

Lights

Fizzy can change colors based on button presses(Step 5A), or preset light patterns(Customization steps) can be assigned to certain interactions. These light changes visually guide children through tasks, such as indicating which hoop to jump through.

Various LED light patterns and colors can be programmed for different interactions, such as a pattern for return to the hub,(Step 2C) coming from home, or celebrating an achievement (step 7A, figure 65).

Vibration

Provides tactile stimulation essential for sensory therapy, with adjustable intensity for customized sensory input, particularly important for the proprioception sense. Fizzy can vibrate either when a button is pressed (Step 6A) or when held for a certain duration to activate the vibration.

Sound

Range of sounds and musical cues can signal transitions, and provide auditory feedback. Customizable sound options (2C, 2I, 4B, 7B) can include a beep before movement, a melody upon arrival at the hub, or celebratory sounds together with movement for achievements, which can be triggered via preset buttons.

8.2.4 Interactivity and Responsiveness

Autonomous Rolling

This activates a mode that fizzy moves independently, encouraging children to engage in physical activities such as chasing or catching, which promotes active play. (Step 4A) This feature includes directional changes every few seconds to keep the activity dynamic and engaging.

Responsiveness to Touch

Fizzy EDU can also respond to touch, pausing its movement when held and continuing to roll when released.(Step 4F) Additional responses like lights or vibrations can be triggered by touch if customized to engage the children further.

8.3 Core Advantages of Fizzy EDU in Special Education Therapy

Each of these features contributes to Fizzy's role as an engaging therapy tool. They don't only enrich the therapeutic experience but also address comprehensive benefits that are crucial in special education settings. They align with key goals and values that are pivotal for enhancing therapeutic outcomes such as engagement, skill development, and customized interventions;

8.3.1 Engagement

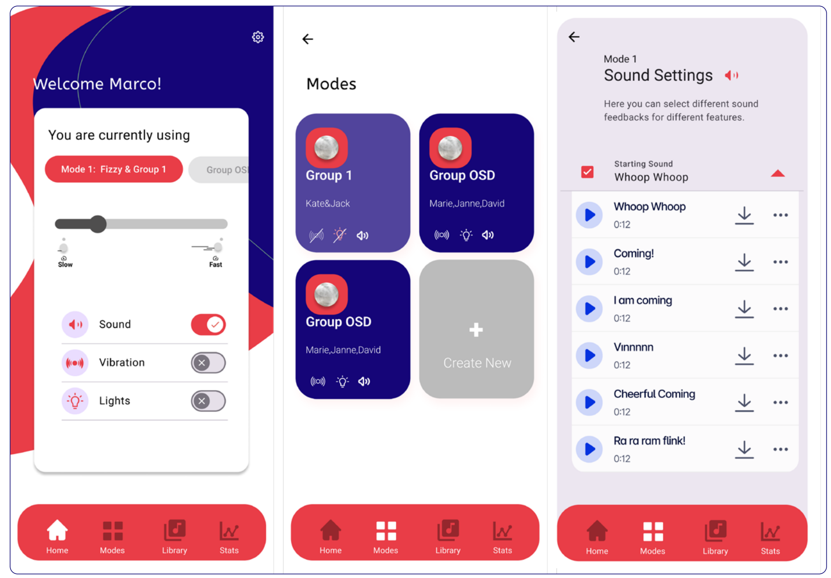
Fizzy Edu's interactive and multisensory features are designed to captivate children's interest more effectively than static or non-interactive therapeutic tools and also eliminates the need of using multiple devices to stimulate different senses thanks to its multisensory features. This increased engagement is crucial for maintaining interest and participation throughout therapy sessions.

8.3.2 Skill Development

Participating in activities involving Fizzy, facilitate the development of essential skills. Its movements aid in motor skill development, while its multisensory features—like sounds and lights—boost cognitive growth by adding an extra layer of information processing. The playful nature of Fizzy also encourages social interactions, offering a structured yet flexible environment for children to learn and grow and making it a versatile tool for therapists aiming to support multiple developmental skills simultaneously.

