Constructive Physical Visualization and Children: Benefits and Challenges

by

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ABSTRACT

Data visualization is a medium that allows us to understand, analyze, and communicate information on a daily basis. There is considerable research on the role of visualization for adults, both in professional and casual contexts. However, very little research is available on its role for children. Despite the growing body of work on the topics of data and visualization literacy, we still lack an understanding of how young children might construct, read, and interact with visualizations; and how they might acquire and communicate data insights. To bridge this gap, we contribute the first study that aims at how young children are able to understand the concept of mapping data to abstract representations, how they construct visualizations and interact with them, and how these interactions affect what they learn, reflect on, and communicate to others. We report the results of an exploratory qualitative study in which children aged 4-6 were asked to map, encode, and derive insights from creating physical data representations of their emotions using art and craft materials over a period of two weeks. We found that involving young children in data visualization exercises helps them explore new ways of communicating and reflecting on their personal data. From this exploration of physical visualizations constructed by young children, we contribute 1) a description of how young children associate their mappings with their reflections on their data, 2) a list of interactions young children use to get insights from their visualization, and 3) a discussion of benefits and challenges of working with young children with the aim of engaging them in data visualization.

Contents

Supervisory Committee **ii**

Abstract **iii**

Contents **iv**

List of Tables **vii**

List of Figures **viii**

1 Introduction **1**

1.1 Motivation 1

1.2 Context 3

1.3 Research Questions 4

1.4 Research Approach 5

1.5 Research Contributions 7

1.6 Thesis Scope 7

1.7 Thesis Overview 8

2 Background **9**

2.1 Visualization and Children's Communication 10

2.1.1 Understanding children's data skills 10

2.1.2 Using physicalization and tangible interfaces 11

2.2 Situated Visualization 12

2.3 Constructive visualization 13

2.3.1 Studies Related to Constructive Visualization 14

2.3.2 Constructive Visualization and Children 18

2.4 Summary 19

3 Study Methodology **20**

3.1 Design choices 21

3.1.1 Group age 22

3.1.2 Continuous Self Through Time 23

3.1.3 Emotional Competence 23

3.2 Study Design 24

3.2.1 Before the study 25

3.2.2 Phase 1: Introduction to mapping (Week 1) 25

3.2.3 Phase 2 (Week 2): 28

3.2.4 Recruitment 31

3.2.5 Data Collection 33

3.3 Data Analysis 33

4 Findings **37**

4.1 Types of Encoding 37

4.2 Updating the visualization 39

4.3 Communicating insights from visualization 40

4.3.1 Providing details 40

4.3.2 Comparing 43

4.3.3 Identifying trends 45

4.3.4 Identifying distributions 46

4.3.5 Self-reflection 47
4.3.6 Summarizing the data 48
4.3.7 Matching their mental model 49
4.3.8 Other social interactions 51

5 Discussion **54**
5.1 Constructing visualizations 54
5.1.1 Children applying new visual variables 55
5.1.2 Children applying new dimensions 55
5.2 Communicating with visualizations 57
5.2.1 Children communicating insights 57
5.2.2 Tangible visualization interfaces for young children 60
5.3 Visualizing data at home 61
5.3.1 Constructive visualization for data exploration 62
5.3.2 Encouraging to visualize personal data 62

6 Conclusion **64**
6.1 Research Contributions 64
6.2 Addressing Research Questions 65
6.3 Limitations and Future Work 68
6.3.1 Limitations of the study 68
6.3.2 Engaging young children in future data visualizations 69
6.4 Conclusion 71

Bibliography **73**

A Study Handout **90**

List of Tables

Table 2.1 Review approaches on constructive visualization and physicalization with non-experts 15

List of Figures

Figure 3.1 Process that was followed to design, collect, and analyse data from the study. 21
Figure 3.2 Eight developmental levels supported by research and by theoretical consensus [31].
*These ages indicate the period when a level first appears according to research on middle-class Western children. 22
Figure 3.3 Structure of the study. 24
Figure 3.4 Participants where given two groups of beads and fuzzy sticks. The child choose which group represented being "Happy" and which represented being "Not Happy" 26
Figure 3.5 Example of how the tokens could look like in the corresponding scale 27
Figure 3.6 Tokens created by participant P2 on week 1 28
Figure 3.7 The kit included materials such as: beads, fuzzy sticks, craft sticks, gem stickers, pompoms, wiggly eyes, clothespin, glue, tape 29
Figure 3.8 Tokens created by participant P2 on week 2 30
Figure 3.9 Call for participants poster 32
Figure 3.10 Selecting the lower level concepts for coding through the comparison on the interaction with physical visualization literature. 35
Figure 3.11 Suggested structure to generate the codes. 35

Figure 4.1 When constructing their tokens, P2 was consistent in the way they grouped the beads by colour in the bracelet. P7 was consistent with their selection of colours for the pipe cleaners. . . . 38
Figure 4.2 Tokens created by P2, P4, P5 and P8 at the end of the second week 39
Figure 4.3 P3 showing the token made with all the colours of the beads because she felt happy and not happy at the same time. 40
Figure 4.4 P4 showing the researcher the new face they would add to the scale to place their new emotion. 41
Figure 4.5 P3 explaining the token on the right is big because they spent a lot of time playing and the token on the left was small because the played for a little time 42
Figure 4.6 Participants placing the tokens on the scale to indicate the corresponding level of emotion 42
Figure 4.7 P8 comparing the token on the scale with the token in their hand to indicate were on the scale would the token go 43
Figure 4.8 P5 showing the container that had the tokens of the the activity they did the most 44
Figure 4.9 P7 is counting the tokens in each container before saying which activity they did the most 45
Figure 4.10P2 compares two tokens. The one on the right is extremely happy and the one on the left is just happy. 46
Figure 4.11P5 groups tokens that represented being extremely happy . . . 47
Figure 4.12Times participants could and could not describe the reason behind the token they created. 48

Figure 4.13 P5 shows the container that has more tokens to indicate which activity they did the most. 49
Figure 4.14 P7's parent asked why the token they were talking about was in the Happy point on the scale but P7 corrected their parent and pointed at the correct place which was Not happy. 50
Figure 4.15 Example of how participants labeled the containers for each activity. 51
Figure 4.16 P8 switching the position of two tokens after realizing they were in the wrong place. 52
Figure 4.17 P7 explaining how some parts of playing with LEGO were frustrating, like the times the blocks fell apart. 53

Figure A.1 Study Handout page 1 91
Figure A.2 Study Handout page 1 92
Figure A.3 Study Handout page 3 93
Figure A.4 Study Handout page 1 94
Figure A.5 Study Handout page 5 95
Figure A.6 Study Handout page 6 96
Figure A.7 Study Handout page 7 97
Figure A.8 Study Handout page 8 98
Figure A.9 Study Handout page 9 99
Figure A.10 Study Handout page 10 100
Figure A.11 Study Handout page 11 101
Figure A.12 Study Handout page 12 102
Figure A.13 Study Handout page 13 103

Chapter 1

Introduction

In this thesis, we explore if and how young children are able to understand the concept of mapping data to abstract representations, how they construct visualizations and interact with them, and how these interactions affect what they learn, reflect on, and communicate to others. As the first step in this direction, we designed a study involving young children in their homes to understand how they collect and map their own data without any previous knowledge about data visualization. Through this study, We offer a perspective on some of the benefits of involving young children with data visualization in everyday scenarios.

1.1 Motivation

Information visualization is the process of representing data in a visual and meaningful way so that a people can better understand it [16]. In an increasingly data-driven world, visualizations are key to understanding the world around us. They help us make sense of complicated data and find patterns in it. They provide a new perspective on the world, one that is more accessible than text or numbers [17]. They can help non-experts learn and make smarter choices in their environment, learn new skills, or even just collaborate better with their peers [46]. In addition, visualizing personal data can help people get a better understanding of self, of their environment and how their spend their time [51].

Research about information visualisation has existed for several decades [16, 15, 36] and there has been a lot of studies in the field that have shown information visualization to be very useful in different aspects of our life such as business decisions, health care [71, 85], personal tracking and communication [51] with others, but so far we know little when it comes to young children [7]. Data representation is an important skill for young children to learn about as it has the potential to help them understand the world and how they interact with it. LEGO education [44] addresses this with a learning system where abstract concepts become tangible as children progress through grades, allowing them to tackle more complex real-world issues. Data representation can also allow them to communicate their thoughts and ideas more effectively, which can lead to better reflection of their every day life [8], ss demonstrated by research around self-reflection and personal physicalization that showed how physicalization, data collection, construction, and self-reflection are deeply interconnected [103].

With this thesis we explore a new opportunity around this gap and understand how young children engage in data visualizations to understand the world around them.

Data physicalization is a recent visualization approach defined by Jansen et al. in 2015 as "a research area that examines how physical representations of data (i.e., physicalizations), can support cognition, communication, learning, problem solving, and decision making" [61]. To address our research goal, we take a data physicalization and constructive visualization approach.

Constructive visualization [54] is a paradigm which provides means for non-experts to create visualizations that allow them to engage directly with data. It is simple as the basic skills involved with constructive visualization are similar to kindergarten play, constructive visualization is expressive as one can build freely within the constraints of the chosen environment, and since visualizations created in this manner can be rebuilt and adjusted, it also supports dynamics. Studies investigating this paradigm found that it allows novices to author visualizations [54] and spend more time on data-related actions compared to using Excel [114]. The constructive paradigm has been adopted by digital visualization tools [78] which shows potential to support more "thoughtful exploration" compared to more automated tools [77]. Researchers who used constructive approaches in workshops [55, 56] and classroom settings [112] further highlight the pedagogic potential of the approach.

1.2 Context

Data analysis has become a critical skill as the information-driven society of this century becomes more complex [34], and the visualization research community has stressed the importance to build data literacy skills from early ages [8, 7, 58]. We contribute to this ongoing exploration by investigating how young children construct, read, interact with and derive insights from physical representations of their own data.

Although we know a lot about how adults interact with visualizations to communicate and derive insights from them [24, 60, 118, 18, 103], we know little about whether young children derive insights from data by constructing and interacting with visualizations.

In this thesis, we rely on *constructive visualization*, a visual mapping paradigm that provides people the means to construct visualizations of their own in a simple, expressive and flexible way [54]. Constructive visualization is well-suited to answering our research questions given that i) it has been shown to be beneficial to non-data visualization experts and non-technical audiences [57, 112, 56], and that ii) children in early ages are active learners drawing on direct physical and social experiences to construct their own understanding of the world (e.g., [116, 115, 13, 50]).

1.3 Research Questions

The overall question that guides this thesis is: **How do young children engage in a constructive physicalization process to support understanding of self?** Specifically, to aid in the overall goal of learning about the approach for young children to collect and represent their personal data, we break down this larger question into four separate topics:

- Q1: How do young children understand, interpret and apply the concept of mapping?

- Q2: How do young children construct a visualization over time? How do they read and understand their visualization?

- Q3: How do young children communicate the insights they gained from their visualization?

- Q4: How can researchers and designers use young children's existing relationships with personal data and their preferences for data visualization to engage young children in the design of future in-home data visualization?

1.4 Research Approach

This section describes the research approaches taken to answer the research questions.

How do young children engage in a constructive physicalization process to support understanding of self?

This thesis centers around responding to this overall question. We conducted an exploratory qualitative study in which 6 children aged 4-6 were asked to collect, construct and discuss physical visualization of their own data using arts and craft materials over a period of 2 weeks. To answer each of these questions, we designed a study handout with step by step instructions to prompt participants to discuss the data they collected, the mapping of that data and their design choices behind their mapping.

Q1: How do young children understand, interpret and apply the concept of mapping?

During the first week of the study, participants were provided with a specific mapping to use to construct their physical visualizations. We introduced participants to a scale to measure their level of emotion and provide them with a constrain choice of materials for them to map the scale. Participants were asked to create tokens every day using the mapping they created as a reference. During the second week of the study, they were free to come up with mappings of their own to create their physical visualizations. We provide participants with a wider range of choices of materials to create a new mapping for the scale and they were asked to collect and create tokens for the same data during the week.

Q2: How do young children construct a visualization over time? How do they read and understand their visualization?

During these two weeks, the participants were asked to represent the way they felt using the provided materials, each time they finished specific activities of their choosing. For each activity they completed, they were asked to build one physical visualization that represented their emotions associated to that activity. We asked participants to provide daily pictures of their tokens and video recordings answering questions about their creations to observe the consistency of the mapping they created through time as well as their reasoning behind the design choices they made and applied to the tokens during the second week.

Q3: How do young children communicate the insights they gained from their visualization?

We analyzed the way young children communicate about their insights through the lens of the interaction frameworks that describe interaction steps and approaches in the visualization creation process. This allowed us to describe which interactions young children rely on to derive insights from their personal data and communicate these insights.

Q4: How can researchers and designers use young children's existing relationships with personal data and their preferences for data visualization to engage young children in the design of future in-home data visualization?

Using the data we collected above, we discuss different ways to design future visualization interfaces, which we discuss in detail in Chapter 5.

1.5 Research Contributions

Our analysis suggests that involving young children in data visualization exercises helps them explore creative ways of communicating and reflecting. From this exploration of physical visualizations constructed by young children, we contribute:

- C1: A description of how young children associate their mappings with their reflections on their data.
- C2: A list of interactions young children use to get insights from their visualization.
- C3: A discussion of benefits and challenges of working with young children to study visualization.

1.6 Thesis Scope

This thesis relates to the field of Data visualization with a focus in (1) Visualization as a way of communication, (2) Situated visualization and (3) Constructive Visualization.

In this thesis we do not address how young children could learn about data visualization, but we looked into some aspects from data literacy and pedagogy to understand current visualization skills among children. This thesis focuses on the engaging aspects of constructive visualization for young children and how it could impact their understanding of self.

1.7 Thesis Overview

This thesis contains five additional chapters.

- Chapter 2 reviews previous research into visualization as a way of communication, situated visualisation, and constructive visualization.
- Chapter 3 presents, in detail, the experimental methodology used in our study.
- Chapter 4 discusses the analysis and findings of this study.
- Chapter 5 consists of the discussion of these findings and presents a framework derived from the study findings.
- Chapter 6 concludes this thesis and summarizes the study, its findings, research contributions and outlines future research directions.

Chapter 2

Background

This chapter has three sections: Visualization as a way of Communication, Situated Visualizations, and Constructive Visualization.

In the Visualization and Children's Communication section, we looked at the literature to determine how data skills and visualization literacy are being introduced to children and found that pictorial and tangible representations help make abstract concepts more concrete.

In the Situated Visualization section we looked at the concept of situated visualization and how it connects withing the context of engaging people with data visualization. We found that *place* and *activity* are two of the key perspectives that expand the concept of situatedness and listed some examples of physicalization for situated data collections that support awareness of data, self-reflection and insight.

Lastly, in the Constructive visualization section, we looked at the paradigm and how it works as well as examples of studies around constructive visualization that demonstrated the benefits of using physical representation as a way of teaching, understanding and communicating the information gathered with the data.

2.1 Visualization and Children's Communication

Data visualization changes the way people experience information and the way we live.

2.1.1 Understanding children's data skills

In a study, J. Gabler et al. mentioned that data literacy has become a critical skill to deal with the complexities of the information-driven society of the 21st century. Additionally, data visualization has long escaped the boundaries of science and has become an integral part of our daily lives and often unrecognized [34]. In their study, they introduced an educational game to foster data literacy among children 9 to 11 years old by teaching about diagrams and charts in a playful manner.

In a different study, B. Alper et al. offer a different look at visualization literacy, focusing on the role of data visualizations in grades K to 4 [1]. They identified the opportunity to enhance visualization literacy in early grades and formulated a set of design goals inspired by pedagogical approaches advocating that students should be guided from concrete examples to abstract knowledge, while leveraging interactive techniques commonly used in information visualization.

Children are familiar with common representations such as clocks and pictures, but when it comes to teaching them about data, presentation tends to focus more on quantities. According to Alper et al., [2] the six most common educational data visualizations used in the early years were pictograms, tables, free form pictographs, fraction diagrams, and bar charts. Given that children around the age of four or five are still developing their ability to understand cardinality (that "5" represents five items) [33], the choice of representation may play an important role in scaffolding children's numerical abilities.

2.1.2 Using physicalization and tangible interfaces

Research has found Physicalization to be a productive way to introduce people to activities around data collection, processing, and representation [48]. In a paper about using sculptures as a low-tech and playful way of learning about data, it was concluded that activity-based data sculptures with low-tech materials are uniquely suited to introduce novice learners into the field of working with data. Novices in these settings can very quickly begin to engage with problems that visualization experts face everyday, including selecting physical and visual variables, mapping data to those variables, layers of reading, and narrative structures [5].

Research about the role data physicalizations play in enhancing STEM learning with young people [45] explores the connection between the fields of data physicalization and tangible interaction towards developing educational tools. Multiple researchers have suggested that tangible user interfaces have potential for supporting children's informal and formal learning [14, 119].

The use of physical materials has been shown to have two main educational benefits: 1) to help children offload cognition by providing physical traces of thought processes and 2) to provide conceptual metaphors to help them relate concepts to their real-world experiences [74]

There are multiple studies involving children in early ages and tangible interfaces [116, 115, 13, 50]. A different study used tangible interfaces to support early narrative development for young children [13]. These studies support the idea that using tangible tokens is a viable option to address the challenge of building visualization literacy skills from early ages. These studies stated that based on childhood cognitive development, children between 3 to 7 years old are active learners drawing on direct physical and social experiences to construct their own understanding of the world.

2.2 Situated Visualization

In the last decade, situated visualization [79, 110, 113], defined as "a visualization that is related to its environment" [111] has emerged as a research area and a concept in the area of Ubiquitous Computing and Human–Computer Interaction [42, 90, 98, 109]. The main idea is to bring data visualizations into their context of use, place and people by connecting data with the physical environment or physical elements that the data refers to [110, 113]. The area of situated visualization follows a set of research agendas that aim to move beyond traditional desktop applications in the area of visualization [88] such as "Ubiquitous Analytics" [27], "Immersive Analytics" [3, 29], or "Situated Analytics" [28, 102].

In an overview survey of current research in situated visualization [11] it was discovered that there is limited interest in how data is represented and visualized as well as a low level of interest and consideration of the target audience for the visualizations mentioned in the survey. This ties into the fact that lab studies were the most common method used to study situated visualization in the survey. The same research expanded the concept of situatedness, and introduced five key perspectives that include place, and activity. A place perspective means paying attention to a location while separating from a purely spatial perspective and representational approach. For example, a place is shaped by its history, local identity and the meaning it has for the people that live in it [104]. Therefore, visualizations become situated when they represent the unique characteristics of a particular place, such as data collected by local residents or local cultural heritage. From an activity perspective, situatedness implies that visualizations are not used in isolation but are embedded and connected to a wider set of human activities of target audiences. As visualizations move into everyday environments, designers must consider why people conduct certain activities and how visualizations can be meaningfully used to mediate these activities as well as how they relate to broader activities conducted across spaces, over longer periods of time, or through collaborations.

Thudt et al.'s exploration of personal physicalizations in domestic settings [103], highlights how self-tracking using simple data physicalizations can support self reflection and insight. Other relevant examples include Cairn [39], a physicalization for situated data collection in FabLabs, Physikit [49], a system that supports the creation of physical ambient visualizations of environmental data in the home, and Karyda et al.'s [63] work on data objects for reflective self-tracking.

Bressa et al.'s recent work about personal situated visualizations [12] explored the design and utility of situated manual self-tracking visualizations on dedicated displays that integrate data tracking into existing practices and physical environments and concluded that situating self-tracking tools in relevant locations is a promising approach to enable reflection on and awareness of data.

2.3 Constructive visualization

Constructive visualization [54] is a paradigm within data physicalization which provide means for non-experts to create visualizations that allow them to engage directly with data. Huron et al. presented constructive visualization to offer the possibility of providing people with means to construct visualizations of their own in a simple, expressive and flexible ways. Studies investigating this paradigm found that it allows novices to author visualizations [54] and spend more time on data-related actions compared to using Excel [114]. The constructive paradigm has been adopted by digital visualization tools [78] which shows potential to support more "thoughtful exploration" compared to more automated tools [77]. Researchers who used constructive approaches in workshops [55, 56] and classroom settings [112] further highlight the pedagogic potential of the approach.

By applying the concepts of constructionism, Huron et al. defined its components: token, grammar, environment and assembly model, and outlined the processes necessary to this approach. This process starts from initializing the environment in which the construction will take place. Then the data units are mapped to the tokens and the visual attributes that represent different meanings according to the data. These tokens are then assembled in the environment. Finally, changes in data can be expressed by manipulating the data token [54].

Different studies applying constructive visualization [55, 112, 56, 57] demonstrated the benefits of using physical representation and tangible tokens as a way of teaching and understanding how information visualization works as well as explored different ways to communicate the information gathered with the data.

2.3.1 Studies Related to Constructive Visualization

In order to find examples relevant to our research scope, we examined case studies related to constructive visualization and physicalization. We collected publications through Google Scholar that included studies covering at least one of the following key words: constructive visualization, physicalization, collaboration, and non-experts. We then reviewed them by reading the abstract and conclusion to make sure these topics were covered. Finally, after reviewing the studies, we selected studies that covered at least three of the topics we sought, as these provided more relevant findings to help frame our own work.