8.3.3 Customized Interventions and Adaptability

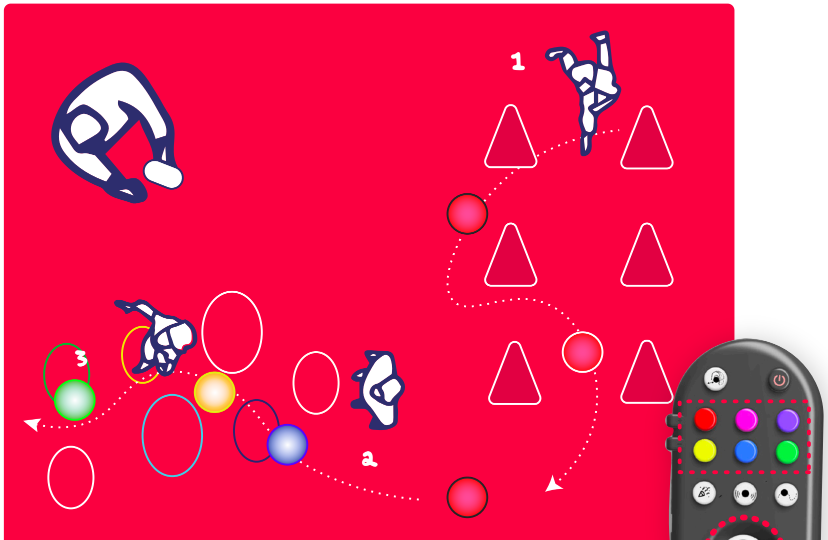
The ability to tailor Fizzy's responses—adjusting lights, sounds, and movement patterns—allows therapists to create personalized therapeutic experiences that meet the individual needs of each neurodivergent child. The adjustments can be made through the app. This enables Fizzy to perform exactly as needed, enhancing the therapy experience by adapting to the preferences and requirements set by therapists for each session. (See Appendix 7 for other screens)



Some scenarios about the different ways to use fizzy can be seen in Figure 66.

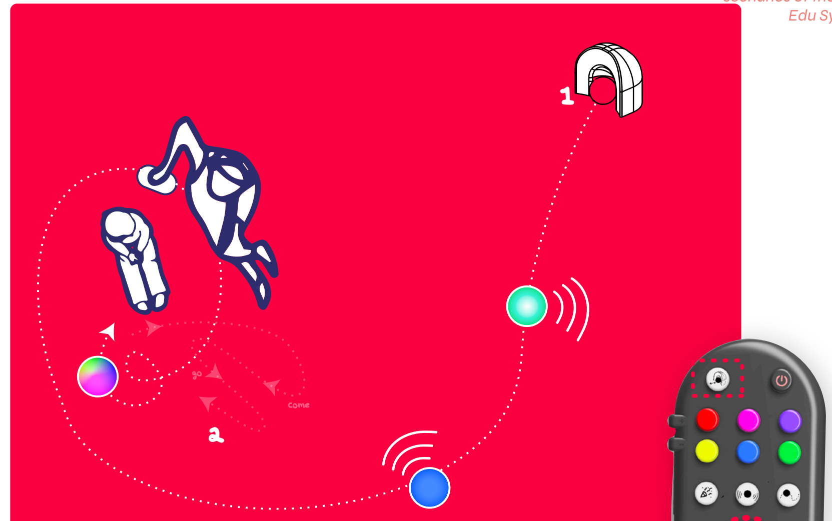
Figure 66: Illustrates different usage scenarios of the Fizzy Edu System.

Guiding Complex Tasks: Parkour and Multistep Activities



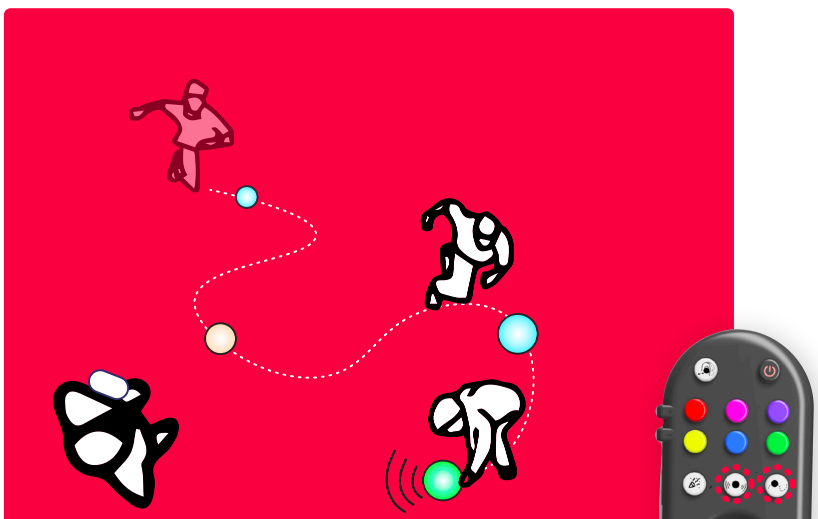
To enhance children's motivation during challenging tasks like parkour, therapists can use Fizzy to demonstrate the steps. Fizzy can be directed to move along the course, and its color can change to signal what to do next, adding an extra layer of cognitive support. This helps children follow cues and stay engaged in the activity.