Table 2.3.1 summarizes our exploration of different studies that applied the principles of constructive visualization or physicalization as well as those focused on non-experts participants

Literature	Case study	Constructive Vis	Physicalization	Collaboration	Non-experts
Constructing Visual Representations: Investigating the Use of Tangible Tokens [57]	x	x	x		x
Building with Data: Architectural Models as Inspiration for Data Physicalization [52]	x		x		
Citizen Engagement through Tangible Data Representation [62]	x		x	x	x
Exploring the potential of physical visualization [96]	x		x	x	
Self-Reflection and Personal Physicalization Construction [103]	x	x	x		x
Construct-A-Vis: Exploring the Free-Form Visualization Processes of Children [8]	x	x		x	x
An Interaction Model for Visualizations Beyond The Desktop [60]	x	x			
Opportunities and Challenges for Data Physicalization [61]	x		x		
Zooids: Building Blocks for Swarm User Interfaces [67]			x		
Exploring Interactions with Physically Dynamic Bar Charts [100]	x		x		
Revisiting Bertin Matrices: New Interactions for Crafting Tabular Visualizations [84]	x				
An Exploratory Study of Data Sketching for Visual Representation [106]	x	x	x		
Visualization by Demonstration: An Interaction Paradigm for Visual Data Exploration [106]	x				
VisOHC: Designing Visual Analytics for Online Health Communities [64]	x				x
How Data Workers Cope with Uncertainty: A Task Characterisation Study [10]	x				
Iterating between Tools to Create and Edit Visualizations [6]	x				
Investigating the Use of a Dynamic Physical Bar Chart for Data Exploration and Presentation [101]	x		x		x
Active Reading of Visualizations [107]	x				
Comparing Bar Chart Authoring with Microsoft Excel and TangibleTiles [] [114]	x	x	x		x
Using VisKit: A Manual for Running a Constructive Visualization Workshop [55]		x	x	x	x
Let's Get Physical: Promoting Data Physicalization in Workshop Formats [56]	x	x	x	x	x
SmartTokens: Embedding Motion and Grip Sensing in Small Tangible Objects [65]			x		
Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments [9]			x		x
Design Guidelines for Business Intelligence Tools for Novice Users [93]	x				x
If Your Mind Can Grasp It, Your Hands Will Help [97]	x	x	x		
Dynamic Composite Data Physicalization Using Wheeled Micro-Robots [69]	x		x	x	
The Visual and Beyond: Characterizing Experiences with Auditory, Haptic and Visual Data Representations [47]	x		x		x
Understanding Concept Maps: A Closer Look at How People Organise Ideas [82]	x	x	x		
A Constructive Classroom Exercise for Teaching InfoVis [112]	x	x	x	x	x
Physical Visualization of Geospatial Datasets [25]			x		
Usability Guidelines for Designing Information Visualisation Tools for Novice Users [94]	x				x
Design Considerations for Composite Physical Visualizations [66]			x		
Data Tectonics: A Framework for Building Physical and Immersive Data Representations [53]	x		x		

Table 2.1: Review approaches on constructive visualization and physicalization with non-experts

Interesting Findings

A study conducted by Huron et al. [57] sheds light on how people transform data into visual representations. Using only tangible building blocks, they asked participants to create, update, and explain their own information visualizations. Their research revealed that all participants, many of whom had little experience in visualization authoring, were readily able to create their own visualizations and describe them. After this study, Huron et al. presented VizKit [55], a toolkit designed to introduce the basics behind authoring and interpreting visual representations of abstract data to lay audiences. The goal of VisKit is to provide both the material and procedure for conducting constructive visualization workshops that can engage lay audiences in a pleasant collective exercise. They also presented a method to facilitate hands on physicalization processes during workshops [56].

Following these studies, Willett et al. described the unique pedagogical goals and practical challenges associated with using construction exercises in an undergraduate course[112], and described how they modified VizKit for use in the classroom, introducing new construction exercises and materials.

Using tangible three-dimensional objects rather than keyboard and mouse interactions, Jofre et al. present a rationale for designing a tool that permits users to explore a data set [62]. They argue that, the use of tangibles facilitates the understanding of abstract concepts as well as facilitates the development of many concrete learning scenarios. Additionally, tangibles have the advantage of fostering collaboration, which contributes to a productive working environment.

Thudt et al.'s qualitative study investigates the construction of personal physicalizations in people's domestic environments [103]. In their study, they describe how digital and physical systems may be able to benefit from benefits such as reflection through manual construction, personalization, and presence in everyday life.

A study by Bishop et al. explores ways of engaging children in free-form mapping exercises that are driven by their own mapping ideas, and present Construct-a-Vis [8], a tool designed to explore the feasibility of free-form and constructive mapping activities with elementary school children, providing adjustable levels of scaffolding for visual mapping activities.

Wun et al., present a study examining the differences between two visualization authoring tools, tangible tiles and Microsoft Excel. The authors observed how people use these tools to author, edit, and read bar charts [114]. Specifically, they observed how the distribution of time spent, and sequence of actions in different operations from the InfoVis pipeline [60] is different according to the tool used. As a result of their observations, they were able to identify that when using Microsoft Excel to generate visualizations, participants spent more time exploring the tool. However, when using tangible tiles, participants spent more time on actions directly related to the data, such as visual mapping operations.

Open Challenges and opportunities

Considering Huron et al. implications for the design of non-expert digital and tangible authoring tools [57], the authors argued that research into supporting procedures for visualization authoring would be beneficial. In response, Huron et al. presented VizKit [55], a toolkit designed to introduce non-experts to the basics of authoring and interpreting visual representations of abstract data, which provided instructions on how to conduct a constructive visualization workshop. This toolkit and the method proposed as part of another physicalization workshop [56] shows its potential for participant engagement, prototyping and design reflection. In addition, Willett et al.'s exercise for teaching information visualization [112], hope to help encourage the development of a broader set of practical exercises for teaching visualization.

Jofre et al. found that several tools for data visualization have been developed for people to create their own visualizations, allowing non-experts to manipulate and gain insights into their data, but most of these tools are restricted to the computer screen, keyboard, and mouse. They suggest that through embodied interaction with data, cognition and analysis may be strengthened even further [62].

In both the context of physicalization creation and the development of tools for self-reflection, Thudt et al.'s findings indicate exciting directions for design and future research [103]. They also found that physicalization construction in a personal context had a number of benefits, including its integration with people's routines, capture of qualitative and subjective aspects, and support of shared experiences as well as the potential for using constructive visualizations as a tool for planning and creative exploration.

Findings from Bishop et al.'s study with elementary school children [8] highlighted the potential of this free-form constructive approach, as visible in children's diverse visualization outcomes and their critical engagement with the data and mapping processes.

According to Wun et al. [114], people typically perform data transformations spontaneously using tiles while modifying visual elements that represent columns directly to reorder the dataset. The authors conclude that actions like this, where participants manipulate and transform data using the visual variables, could be incorporated into visualization creation software. There may also be a possibility to move beyond redesigning interactions and design a new class of digital tools that allow people to design their own visual representations, while also offering some automation.

2.3.2 Constructive Visualization and Children

By the time of this thesis, the concept of constructive visualization is relatively new. The research around children and constructive visualization is limited mostly to children in elementary school [8, 7]. These studies point to the importance of data analysis skills and bring the challenge of how to build visualization literacy skills from early ages. They started exploring visualization tools for children in elementary school [8] and documented the challenges of running constructive visualization workshops with children [7].

Mathematics in the early years often uses representations such as blocks and tiles. Research [75] and practice indicate that children can comprehend the relationship between representations and their referents at around the age of four or five (e.g. five blocks to represent five horses). This allows for designing activities in which children are able to represent different data, such as the number of colour blocks on a table.

2.4 Summary

This chapter has three sections: Visualization as a way of Communication, Situated Visualizations, and Constructive Visualization.

In the Visualization and Children's Communication section, we looked at the literature to determine how data skills are being introduced to children and found that pictorial and tangible representations help make abstract concepts more concrete. In the Situated Visualization section we looked at the concept of situated visualization and how it connects withing the context of engaging people with data visualization and listed some examples of physicalization for situated data collections that support awareness of data, self-reflection and insight. Lastly, in the Constructive visualization section, we looked at the paradigm as examples of studies around constructive visualization that demonstrated the benefits of using physical representation as a way of teaching, understanding and communicating the information gathered with the data.

The findings gathered in this literature helped us to formulate the design of our study that would address the main goal of this thesis.

Chapter 3

Study Methodology

Constructive visualization [54] provides people the means to construct visualizations of their own in a simple, expressive and flexible way. This paradigm is well-suited to answer our research questions since it has shown to be beneficial for non-data experts and non-technical audiences [57, 112, 56]. In terms of methodology, this approach might face several challenges, mainly with regard to the choice of visualization materials and data, as well as the nature of the study environment [7]. It is informed by these benefits and challenges of the approach that we designed our study.

In this qualitative study, we examined whether young children can conceptualize data as abstract representations, how they construct visualizations and interact with them, and how these interactions affect what they learn, reflect on, and communicate. To do this, we explored qualitative research methodologies to collect our data. After reviewing different methodologies [91] and taking into account the constrains from the pandemic, our methodology combined a diary study method with remote semi-structured interview. Through this method we collected videos and pictures of the children's creations and daily interactions with their visualization that we later analysed through several iterations of coding.

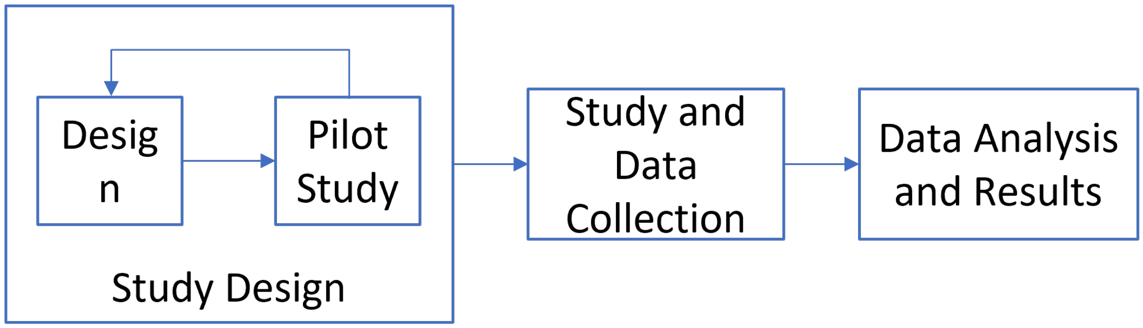

Figure 3.1: Process that was followed to design, collect, and analyse data from the study.

3.1 Design choices

It is important to distinguish between providing children with the opportunity to construct their own representations and helping them interpret a representation that has been presented to them [20]. The latter supports children to personalise, share, reflect and ultimately develop meaning. "Observe, collect, draw" [73] is a visual journal that teaches a general audience how to collect and draw their own personal data. This guided diary allowed children to learn how to notice and record the minutiae of their lives, and how to use data as a material for their creations. The same way, constructing representations may provide children with an opportunity to explore how their interactions can be represented and shared with others. Therefore, this indicates a rich area for further research to explore [76].

Therefore, in order to provide children with the opportunity to construct their visualization and help them interpret their representation, we separated the study in two phases. Phase 1 (week 1), in which participants were provided with a specific mapping to use to construct their physical visualizations and introduce them to the concept of mapping their tokens. And phase 2 (week 2), in which participants were free to come up with mappings of their own to create their physical visualizations.

3.1.1 Group age

In chapter 2, we found the research around children and constructive visualization is limited mostly to children in elementary school [8, 7]. In a consensus about the main levels of development in infancy and childhood, there have been hypotheses that children learn how to combine two or more representations at approximately four years of age (Figure 3.2), allowing them to work on coordinating two or more ideas at the same time. [31].

Level	Documented characteristics	Modal age of emergence*
Sensorimotor actions	Single actions and perceptions, first social responsiveness	2-4 months
Sensorimotor relations of a few actions	Differentiation and coordination of means and end, attachment relation to caretaker	7-8 months
Sensorimotor systems of several actions	Location of characteristics in objects and people, single words	11-13 months
Representations	Symbolization of people and objects, vocabulary spurt, multiword utterances	18-24 months
Relations of a few representations	Coordination of categories in a simple relation, solution of simplified concrete operations tasks	4-5 years
Concrete operations	Coordination of several complex categories, solution of Piagetian concrete operations tasks	6-8 years
Beginning fonnal operations	Abstractions, hypothetical ideas, solution of easiest Piagetian formal operations tasks, concepts of personality traits	10-12 years
Relations of ahstract generalizations	Coordination of abstractions, solution of most Piagetian fonnal operations tasks, concepts of personality dynamics	14-16 years

Figure 3.2: Eight developmental levels supported by research and by theoretical consensus [31].
*These ages indicate the period when a level first appears according to research on middle-class Western children.

For this reason, we recruited young children between the age of four and six years old.

3.1.2 Continuous Self Through Time

At the age of five, children begin to understand the relationship between their past and present selves. After the preschool years, children begin to develop a subjective perspective on the past, which is characterized by persistent internal states, which create a continuity of self through time. It is possible for preschoolers to accurately determine whether two events occurred in the recent or distant past, but only if they occurred within a relatively short period of time [32].

For this reason, we asked participants to provide daily reflections before the weekly check-in to talk about their tokens and what they represent.

3.1.3 Emotional Competence

"Emotional competence is a developmentally-evolving construct that encompasses children's abilities to appropriately express, interpret and regulate their emotions, as well as to understand the emotions of others" [120]. Young children's emotional competence plays a key role in their social and pre-academic development, concurrently and over time. [22, 59]. There are three main components of emotional competence, with specific attainments during the early childhood period accodint to Denham [21]: 1) Expression: Children learn to express nonverbal messages about social situations and relationships using emotional communication. 2) Knowledge: Children are becoming better at identifying and labeling their own and others' emotions, especially happiness, sadness, anger, and fear. Through the use of methods embedded within play, they are able to identify the causes and consequences of these emotions, and they begin to recognize complex, individualized emotional causes. [23]. 3) Regulation: Young children begin to regulate emotions in productive ways by monitoring, modifying, and recognizing their feelings.

For this reason, after evaluating different options of data that participants could collect, we decided to use their level of emotion as the data they would gather throughout the study.

3.2 Study Design

After two iterations of pilot studies and redesign of the study, we came up with a set of materials that were delivered to the participants including a study handout, a diary template and a number of craft materials for the children to use during the study. The participants were asked to collect, construct and discuss physical visualizations of their own data over a two-week period.

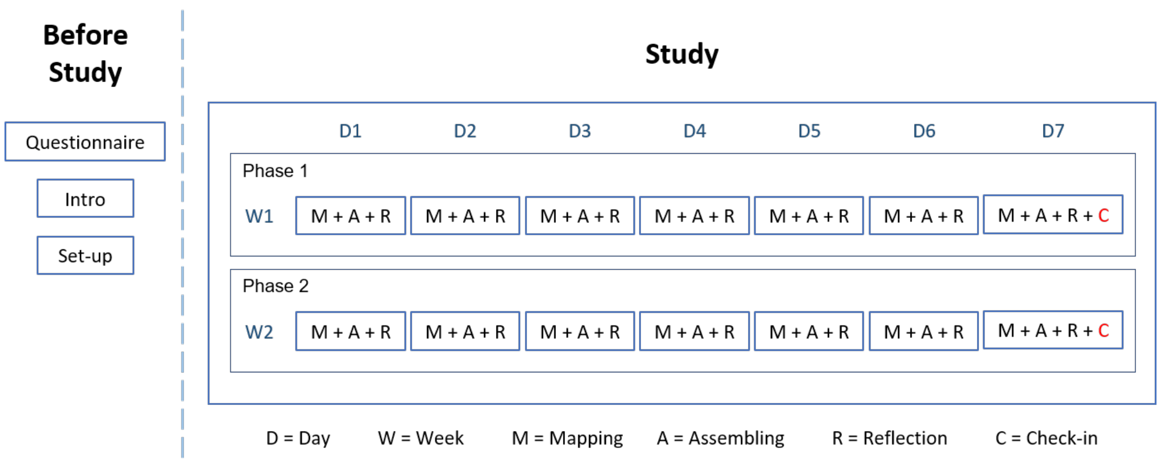

Figure 3.3: Structure of the study.

The study was organized into two parts: an introductory meeting before the study, and the study itself which consists in two phases with for components: mapping; assembling; reflection; and a weekly check-in (Figure 3.3) in which children would be asked to place different tokens on the scale and recall what activity they did that is associated with their token. The questions asked to the children included:

- Can you tell me which activity you did the most this week?

- Looking at your containers can you tell me how you felt ¡doing activity¿ this week?
- Can you take one token from two different activity container and tell me if the emotions associated with them are different or the same? How do you know?

3.2.1 Before the study

Before the study begins, parents/guardians of the child selected four activities that their child performs frequently, and we set a remote meeting with them to walk them through the study and have a short introduction with their child.

3.2.2 Phase 1: Introduction to mapping (Week 1)

During Week 1 of the study, the child created a mapping by associating beads to emotions and building tokens (objects) using these beads and fuzzy sticks, that they would then place in containers.

After evaluating different options of data that participants could collect and learning trough the literature how young children between these range of ages have developed emotional competence, we decided to use their level of emotion as the data they would gather throughout the study, since it would give us the opportunity to observe whether the children are able to map an abstract concept such as emotion and how they would reflect on it using their visualization. Results from our pilot studies indicated that children indeed understood what was expected from them and could talk about their emotions and their magnitudes.

The beads were separated into two groups of colours – resulting in a sort of diverging color scale – so the child could associate one group with a type of emotion. We would then observe if the child would use the colours within the group to map the level of that type of emotion, or just use the whole group of colours as a single value in their encoding. The location of the containers could be anywhere in the house and had to be placed together in a reachable place for the child so they can have a constant visual overview of their visualization.

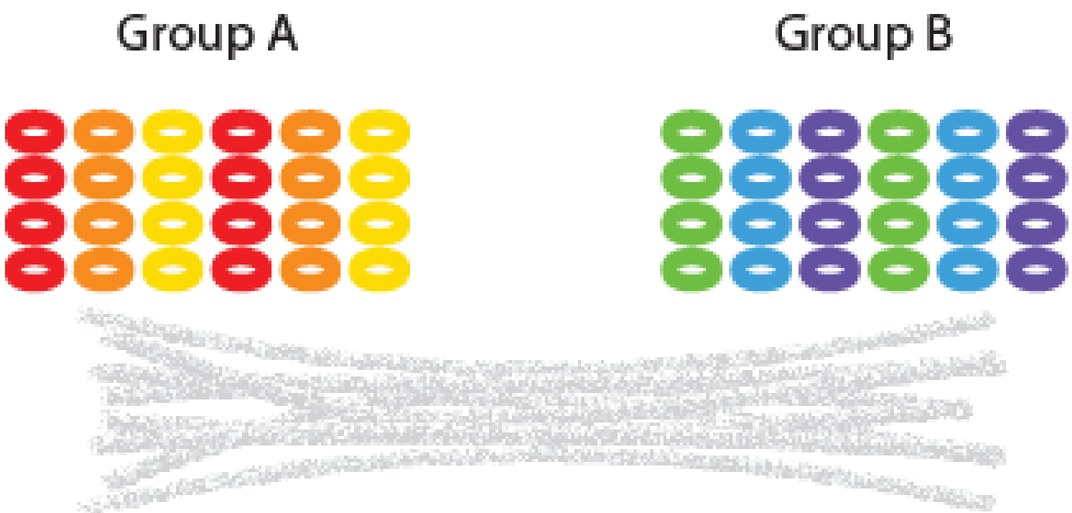

Figure 3.4: Participants where given two groups of beads and fuzzy sticks. The child choose which group represented being "Happy" and which represented being "Not Happy"

- Mapping: The child went through the following four steps together with the researcher, as part of the introductory session for the study:
  - Step 1: Association of the colour group to the type of emotion. The child chose which group of coloured beads (Group A or Group B) they would associate with being “Happy” and which group they would associate with being “Not Happy”.
  - Step 2: Creating two basic tokens. The child picked a fuzzy stick and threaded it through a bead from the group they chose to associate with being “Happy”. This would be a token that represents “Being Happy” and then they would do the same for being “Not Happy”.

– Step 3: Creating two more tokens based on the level of the emotion. The child used as many beads from the group of beads associated with being "Happy" as they wanted, and threaded them through one fuzzy stick to show the researcher what "Being extremely happy" looks like. Then they did the same to represent being "extremely not happy".

– Step 4: Display the Mapping. Parents or guardians placed this mapping in a place visible to their child and close to the containers for each activity so that they can refer to it later during the study.