Capturing Attention



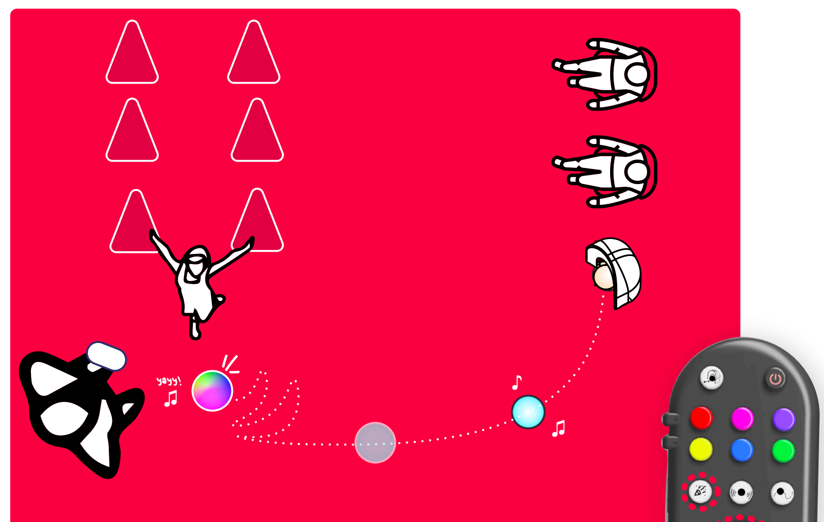
When a child disengages or doesn't collaborate with the therapist, Fizzy can be called from its house to capture their attention. Fizzy would locate the remote, and approach with a default "joyful coming" mode, featuring lights and a vibration, unless customized differently in the app. Therapists can later take control with directional buttons, guiding Fizzy towards the child and follow child's guidance to re-engage the child in the session.

Promoting Activating Play



To promote collaborative and active play, Fizzy can be set to autonomous roll mode. It will change direction every few seconds, challenging children to catch it. When caught, therapists can reward the child with vibrations or celebratory sounds from the remote, reinforcing positive behavior.

Reinforcing Positive Behaviours and Rewarding



When a child completes a task or displays appropriate behavior, Fizzy can be directed to approach the child's gaze from its waiting area (house or another spot). The therapist can then press the celebration button, triggering Fizzy's celebratory expression—wiggling, emitting lights, and playing a short celebration sound. These expressions can be customized through the app.

8.4 Technological Basis and Current Constraints

Above mentioned functions of Fizzy EDU concept are envisioned to be realized through advanced technologies to enhance interactive learning. This includes motion sensors for precise movement control, proximity sensors, and navigation systems like IPS, RFID, or Bluetooth for automated navigation between the hub and activity areas. RGB LEDs can provide customizable light displays, and a sound module can enable various auditory expressions. Integration of Bluetooth or Wi-Fi modules, coupled with a microcontroller, would facilitate real-time remote control and customization of settings via an app.

Although these technologies set a high standard for functionality of employing Fizzy Edu as a desirable therapy tool, the actual implementation in the near future may be constrained to simpler technologies due to practical limitations as well as promoting fizzy as an inclusive and accessible solution for a wider range of educational settings. This creates a gap between the ideal Fizzy EDU concept and the capabilities of the current prototype being developed by a team of PhD students and engineers. Reflecting on the desired values and currently achievable technological features of the current Fizzy model is crucial. This re-evaluation aimed to identify how fizzy might still provide the core therapeutic values within the realistic boundaries of available technology and to what extent, illustarted in Figure 67. To address this, a meeting was scheduled with the design and engineering team working on Fizzy. This session focused on discussing potential limitations and brainstorming adaptations. Following this crucial discussion, a thorough reflection and reevaluation of the features and functionalities were undertaken to align Fizzy's capabilities with the available technological resources, this subsection will detail the adaptations made to Fizzy's design to accommodate these constraints.

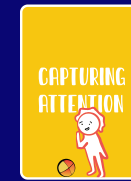
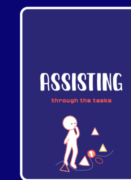
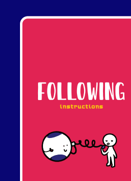
The Value	Correlated Cards	Corre (Remote
Grabbing Child's Attention and introducing fizzy to the child, mediating joint attention. Joint Attention Joint Engagement Social COmmunciation Skills	 	**Locatin** Fizzy loc expressio **MultiSe** colour, so **Directio** by the us
Guiding children through defined routes such as obstacle course and promoting motor skills Increased motivation Motor Skills(Gross and Fine) Improved mobility Increased engagement	 	**Directio** by the th
Stimulating physical movement and promoting collaborative play Joint Engagement Gross Motor Skills Hand-Eye Coordination		**Autono** Fizzy sta can alter **Respon** moveme **Speed**
Providing feedback and reinforce desired skills. Improved self-regulation during a behavioral goal Successful completion of a social interaction goal		**Directio** controlle **MultiSe** When ce wiggling, apps allo moveme
Promoting classroom rules, and appropriate behaviours by positioning Fizzy as a social actor/playmate. Turn Taking Social Interaction Skills Joint Engagement	 	**Locatin** button, F turn, fizzy activated
Guiding children through multistep activities, promoting cognitive skills such as association, reasoning, decision making. Receptive language skills Multi-Step Commands Motor Skils	 	**Lights:** same but **Precise** direction

Figure 67: ISuggested adaptations with the current Technology.