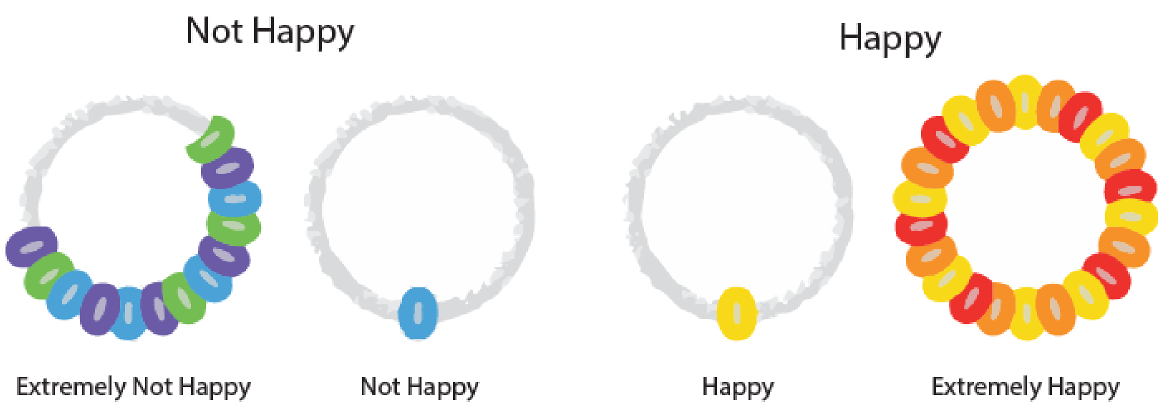

Figure 3.5: Example of how the tokens could look like in the corresponding scale

- Assembling: Every time the child finished one of the activities, they were asked to create a token that represents how "Happy" or "Not Happy" they felt using the mapping they created as a reference. They would then place this new token in the container corresponding to the activity they just did.

- Daily Reflection: At the end of each day of the study, parents or guardians would ask the child to place their tokens on the scale they created on the first day and explain the reasons behind their choices.

- Weekly Check-in: At the end of the week, participants met remotely with the researcher to talk about what happened during the week. Children would be

Figure 3.6: Tokens created by participant P2 on week 1

asked to place different tokens on the scale and recall what activity they did that is associated with their token.

After they had asked these questions, the researcher had a short interview with the parent or guardian of the child. During this interview, they would talk about what happened during the week, and what interactions or comments the child made about the activities that were not captured during the recordings. This would help the research team to fill gaps between the observations of the study.

3.2.3 Phase 2 (Week 2):

In the second week of the study, the child kept creating tokens that represent their emotions when conducting activities, however, in this second phase they were able to use more material and have more freedom in terms of which mappings they would follow. The materials chosen for this study were selected after conducting the two pilot studies. These pilot studies allowed us to test which craft materials would be used by the children, how they would work within the set up of the study, and what materials are well-suited to be combined together to form a token.

- Mapping: Using the new kit of materials, the child repeated the process of Creating the Mapping in Phase 1. The child went through the following three

Figure 3.7: The kit included materials such as: beads, fuzzy sticks, craft sticks, gem stickers, pompoms, wiggly eyes, clothespin, glue, tape

steps:

- Step 1: Creating two basic tokens. The child chose between all the materials in the kit, what would they use to associate with being "Happy" and what would they associate with being "Not Happy"? Because they had more freedom in terms of materials to use than in the first phase, this time the tokens could be made using the materials provided in the kit and any other physical material found in-home (such as home supplies) or in nature (such as small marbles and wood chips). A token could be made using a single piece of material, or by combining several as long as these were put together to form a single object.

  - Step 2: Creating two more tokens based on the level/intensity of the emotion. The child used as many materials as they wanted to show what "Being extremely happy" looks like. Then they did the same to represent being "extremely not happy".
  - Step 3: Display the Mapping. As in Phase 1, parents or guardians placed this mapping in a place visible to their child and close to the containers for each activity so that they could refer to it later during the study.

- Assembling: They followed the same instructions presented in Phase 1.

Figure 3.8: Tokens created by participant P2 on week 2

- Daily Reflection: At the end of each day of the study, parents or guardians asked the child to place their tokens on the scale they created on the first day and explain the reasons behind their choices. In addition, they asked questions about comparing some of the objects their child created such as Why are these two objects similar? Why is this one different from the others? What does it mean?

- Weekly Check-in: At the end of the week, participants met remotely with the researcher to talk about what happened during the week. Children were asked to place different tokens on the scale and recall what activity they did that is associated with their token.

After these questions, the researcher would have a short interview with the parent of guardian of the child to talk about what happened during the week that included interactions or comments from the children about the activities that were not capture during the recordings. This would help the research team to fill any gap between the observation of the study.

3.2.4 Recruitment

For the process of recruitment, we looked at various diffusion channels, including Slack, social Media and mailing lists. We considered Slack, because we were part of the group of researchers across Canada in the area of human-computer interaction (i.e., HCI Canada) and that gave us a medium to collaborate with other researchers conducting studies in related areas. Through this channel, we expected to find participants familiar with the goals of our research. Social media, was selected to broaden the range of participants, reaching to families that even though might not be familiar with our area of research, are willingly to participate in our study. Finally, we used relevant mailing lists where the recipients were graduate students and faculty of the departments of engineering and computer science, reaching to other participants familiar with academic work like our research, although not necessary familiar with our domain area. In addition, we leveraged world's current state of remote working making the participation in our study available outside our local boundaries. Figure 3.9, depicts the call for participants poster that was shared through all three channels.

The most effective channel was mailing lists with 11 people willingly to participate. The less effective channel was Slack with no replies, and through social 4 people showed interest. As a result, we reached to 15 people to coordinate the study, 10 of those engaged to get more information, 8 our of those agreed to participate and 6 completed the study. In addition, the majority of the participants 5 are residents of

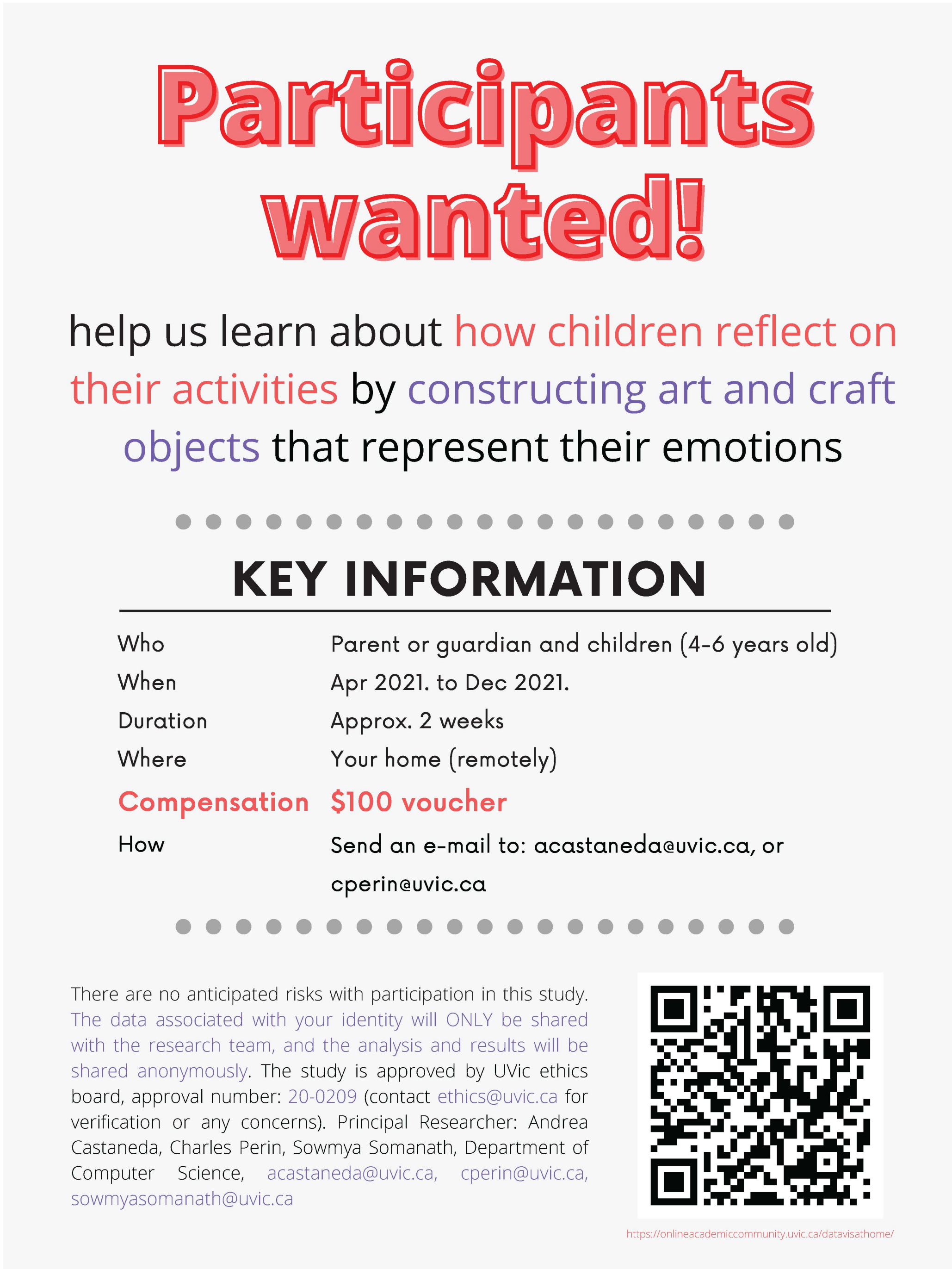

Figure 3.9: Call for participants poster

British Columbia and 1 is resident of Alberta.

Given that this study was intended to be conducted with children, a Human Ethics application was submitted and approved (i.e, approval number 20-0209) by the ethics board at the university of Victoria.

3.2.5 Data Collection

Six out of eight participants that were recruited completed the study. Due to the nature of our study, we anticipated that most participants wouldn't be able to perform the study every day during the two-week period so we encouraged participants to perform the study at least four times each week. At the end of the study, we collected 57 videos of daily reflections, 12 videos of weekly check-ins and 6 diaries that include pictures of the tokens created by the children and notes from their parents. At the end of the study, we collected 99 pictures and around 4.5 hours of video recordings

3.3 Data Analysis

After collecting the data form the participants, we analysed the data trough several interactions of coding. We started our analysis with an emergent coding approach based on the notion of grounded theory [37] and followed two out of the four stages of grounded theory introduced by Corbin and Strauss [91]: 1) open coding; we analyzed the recordings and noted any interesting phenomena including actions, expressions, comments and interactions from the children. 2) Development of concept; we started grouping collections of codes that describe similar contents to form higher level "concepts," that later would be grouped into "categories" during the third stage. While performing this stage, we realized that the concepts that we started to identify merged with concepts from the literature on interactions with physical visualization.

From this, we decided to shift to an a priory coding approach. We looked into the literature and compared the concepts from each paper to frame the codebook starting with the lower level concepts and then moving to higher categories (figure 3.10). We identified the interactions with physical visualizations are categorized in three parts:

1. Interactions during the construction: Here, people decide on their topic and goals. Following that, they create a summary of the data, which includes a decision on data attributes, categorizations, scales, and possible value ranges [54, 103]. Interactions in this category include: logging data digitally or on paper in a textual, numerical, or visual format separate from their physicalization [103]. Transforming new data into physical form by processing raw data into a form that is suitable for visualization by assigning perceptual marks and variables, as well as arranging the layout [24, 103, 60].