esponding Features in the Fizzy Edu Concept e Control for all)	Suggested adaptations with the current Fizzy Prototype
g the Hub and the Remote: When pressed to a house button, ates the remote and moves toward it. If customization is applied, preset ons are activated. **ensory Expressions:** Pressing these buttons triggers changes of the ound feedback, vibration or movement patterns. **onal Movement:** Fizzy moves in the specified direction as controlled er.	A non-technological house-like structure or an area marked by an indicator can be dedicated to Fizzy as its waiting area in the classroom, signaling its belonging and integrating it into the classroom environment Therapists can manually place Fizzy in there before the class starts and steer Fizzy towards the children to grab their attention. A gentle tap on Fizzy can trigger a change in acceleration, prompting movement without the need for advanced multi-sensory expressions.
onal Movement: Fizzy moves in the specified direction as controlled erapist to model defined physical tasks .	Basic forward and backward movements can still support directional activities. Ensuring that Fizzy's moving axis is perceivable by therapists can help them navigate Fizzy in the preferred direction of the activity aiding children in following along and engaging in the activity. This can also act as a cue for Fizzy's line of sight and enhance children's understanding of Fizzy's intended path and encourage them to interact with it.
mous Rolling: When the autonomous rolling button is pressed, ts rolling and changing directions every few seconds. Customisations its expressions during this mode. **siveness to touch:** Fizzy responds to being held by stopping its nt and resumes rolling once released. **Control:** Adjustments can be made to suit the pace of the activity.	Setting preset movement patterns for Fizzy, such as changing its axis up to 60 degrees and moving forward every few seconds or even simple back-and-forth movements, can encourage children to follow or interact with it, support physical activity and joint engagement. This can also be enabled by directional buttons operated by therapists. By integrating a game mode children can be encouraged to participate in motor development collaboratively.
onal Movement: Fizzy moves in the specified direction as d by the user. **ensory Expressions, App Integration for Customisation:** lebration buttons are pressed, Fizzy performs preset actions such as emitting lights and sounds, or drawing circles. Customizations through w for specific expressions to be activated such as sounds light or nts patterns.	The use of preset movement patterns and vibratory feedback can still support engagement and reinforce desired behaviours. Fizzy can enact a small or wide wiggle by turning its motor axis in different speeds, allowing it to stay in place while wiggling or perform back-and-forth movements through movement. Those can be saved as presets for ease of use in the remote.
g the Hub and the Remote: When pressed to a house izzy locates the remote and moves toward it. When it is child's stays still. If **customisation** is applied, preset expressions are l.	The combination of stillness, vibrations , and movement cues can position Fizzy as an interactive playmate who models appropriate behaviors. Fizzy can remain still until its turn, signal readiness to move by vibrating and steer its way to its dedicated area for reinforcing the concept of taking turns and waiting appropriately. Incorporating an indicator on Fizzy's surface can act as a cue for Fizzy's line of sight, signalling that it follows what their friends are doing, promoting the classroom rules and waiting patiently for others.
Pressing these buttons changes the color of Fizzy's lights. If the ton is pressed continuously, the colors change randomly. **Directional Movement:** Fizzy moves in the specified as controlled by the therapist.	Fizzy can guide children through tasks by bumping into different coloured objects, signalling where to go next without needing lights itself. Basic parkours can be structured to be guided by Fizzy's movements. For example, children can follow where Fizzy goes, stopping when Fizzy stops. This can still provide guidance, engaging them in multistep activities and promote cognitive skills such as association, reasoning, and decision-making as children interpret Fizzy's movements and respond accordingly.

8.4.1 Adapting Features Within Technological Limitations

The existing version of Fizzy (see chapter 1.1) being developed is equipped with more basic components. The primary communication method of the Fizzy prototype is through movement. With only one actuator and IMU, fizzy has limited navigation and mapping capabilities, and basic user interaction modalities. These design choices affect the ball's response time and maneuverability such as how promptly the ball can change direction or speed in response to input and how accurately the ball can change direction. Given the current technological constraints, although some of the envisioned functionalities of Fizzy Edu may not be immediately achievable, the prototype's existing capabilities can be adapted to promote certain values in different ways. Below (Figure X), the table outlines the defined values from the cards, together with corresponding features in Fizzy EDU, and suggested adaptations for the current prototype emphasizing how they can support the intended values.

8.4.2 Reflection on Technological and Conceptual Differences Between Fizzy and Fizzy Edu

Reflecting on these capabilities, the existing Fizzy prototype, despite not fully matching the multimodel functionalities envisioned for Fizzy Edu, still holds potential to facilitate the therapeutic values with the current capabilities, particularly for tasks that are less defined and more open-ended.

The prototype provides a practical starting point and serves as a foundation for iterative testing, enabling the collection of feedback from therapists and end-users. This process is vital to determine the extent to which adaptations of the current technology can achieve the desired therapeutic values. Like any other new technology, understanding and managing the learning curve for therapists—who need to become accustomed to Fizzy's movements and control mechanisms—is crucial. The current Fizzy model requires therapists to develop their own strategies for effective use before embedding fizzy into their tasks. Although this may limit the scope of interactions and activities due to what Fizzy can currently achieve, it is still essential to test this model. For the future study, suggested adaptations implemented in the Fizzy prototype might help therapists to envision scenarios in which embedding fizzy would be beneficial. On the other hand, Fizzy Edu represents a more tailored approach, where the technology is specifically developed to meet the needs and tasks envisioned by therapists, aiming to reduce the burden on therapists to adapt to its uses and allowing them to start using these functions for therapeutic benefit without having to worry about technological constraints as much.

The core concept of Fizzy, developed primarily for general health and preventive care, capitalizes on its function as both an exercise device and a social robot that users can intuitively interact with (Horstman, 2024). This approach leverages the inherent playfulness of a ball, enhancing user engagement without the need for direct instructional intervention. However, the Fizzy Edu framework is tailored for a distinctly different context—special education, where the cognitive and developmental needs of children are more complex and require structured guidance to engage them effectively due to their conditions in joint attention, information processing and joint engagement.. Unlike in other settings where individuals might need to interact with the ball without instructional intervention, children in special education often need therapists to actively interpret and verbalize Fizzy's cues. For example, while Fizzy might roll or change colors, children may not naturally understand that these actions prompt them to perform specific movements unless the therapist explicitly instructs them, saying, "When Fizzy does this, you do that." A neurotypical person would try to help when fizzy is stuck, but for neurodivergent children it is is often the cae that tehrapsits would say "let's help fizzy to get that out of there" Thus, the meaning-making process with Fizzy relies heavily on the therapist's facilitation, making their role essential in using Fizzy as an educational tool that guides, participates in, and models therapeutic activities. In special education, Fizzy might also serve a broader audience, such as in group classes, where it models behaviors for multiple children at once.

Fizzy Edu aims to promote not only physical activities but also to support a broad spectrum of developmental goals, including enhancements in cognitive, physical, and social skills through being part of different activities by engaging with children at different levels. Therefore, while the standalone Fizzy concept may still suffice as an engaging exercise device and social robot for a population that requires assistance with physical movement, the diverse needs of neurodivergent children necessitate that the ball should adapt to support both guided and open-ended activities and also model appropriate behaviors within a classroom. Interventions with Fizzy Edu must provide meaningful guidance while allowing for collaborative meaning making within a controlled framework, therefore making fizzy a dynamic social actor in the educational therapy setting for multiple children at a time.

Given the gap between the current technological capabilities and the comprehensive features envisioned for Fizzy EDU, if Fizzy is envisioned to be an educational tool in the future, it is advisable to focus on developing a prototype that integrates the advanced features from the list. By building a prototype that closely aligns with the educational objectives and needs identified by educators and therapists through sessions, Fizzy EDU can serve as a supportive tool that integrates seamlessly into therapy sessions without requiring extensive adaptation and learning curve by its users. This approach would position Fizzy EDU to offer a desirable, practical and easy-to-use solution right from the start, enhancing its utility and effectiveness in special education environments.

To ensure Fizzy's effectiveness across various therapeutic contexts, a service system model could be introduced. This model would allow for the integration of add-ons and extra sensors, which users can order based on their specific needs. Such modularity can ensure that Fizzy remains adaptable and relevant to diverse needs, aligning with the theoretical underpinnings of neurodiversity as well as Fizzy's value proposition for adaptability for diverse setups.

8.5 Limitations of the Fizzy EDU Concept

While Fizzy Edu offers a tailored approach specifically developed to meet the needs and tasks envisioned by therapists, it also presents certain challenges.

Although the ability to customize Fizzy EDU to individual children's needs is a significant advantage, it could also become a limitation. Therapists would need to invest time and effort into learning and mastering its control mechanisms. Setting up and adjusting various features for each child, while beneficial, could potentially lead to overstimulation for some children, particularly those with sensitivities such as epilepsy or other sensory conditions. This necessitates careful adjustments and constant monitoring by therapists, which could be time-consuming. Therefore, developing well-tested default modes is essential. These default modes—such as joyful coming or neutral rolling—should be carefully designed and validated with input from therapists and children. However, due to time constraints, the final features and modes of Fizzy Edu, though defined as an outcome of the Wizard of Oz testing and therapist involvement, were not tested within the timeframe of this project. Future research should prioritize testing and refining these predefined behaviors and features to ensure they adequately meet the diverse needs of different cases.

Furthermore, the inclusion of multimodal features will inevitably increase the cost of the system, potentially limiting its accessibility, particularly in low-income or underserved educational settings. The complexity of the system also raises the risk of technical issues such as software glitches, hardware malfunctions, or connectivity problems. Such failures could disrupt therapy sessions, potentially diminishing trust in the technology among both therapists and children, especially given the limited time available during sessions.