2. Interactions to get insights: This type of interactions define how information is extracted from the visual mental model [60]. People explore a dataset by adjusting the level of abstraction and/or the range of selection of the data (e.g. filtering, grouping) and find specific distributions, trends, frequencies, outliers, or structures in the dataset [118, 18, 103, 117, 92].

3. Non-data interactions: This type of interactions do not operate explicitly on the data nor on the data presentation. These interactions include: meta actions (undo, redo, record activity, log, and change history), social actions (communicate, share and discuss with peers) and interface actions (take notes, organize, externalize thoughts) [24].

Even though we separated the interactions in these three convenient categories to guide our coding, Thudt et al.'s work [103] highlights that reflection is happening throughout the physicalization process, from data gathering to construction to placing the physicalization to a dedicated place at home to analyzing the constructed physicalization. This is reflected on later in Section 5, where we discuss how children would add abstract concepts to their mappings depending on how they perceive their own data.

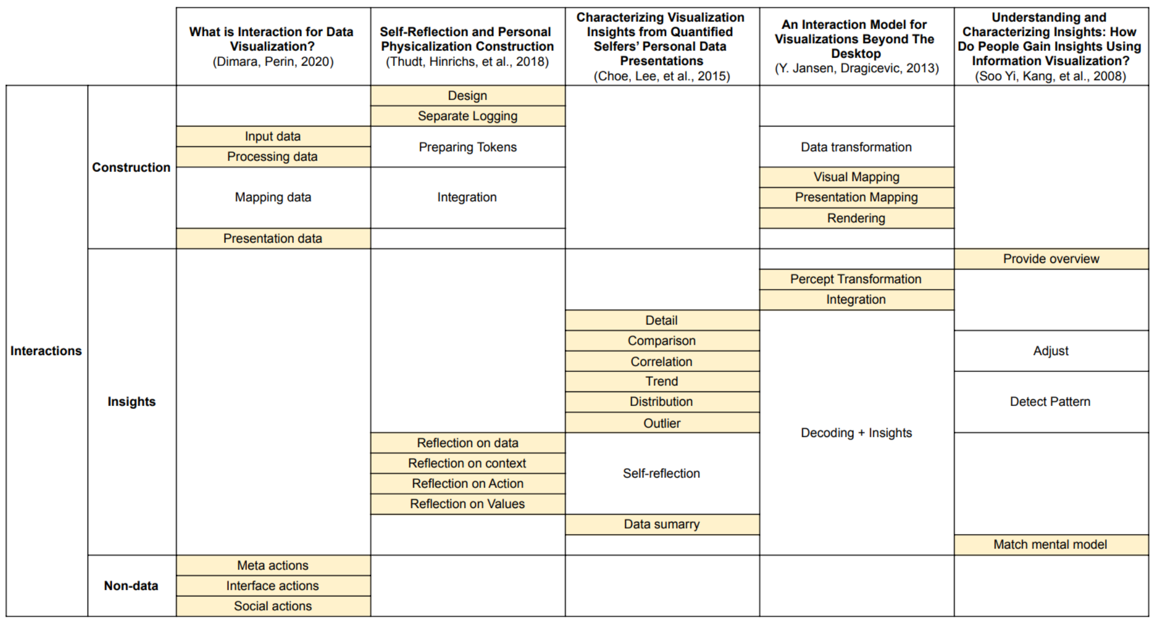

Figure 3.10: Selecting the lower level concepts for coding through the comparison on the interaction with physical visualization literature.

To validate the codebook we looked into different qualitative studies to get an insight on their process [86, 30, 4, 40, 99] and decided to use the intercoder reliability method [35]. Two researchers then coded separately the complete data from one participant using NVivo, combining open coding with the framework from the literature to create the new list of codes (figure 3.11).

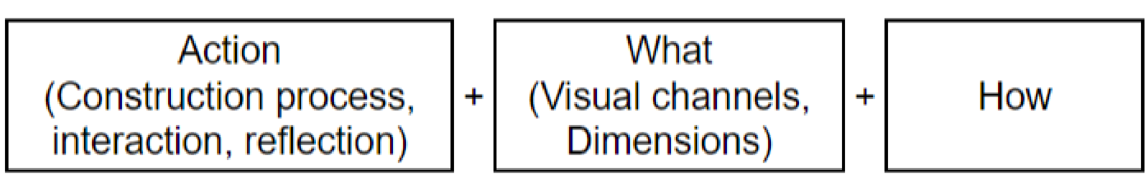

Figure 3.11: Suggested structure to generate the codes.

After the first round of coding, the team of researchers came together to discuss the list of codes and decide for which codes there was an agreement and which codes should be removed. Since there was a large diversity in our data, in the iterations with the research team, we simplified the codes removing the keywords from "Action" and "What" proposed in the structure of the codes (Figure 3.11) so the codes could be more concrete. We then compared each code from the two researchers for the same sample, and redefined them until we converged on the final list of codes. Then we applied the formula for the intercoder reliability resulting in an agreement of 58.54% and a kappa of 0.6, which we agreed was not satisfactory. Next, we proceeded to do a second round of coding. The researchers again coded separately the complete data, from a different participant. After this second round and the discussion with the team, we applied the formula for the intercoder reliability again resulting in an agreement of 95.71% and a kappa of 0.9. A kappa of 0.9 is generally seen as high agreement [35]. With this, the research team validated the codebook and a single coder proceeded to finish coding the rest of the data.

Chapter 4

Findings

In this chapter we describe the findings of this study following the physicalization process of constructing the visualization with the types of encoding used by the children, how they updated their visualization over time, and how they communicated the insights from their visualization.

4.1 Types of Encoding

During week one when the creation of the materials was limited to bracelets made with pipe cleaners and beads, all participants were consistent with the group of colours they chose during the introduction of the study to represent a type of emotion. In other words, they were able to apply the mapping they had chosen throughout the week. Some participants showed a pattern in their design choices as shown in figure 4.1. P4 and P7 said they choose their favorite color of pipe cleaners to create their tokens. P7 also mentioned putting the same amount of beads as the ones already on the scale to represent that same level of emotion.

During week two, When asked about their design choices, e.g., through asking questions such as ”why did you choose that colour? why is this token bigger than

Figure 4.1: When constructing their tokens, P2 was consistent in the way they grouped the beads by colour in the bracelet. P7 was consistent with their selection of colours for the pipe cleaners.

the other?, etc., some of the times participants indicated using the following visual variables to represent their level of emotion: P2, P3 and P4 used colour. P4 and P8 also mentioned they used the number of colours within the token. P2, P4 and P7 used shape. P3, P5 and P8 used size. P8 used the number of materials in the token (craft sticks, stickers, clothespins and googly eyes). Some participants had design choices beyond visual channels [81]. During the daily reflection on week two, P3 said their tokens represented being unhappy because of the way they made the token, which seems to indicate that the steps they followed to create that specific token was the variable that made it be "unhappy". P8 indicated their token represented being happy because they look like a family member. P4 and P8 used more subjective mappings such as the token being "beautiful" or "cool". Even though participants were able to point and describe their design choices most of the times they were asked about their tokens, participants P2, P3 and P4 were not able to describe their design choices a few times answering "I don't know" or giving vague answers like "just because". When comparing tokens that represented the same level of emotion P4 and P8 mentioned that their tokens do not have to be the same to represent the same emotion. Which indicates that their mappings were not consistent throughout the week.

Figure 4.2: Tokens created by P2, P4, P5 and P8 at the end of the second week

4.2 Updating the visualization

Here we look at the times participants made changes in their visualization either by combining the colours of the beads in their bracelets to represent multiple emotions or changing their mapping.

During week one P3 and P4 represented feeling multiple emotions at the same time, combining beads of both groups of colours in the same token. When asked about where on the scale they would place that token, P3 pointed at all the points on the scale saying it would go in all of them (Figure 4.3). P4 discussed with their parent a new face they would like to have on the scale to map the level of emotion of their new token. In figure 4.4 during the Check-in session, P4 showed the researcher how they would create a new face on the scale to place their token.

Figure 4.3: P3 showing the token made with all the colours of the beads because she felt happy and not happy at the same time.

During week two, P3 added a new dimension to the visualization and mapped the time spent doing an activity using the size of the token as shown in figure 4.5.

4.3 Communicating insights from visualization

4.3.1 Providing details

Here we look at how participants indicated the specific details from specific tokens.

When asked about a specific token, all participants were able to show the corresponding place on the scale of that token as shown in figure 4.6. This was done most

Figure 4.4: P4 showing the researcher the new face they would add to the scale to place their new emotion.

of the time by placing the specific token on top of the scale. Two participants pointed at the place on the scale. Most of the time participants did this right away but a few times they took a few moments. For example, Figure 4.7 shows P8 who took a few seconds to think about the correct position of the token on the scale, compared their token with the ones on the scale, and then indicated the correct answer.

During the weekly check-in when the researcher asked them questions about their tokens such as ”which activity you did the most?, can you show me the token you made when you were sad?, etc.”, participants provided details of their visualization by performing a specific action either by showing a token to the camera or by lifting the container with all their tokens to indicate a specific activity their were talking about (figure 4.8). When they were asked to choose any token they would like, P3, P4 and P8 also made a deliberate choice of a specific token they wanted to talk about. When P4 choose a token saying ”This one because is very colorful”. After talking about that specific token, P4 said ”And did you know this is the first time I did

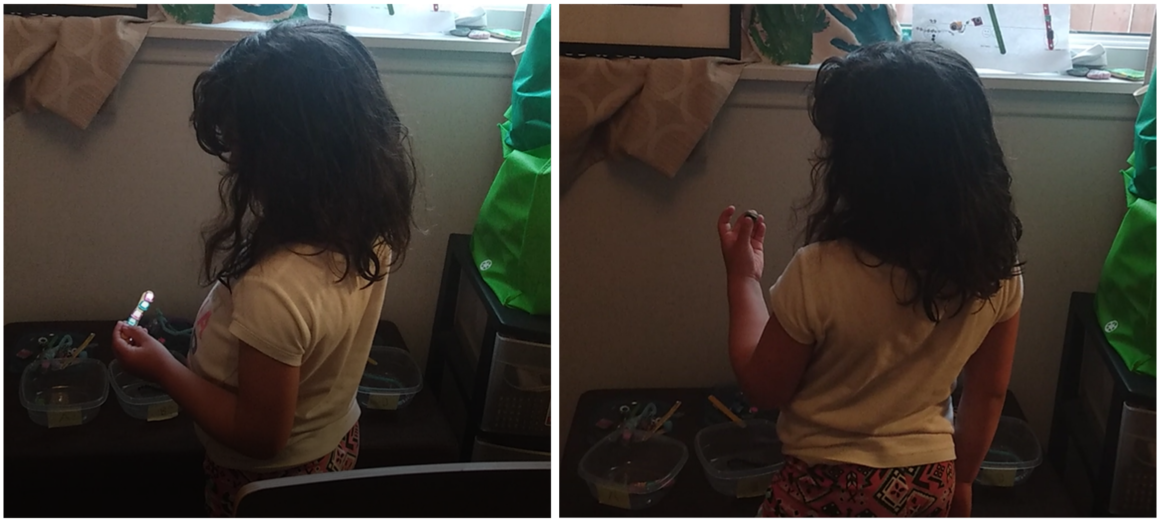

Figure 4.5: P3 explaining the token on the right is big because they spent a lot of time playing and the token on the left was small because the played for a little time

Figure 4.6: Participants placing the tokens on the scale to indicate the corresponding level of emotion

playing?". When P8 was talking about an activity that had mostly happy tokens, the researcher asked "so there was no no sad ones or not happy ones?" P8 answered "Nooo. There was only one uhm sad. Not super sad, this sad" pointing at the level of emotion on the scale and then showed the token to researcher.