This product is expected to be used by various therapists and likely moved between different classrooms, making it essential for both the hub and the ball to be easily portable and durable enough to handle different scenarios across various sessions. The current prototype of Fizzy EDU, designed using a hard shell, raises concerns about durability. Children often play with the ball roughly, indicating the need for a more robust and flexible design than the tested prototype. A softer, textured shell or cover could enhance its durability and usability due to children's unpredictable behaviors when they play. Additionally, since therapists use various materials like shaving cream or therapy putties in sessions, making Fizzy's shell easily wipeable would ensure it can be quickly cleaned between sessions, which is crucial in environments where hygiene is critical.

CHAPTER TAKEAWAYS

Fizzy Edu highlights the importance of developing technology that enhances the therapeutic landscape by being adaptable and responsive to the specific needs of its users with its multimodal features. While the current Fizzy prototype can still support therapeutic values with limited interactions, Fizzy Edu offers more direct alignment with educational and therapeutic objectives than the current one. The progression from adapting to existing capabilities with Fizzy to actively adapting technology to meet specific therapeutic needs with Fizzy Edu signifies the seamless utilization of Fizzy as a desirable educational therapeutic tool.

09

DISCUSSION CONCLUSION AND REFLECTIONS

9.1 Discussion & Conclusion

This research aimed to explore the potential of Fizzy, a spherical robot, in promoting engagement between therapists and neurodivergent children within special education settings. This goal is particularly valuable, as engagement and motivation are often challenging to maintain for neurodivergent individuals.

The primary research question guiding this project was: **"How does the presence of Fizzy, as a mediating artifact, influence neurodivergent children's engagement with their therapists and the environment during therapeutic activities without directly imposing therapy (adult) goals?"**

Grounded in "Activity Theory" and the " Neurodiversity Paradigm" , this study sought to understand how interactive technology could mediate therapeutic activities, foster engagement, and support the holistic development of neurodivergent children. The research was conducted through four distinct studies: one observational study, two testing sessions (one pilot, one actual), and an online co-creation session.

The first observational study at the school provided context-specific insights and helped formulate hypotheses. The observation revealed a gap between therapists' multi-level extrinsic goals and children's intrinsic motivations. The pilot test, involving neurotypical children, highlighted six types of engagement with Fizzy, all relevant to neurodivergent children's needs (e.g., eye-gazing, following, and collaborative play with Fizzy). These insights informed the second visit, where the hypothesis, **"The presence of Fizzy contributes to the engagement between the child and the therapist"** was tested. The results indicated Fizzy's mediating role in enhancing engagement in tasks and facilitating meaningful interactions between children and therapists.

Fizzy played a role as a physical and cognitive guide and a social actor, supporting skill development and enhancing the overall therapeutic experience. This aligns with Vygotsky's concept of the "Zone of Proximal Development (ZPD)", where children achieve more with guidance from a knowledgeable other—in this case, therapists utilizing Fizzy as an interactive tool.

The "Play Phases" outlined in Gielen's framework were also observed in the way children and therapists interacted with Fizzy. Through exploration, functional play, variation, and integration, Fizzy fostered a collaborative and playful environment, aligning children's intrinsic motivations with therapeutic objectives. This reinforced the idea that Fizzy supported both therapists and children in meaningful and engaging ways.

Testing with a concept prototype of Fizzy, followed by co-creation sessions with therapists to explore the ideal version for their context-specific use, enabled the researcher to discover the appropriate design for Fizzy in special education. This led to the creation of a concept that is more advanced than the current Fizzy, underscoring the importance of adopting the "Neurodiversity Paradigm" in designing educational tools. Fizzy Edu, a customizable system consisting of a network of devices with multisensory features, demonstrates how technology can be tailored to meet the diverse needs of neurodivergent children, promoting inclusion and accessibility in therapy.

While cognitive conditions may seem to require unique interaction designs, it is important to recognize that this is not an isolated case (Kaptellinin & Nardi, 2007). As the paradigm suggests, even neurotypical individuals exhibit diverse characteristics, as none of us are the same (Dwyer, 2021). However, it is not practical to design products that cater to every individual need. Instead, designs for diverse groups should strike a balance between predefined features and open-ended possibilities. In the final concept of Fizzy EDU, key features were designed at a level that still allows therapists flexibility in how they use the tool. For example, Fizzy has lights that can be used in different activities, guiding relationships with other tools or serving as a sensory integration tool to calm the child. Its directional movement can be applied in activities like guiding Fizzy towards a child to capture their attention or navigating an obstacle course to indicate where to go. The vibration feature can be used for sensory stimulation, such as a massage tool, or to signal the end of an activity. These open-ended elements allow therapists to tailor Fizzy's use to their specific needs, while some preset functions—like celebratory expressions or autonomous rolling—remain consistent for ease of use. More advanced controls, such as changing expression types, can be adjusted through an app.

With all that, this thesis aims to contribute to the fields of **child-robot interaction studies** and to the growing body of knowledge on **how technology can enhance therapeutic and educational outcomes for neurodivergent children**. The findings and features of Fizzy EDU, developed over six months of generative research, are intended to guide future designers and researchers interested in educational therapy tools for special education settings. The identified features are found to be promising in the special ductaion context and can offer a starting point for future research and design, whether applied to a ball or other interactive therapeutic tools.

9.2 Limitations and Design Recommendations

Overall, using Fizzy as a medium to explore the potential of interactive technologies in promoting engagement between therapists and children in special education settings has been insightful, showing promising potential for Fizzy Edu. While Fizzy facilitated dynamic encounters, it's essential to recognize and reflect on its attributes and limitations:

9.2.1 Limitations

Engagement Variability

Despite the advanced technological capabilities suggested for Fizzy EDU, there is no guarantee that all neurodivergent children will engage with the tool. This variability was evident during testing, where some children who were expected to show interest did not engage, while others exceeded expectations by becoming highly involved. This highlights that Fizzy is not a one-size-fits-all solution. Instead, it offers fundamental features that are open-ended enough to be adapted by therapists but may not benefit all neurodivergent children. Each child's specific condition and preferences play a crucial role in their interaction with Fizzy. While some may not respond at all, others might become overly fixated on the tool, necessitating careful moderation by therapists. Additionally, there is a risk that over-reliance on technology could reduce vital human interaction, which is a critical component of therapy.

The Method

The research employed a Research Through Design approach, using the Wizard of Oz method for testing, Using the Wizard which wallowed for controlled analysis of interactions between children and therapists. This method was useful in understanding the strengths and weaknesses of the concept through a prototype. However, this research primarily laid the groundwork for defining useful therapeutic tools rather than delivering a fully independent product. The development of an actual product that therapists can use independently was not possible within the study's timeframe. The prototype was controlled by the researcher, which may have influenced outcomes. Future research should use the defined features as a starting point to develop prototypes and continue context-mapping studies with therapists to test their effectiveness and refine the product for market readiness.

Involvement levels of Children

Throughout the research, children's participation remained at the fifth level of Roger Hart's Ladder of Children's Participation—"Consulted and Informed". While children were engaged under the guidance of therapists and parents, their direct input was limited. Engagement levels were measured based on therapists' feedback, as they had a deep understanding of the children's past behaviors. If more time had been available, co-creation sessions with children could have allowed for deeper involvement, helping to better understand their perceptions of Fizzy and its behavioral attributes.

Durability Concerns

Using a ball shape for various activities offers benefits, as it is familiar to children and associated with movement and play. However, the prototype struggled to meet the mental attributes typically associated with a ball, such as being thrown, kicked, or jumped on.

Study Constraints

The study's limitations include the small sample size and the short duration of the intervention, which may affect the generalizability of the findings. Additionally, the concept of Fizzy EDU with customizable features remains a conceptual outcome that requires further research and development. The long-term effects of using Fizzy are unknown, as the tool was new and exciting for the children during testing, but sustained engagement over time was not measured.

Learning Curve

The conceptualized version of Fizzy EDU suggests group therapy usage and prioritizes the active involvement of therapists in controlling or guiding Fizzy's behaviors. This implies that therapists will need to dedicate time to develop strategies for integrating Fizzy into their activities, which may add to their workload.

Cost and Accessibility

The incorporation of advanced features could increase the cost of Fizzy EDU, potentially limiting its accessibility in low-income or underserved educational settings.

Given those limitations, future studies should prioritize the following areas:

9.2.2 Recommendations for Future Research

The Shape, Durability and Safety

A ball is familiar to children and is associated with movement and play, which the Fizzy prototype conveyed effectively. However, the ball shape also led to certain expectations—such as throwing, kicking, and jumping—that the prototype could not meet due to its internal sensors and mechanical structure. Future iterations of Fizzy should consider a more durable design, capable of withstanding rough play while maintaining suggested features. A more durable design, perhaps with a softer, textured shell, could enhance its usability, ensuring it withstands different encounters and remains functional.

The inclusion of a wipeable or waterproof shell would also enhance usability in different therapy environments and bring.

Movement Precision

The precision and speed of Fizzy's movement were found to be crucial in therapy sessions, where time is limited and every second counts. However, occasional calibration glitches led to disappointment among therapists. If researchers aim to develop robots and tools for educational settings, they must address the gap between the execution of inputs and the therapists' intentions. Tools with significant discrepancies between these aspects may be less desirable for educators, who need reliable solutions that enhance their sessions. This is essential for gaining acceptance from decision-makers in educational institutions.

Long-Term Impact

Exploring the long-term impact of Fizzy EDU on children's development across various settings will be essential in ensuring its desirability and effectiveness.

Co-Creation with Children

Engaging children directly in the design and testing process will provide valuable insights into their perceptions of Fizzy. Future research should aim to elevate children's participation to higher levels, ensuring their voices more directly shape the design process.