Figure 4.7: P8 comparing the token on the scale with the token in their hand to indicate were on the scale would the token go

4.3.2 Comparing

Here we look at how participants compared their tokens with different elements of their visualization such as the position on the scale, quantity, other tokens, etc.

During their daily reflection three out of six participants indicated the correct position of a token on the scale by comparing it with another token in the same position in a total of 6 times between the two weeks. During week two, participants compared tokens based on their design choices. P8 said that one token was "cooler" than the other which made the token more happy in the scale. P3 said that one token was bigger than the other which meant that one time she spent more time playing than the other.

During the weekly check-in, when asked about a summary of their activities, participants compared the tokens from each activity either by looking at how full the container was or by counting all the tokens in each container to indicate the activity

Figure 4.8: P5 showing the container that had the tokens of the the activity they did the most

they did the most (Figure 4.9) or comparing the colours in each container to indicate how they felt. P4 and P8 compared all the tokens made for two different activities and were able to indicate overall how they felt doing those activities during the week. When P4 was asked "Which one made you the happiest?" referring to the activities, P4 answered "This one", picking the container that represented playing with the computer. When P8 was asked "How did you feel Playing?", P8 answered "Good" while looking at the container and making a gesture of thumbs up to the camera. Then P8 was asked "And how and how about brushing your teeth?" and P8 looked at the container and answered with a thumbs down to say they felt not happy.

When asked about the difference between two tokens that represented different levels of the same emotion, participants where able to compare both tokens and indicate which corresponded to which level as shown in figure 4.10.

At the end of week one, P3 and P4 who combined multiple levels of emotion in one token, were able to indicate which emotion they felt the most by counting the

Figure 4.9: P7 is counting the tokens in each container before saying which activity they did the most

number of beads in their tokens.

When asked about choosing tokens that represent similar level of emotions, participants could group tokens based on the same colour or the the same emotion that was represented in the token as shown in figure 4.11. In a different example, P4 picked two bracelets, each from a different container, and said "This and this, they are the same feeling" showing the bracelets.

4.3.3 Identifying trends

Here we look at how participants identified trends in their visualization.

At the end of week one during the weekly check-in P4 and P7 identified a trend in which the same activity was always associated with the same emotion. For P4 it was being extremely happy every time they played with the computer, after looking at all their tokens P4 pointed at the container and said "This one was happier because

Figure 4.10: P2 compares two tokens. The one on the right is extremely happy and the one on the left is just happy.

I love playing on the computer". In the case of P7, it was being happy every time they played with LEGOS, when P4 was asked about the place of a token on the scale they said "since it's LEGO I always put it right here".

4.3.4 Identifying distributions

Here we looked at how participants identified a distribution on their tokens in terms of the activity they represented and the level of emotion on the scale.

P7 and P8 remembered the distribution of the data during the week by pointing at the scale. When P7 was asked about a token by the parent "okay why don't you put it there sweetie?" referring to a place on the scale, P7 said "Yeah, but then Lego is always over there, and hand washing is always in there" pointing at the respecting

Figure 4.11: P5 groups tokens that represented being extremely happy

position on the scale. At the end of the week when the parent of P8 made a comment saying "I think you rated it every single one of them either happy or extremely happy" P8 answered "I did these two and then these." showing the tokens they made.

4.3.5 Self-reflection

Here we looked at how participants shared insights from their tokens that are not specifically represented in their visualization.

Most of the times during the daily reflections participants had a reason for why they felt a certain way and could describe it, either by giving vague answers like "Because I like it" or more detailed answers like every time P3 was asked about why they were sad for brushing their teeth, they answered "Because I don't like the toothpaste so I don't like brushing my teeth" and every time a token for reading books was representing extremely happy, they answered "Because I like that book so so much". Every time P4 was asked about why the tokens for playing with their computer were extremely happy, they would answer ”Because I love playing with the computer”. Every time P7 was asked about why the tokens for playing with LEGO where extremely happy, they said ”Because I love playing with LEGO”. However, at the end of the week most of the participants couldn’t remember the reason why they felt a certain way for a specific token. Some times participants indicated the had a reason for why they felt a certain way but didn’t provide any details about it.

	Daily reflection	Weekly check-in
Have a reason for why they felt a certain way and can describe it	76	5
Can't remember the reason why they felt a certain way for a specific token	11	14
Indicates they felt a certain way but don't provide detail reason of why	11	0

Figure 4.12: Times participants could and could not describe the reason behind the token they created.

4.3.6 Summarizing the data

Here we looked at how participants provide summary of different dimensions of their visualization.

During the daily reflection, P7 and P8 where able to provide summary of how they felt during the day by looking at the tokens. P7 also was able to provide summary of how many times they did an activity. They said ”I did play LEGO a lot”.

During the weekly check-in for both weeks, when asked about which activity they did the most or how many times they did an activity, participants looked at their tokens in their containers and were able to give to correct answer either by counting the tokens or by looking at how full a container looked (Figure 4.13). They were also able to provide a summary of how they felt doing an activity by looking at the colour, or shape of the tokens or by placing the container with all the tokens in the point on the scale. P2 and P7 provided summary of how many times they felt happy by counting the tokens.

Figure 4.13: P5 shows the container that has more tokens to indicate which activity they did the most.

4.3.7 Matching their mental model

Here we look at the times participants recognize and remembered details of any data point after a period of time.

When asked about specific tokens, 44/49 times participants were able to indicate the level of emotion a token represents without referencing to the scale. Even when five of those times P7 and P8 were getting contradictory information by the parents (Figure 4.14). When P7's parent said "So it seems like you're feeling very happy from all of these things?", P7 pointed at the scale and said "No, that's right there" referring to one of the tokens. When P8's parent was referring to the tokens of one activity, they said "I think you rated it every single one of them either happy or extremely happy", P8 answered "I did these two" pointing two tokens to the happy level on the scale and then said "And then this two" pointing at a different section on the scale. During the weekly check-in of week two, we observed that even though P4 placed a token in a different point on the scale from the time they talked about it in the daily reflection, they placed the token based on the mapping of quantity of colours they previously explained.

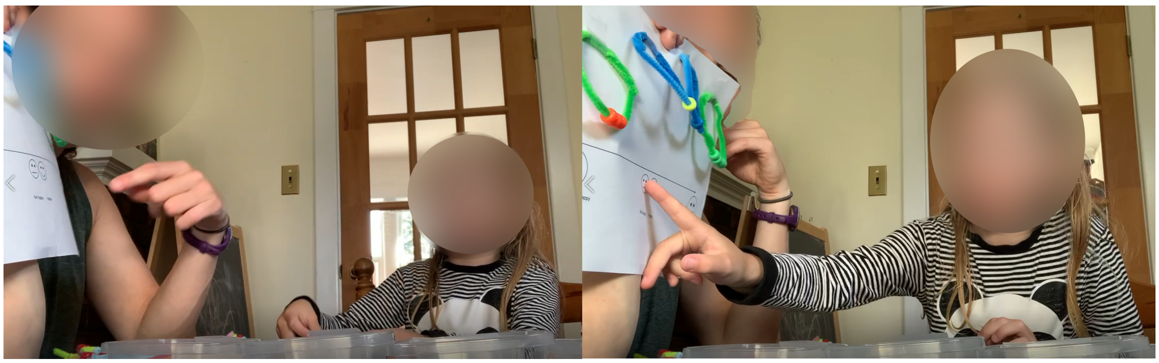

Figure 4.14: P7's parent asked why the token they were talking about was in the Happy point on the scale but P7 corrected their parent and pointed at the correct place which was Not happy.

43/50 times participants were able to indicate the corresponding activity of a token without referring to the containers. Only by looking at the token participants could remember which level of emotion and what activity was represented. The times participants were not sure about the activity, they looked at the label in the containers to give the correct answer (Figure 4.15). During the first week on the daily reflection, the time P3 was not able to remember the corresponding activity of a token, they were still able to place it in the correct position on the scale.

After week one, all participants were able to remember how to use the scale correctly, without having the tokens from week one on top of the scale as a reference. At different points during the two weeks, five out of six participants fixed the position of a token on the scale after realizing they had made a mistake (Figure 4.16). P8 was able to remember the day a specific token was made during the weekly check-in.

Figure 4.15: Example of how participants labeled the containers for each activity.

When P8 was asked about what happend during the day they made a specific token P8 said "Yeah. Well, it was on the day that she said I could do whatever I want".

4.3.8 Other social interactions

During the daily reflection P2, P4 and P8 presented their tokens in a very specific order, but without a specific reason. They made sure to indicate the order they wanted to show the tokens before talking about them. For example, every time P4 started the recording for the daily reflection, they said "Hello, first I'm gonna do this one and then this one, and then and then this one", and then proceed to talk about the tokens.

During the first week, when P7 was talking about a token for playing with LEGO, they initiated a conversation about their emotion with their parent, saying that even

Figure 4.16: P8 switching the position of two tokens after realizing they were in the wrong place.

though there were parts of the activity that were sad and frustrated they felt mostly happy and that is why they created a happy token as shown in figure 4.17. The conversation went as follow: P7's parent asked "why did you put you're playing with Lego all the way over here? And not here or over here? and P7 said "It's because I always feel like extremely happy when I'm playing LEGO". Then their parent followed up asking "Even do sometimes there are frustrating parts of it?", to which P7 answered "That's the sad where my LEGO is broken and I don't know how to build it. Like when the clip clip fell up and then I started screaming over". Then the parent said "But these two things are both saying that the LEGO felt extremely happy. So overall, the LEGO made you feel extremely happy. Is that it?" and P7 said "Yeah".