Multisensory Features

The multisensory features, while beneficial for integrationg it into diverse tehrapuethic activieis, and allowing meanign making, neurodivergent children, could lead to overstimulation in others, particularly those with conditions like epilepsy. Careful monitoring and adjustment of these features are essential to avoid adverse reactions.

By addressing these limitations and recommendations, future researchers and designers can build on the groundwork laid by this study, ensuring that Fizzy EDU becomes a valuable tool in special education therapy settings.

9.3 Personal Reflection

"Everything is play if you accept it to be."

This study has taught me a great deal about the importance of play in learning—a fundamental, yet often overlooked, intrinsic motivation that drives us all. And play isn't just for children; it's for anyone who wants to be involved, transforming interactions in ways that bring joy and engagement. I also realized that the term "robot" doesn't have to refer to something futuristic. If we employ technology that feels familiar and is aligned with what our users are already doing and eases their job, it can open up countless opportunities. This combination of technology and play has shown me how powerful they can be when integrated into learning environments.

Collaborating with special education schools has deepened my understanding of how technology and play can bring significant value to classroom environments through thoughtful design. Designing for children's play has always been a passion of mine, and this project allowed me to explore that interest more deeply while discovering new areas, such as social robots and neurodiversity interventions. When working with a target group that has such diverse characteristics, reading literature alone was not enough. While I read multiple studies and sources to understand the nuances of neurodiversity, collaborating with therapists and neurodivergent children through real-life observations and testing offered invaluable insights I could never have anticipated. I have immense respect for special education professionals who master each child's unique conditions and adapt their sessions accordingly. Their work is crucial in shaping children's lives, and I feel fortunate to have witnessed the impact of their efforts.

When I began working with neurodivergent children, who possess unique characteristics and sensitivities, sparked my enthusiasm about the possibilities of my topic, but at the same time, brought many challenges and questions to my mind. I often wondered, "What if I unintentionally make mistakes and cause distress?" or "What if I can't find professionals who are willing to support my research?" However, looking back, I've come to appreciate the immense value of interdisciplinary research and the importance of remaining proactive. Even in the most uncertain times, asking for help and clearly explaining your intentions can make a significant difference. There are many people out there who are open to collaboration, but the key is to reach out.

I reached out to multiple schools, organizations, and therapists. Although some schools did not respond positively, I found others that were welcoming. When I expressed my enthusiasm for social design, the Fizzy concept, and why I believed it could be beneficial for them, I received positive responses from therapists and teachers, both in the Netherlands and Turkey. This experience reinforced my belief in the potential of multidisciplinary research and fueled my passion for bringing design capabilities to these professionals.

While formulating hypotheses and defining purpose for activities guided my research, I also learned the importance of flexibility. Initially, I struggled to balance research and empathy, but I soon realized that maintaining both was what ultimately brought coherence to my work. I've learned to trust my data and being open to improvisation What if things don't go as planned? But equally, what if they do? There were multiple instances when things really didn't go as planned, and I found myself deeply disappointed. However, now I understand how much those moments taught me. My role was to bring a designer's perspective to what was already there in special education settings, while respecting and learning from professional's expertise. Here I am, reflecting on my growing interest in designing for children, my newfound enthusiasm for child-robot interaction studies, and my new concept for Fizzy EDU.

One of my greatest challenges in this project was analyzing the rich yet highly qualitative data I collected. After each testing and observation session, I often found myself overwhelmed, trying to figure out how to create a framework that would allow me to analyze the data without losing sight of the different perspectives—the child, the therapist, and the robot. I spent countless hours attempting to log the data, exploring previous studies in child-robot interaction, human-robot interaction, and neurodiversity, but they didn't quite fit with what I wanted to record. Activity theory, however, helped me develop my own method of analysis. It allowed me to capture both the explicit behaviors and the tacit and latent meanings of the interactions, ensuring that my analysis could generate valuable insights. This was especially important given the diverse characteristics of my target group, even when they shared the same diagnosis.

Completing four studies within the given timeframe was something I never imagined possible at the outset. Yet, the empirical data I gathered, thanks to the collaboration with dedicated teachers and therapists, and my supervisor's guidance and support enabled me to complete this project with a sense of pride and accomplishment.

Last but not least, I would like to extend a heartfelt thank you to my supervisors Marco and Eda. Without your guidance, support, and encouragement, it would not have been possible to explore so many aspects of the human-robot interactions, understand complex terms, and navigate this process with such structure. Your constructive feedback and insightful suggestions helped shape my journey, allowing me to delve deeper into my research and achieve outcomes that I am proud of. Thank you for being a critical part of this journey.

To add on those, taving taken two courses with Mathieu Gielen before starting this project—co-creation with children and design for children's play—was a great foundation for shaping my activities. This quote, "Everything is play if you accept it to be," was the first thing I noted in my notebook during his first class, and it has remained a guiding principle throughout my research.

I hope that one day, the importance of play in learning will be universally recognized, along with the promising role that technology can play in enhancing educational interventions. After all, aren't we all neurologically diverse? And why not use technology to meet our diverse needs?

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