When talking about their tokens some participants seemed to have identified a motivation to create a token. During the weekly check-in on week one, after P4

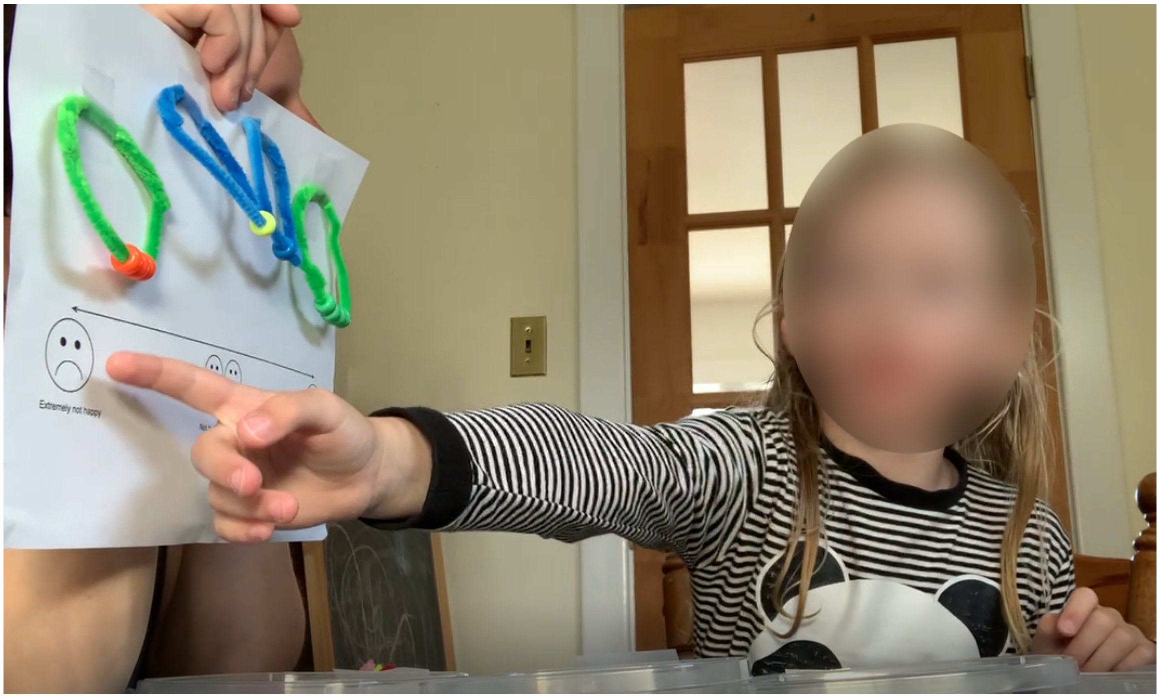

Figure 4.17: P7 explaining how some parts of playing with LEGO were frustrating, like the times the blocks fell apart.

counted the tokens for playing in the computer they said "I have to do those now!". During the daily reflection on week one, P7 was exited about using all the materials the next week and said "Need to build seven days and then into glue!". Then after talking about the tokens they made during the day P7 said "I think I'm gonna need to make another bracelet after the routine because I always brush my teeth". During week two on the daily reflection, P8 mentioned they wanted to build tokens because the wanted to buy something at the end with the compensation from the study. P8 said "Well because I wanna buy a slip and slide" and mentioned it again during the weekly check-in.

Chapter 5

Discussion

In this chapter we discuss the following points from the results: Constructing visualizations, Communicating with visualizations, and Visualizing data at home.

5.1 Constructing visualizations

We asked children with no background knowledge of data collection and visualization to collect and represent data about their emotions when doing an activity. We presented the children with the task in a constrained way during the first week of the study. We gave them the specific scale and materials to work with and expected that they would become familiar with mapping emotions on a scale. The children quickly picked up the idea that placing more beads in their bracelets meant they were extremely happy or unhappy depending on the colour they chose to represent that emotion. When they were asked about a specific token they could easily place it at the corresponding place on the scale. As the children got familiar with the concept of mapping, we expected that in the following week the children would be able to keep applying the concept when presented with more freedom to map their level of emotion.

5.1.1 Children applying new visual variables

Since children had more range of materials to use to map their emotions, they started applying different visual variables from the materials to map and construct their tokens like colour, shape, size, quantity of colours, quantity of materials and abstract concepts like "beautiful" and "cool". Yet these variables were not necessary a constant in their mapping, especially when their variable was and abstract concept such as "pretty" or "cool". When they decided that the "prettier" or "cooler" a token would look like, then it meant that the happier they were when doing an activity. However, at the end of the week we could see that the "cool" tokens were not the same. This type of mapping was easier for them to describe during the daily reflection with their parents as they created the token in that same day. At the end of the week most children could remember their mapping and place the tokens in their corresponding place on the scale yet some children miss placed the tokens. We believe this has to do with the fact that it is hard for young children to remember specific details about past events [89] and that the perception of pretty and cool could have change during the week. They could remember their mapping "cooler means more happy" but a token that did not look as "cool" as it did when they created it, was now placed at a different position on the scale.

5.1.2 Children applying new dimensions

Over time, participants were able to update their visualizations either by updating their encoding or adding more dimensions to their visualizations. We noticed some children like P3 started to use the size of their token as a way of mapping the time they spent during an activity adding a new dimension the their data.

We also observed that unlike in week one where they had a reference to the mapping they created on the scale, most of the participants did not update that reference when creating a new mapping on week two which could have contributed to the inconsistency in some of the cases.

Based on the data we collected about week two, we came to realize that young children are capable of understanding the concept of mapping and can apply that concept to construct tokens to represent data. However, having a complete freedom to modify their mapping would lead to inconsistencies through the construction of the visualization over time, making it difficult to interpret it in an accurate way.

This observation makes us think that future visualizations interfaces that would involve children to create their own visualizations can offer a diverse range of visual variables for them to map their data. Beyond the standard visual variables such as colour, size and shape [81], we can also consider haptic variables such as resistance, friction, and temperature that can be used to augment visual variables [43]. Roberts and Walker suggested the identification and use of such variables for each of our five senses [87]. However, addressing the opportunities and challenges for data physicalization, Jansen et al. argue that instead of studying individual sensory (e.g., visual or haptic) variables, it is necessary to study how they can be combined in physicalizations [61]. They propose to call physical properties such as smoothness, hardness, or sponginess, physical variables. Identifying, exploring, and classifying physical variables is a research opportunity that will be key to understanding the design space of data physicalizations specially when thinking of engaging young children in the construction process of future visualizations.

We also think that when it comes to visual variables, it is important to consider constraining the ability to update the visual variables once the mapping is decided at the beginning of the construction process or make sure that the interface will update all the tokens with the new visual variable. As we noticed that young children can identify more dimensions in the context of the data that they are collecting, it is important to also consider creating adaptive visualization interfaces that would allow children the freedom update the mapping of their visualization to better communicate the information about their data. In the field of storytelling, one approach to striking the balance between an open ended story crafting kit and a guided one is to adopt the style used by the popular "Choose Your Own Adventure" gamebooks [70]. In these books, the reader (the protagonist) takes on the role of the main character and chooses the action and outcome that determines the story. Many children enjoy these books partially because they feel like they are in control of the stories [19]. The tangible kit approach by Wallbaum et al. [105] is ideally suited to recreating these kinds of stories engaging children in constructing their own narratives and giving children an opportunity to collaborate, play, and reflect on their pretend stories.

5.2 Communicating with visualizations

As the children interacted with their visualization to answer the parent's or researcher's questions during the daily reflection and weekly check in, we observed the different actions made by the children during the study and compared them with the interactions that have been categorized by the literature.

5.2.1 Children communicating insights

We identified the most common interactions that these young children used to derive insights trough the period of the study and categorized them according to the literature:

- **Detail:** The most common interaction among the participants to provide details from their tokens was grabbing the token and physically moving them on the scale to indicate what the token was representing. Other interactions included pointing at a specific token or a location on the scale.

- **Comparison:** To compare tokens and talk about the difference between them, children would grab tokens an put them beside each other to point at the difference or similarities between them. They would also place the tokens on different locations on the scale to show the difference or similarities on the level of emotion that was represented by each token. In the case of P3 and P4 that combined multiple level of emotions in one token, they would count the beads of each colour to indicate the specific level of each type of emotion.

- **Distribution:** In the case of P7 and P8 when they made a reference to the distribution of their tokens during the week, they pointed at a position on the scale and talked about their tokens. P7 said "Lego is always over there, and hand washing is always in there" pointing at the positions on the scale and P8 did the same saying "I did these two and then these" while showing the specific tokens as well.

- **Self-reflection:** As participants were grabbing the tokens and moving them around around the scale to show the level of emotion that they felt during an activity, they would also discuss the reasons why they felt that way. While discussing their reasons at the end of the week, some children would also identify a **trend** in which the same activity always was associated with the same emotion. For P4 it was being extremely happy every time they played with the computer and for P7 it was being happy every time they played with LEGOS.

- **Summary of data:** The most common actions among the participants to provide a summary of their data at the end of the week was to look at their tokens in the containers and identify differences in quantity, colour or shape between each container. P2 and P7 provided summary of how many times they felt happy by counting the tokens.

- **Match mental model:** We observed that often during the daily reflection of the study, children did not need to reference the mapping they had created at the beginning of the week. They would remember the colour they chose to represent a type of emotion or the visual variables they chose during week two and then grab a token and place it in the corresponding place on the scale. However, at the end of the week recalling their choices appeared to be difficult for the children without having any reference even though they cold recall the general concept of their mapping. P4 placed a token in a different point on the scale from the time they talked about it in the daily reflection but they placed the token based on the mapping of quantity of colours they had previously explained.

After analyzing the study data, we found that the descriptions of the categories from the literature do not necessary apply to what young children would do in order to communicate the insights from their visualizations. Overall, the most common interaction for children to get and communicate insights from their visualization is to physically move the tokens around the visualization environment, to point at details and to compare tokens by placing them side by side.

In terms of recalling information from their visualization, children are more likely to provide more detailed information from their tokens the same day they create them than after a period of several days. Especially during the second week where they had more freedom to create their own mappings. We believe that mapping data to their tokens without constrains during the second week is what led to this difficulty of maintaining consistency during the construction of their tokens. Hence, there was no specific reference for them that would have aided them to recall more detailed and accurate information.

In this section we discussed how children used their physicalization process to communicate with other people aspects of themselves. Although we are curious about whether young children could use this experience to explore and discover through their insights, it is unclear whether they were really gaining insights through their physicalizations, or if they were simply communicating things they already known about themselves with their physicalizations. This raises the need to design future studies that could address this challenge more deeply.

5.2.2 Tangible visualization interfaces for young children

After observing how young children interact with their visualization to communicate their insights, we support the idea that in future research it is possible to create tangible visualization interfaces so that young children can learn, communicate and collaborate more easily with others. Such tangible visualization interface could be inspired by ”Magic carpet” [95], an interface that uses pressure mats and video-tracked and barcoded physical props to navigate a story in KidPad a shared 2D A drawing tool that allows children to zoom between drawing elements to bring their stories to life [26]. Stanton et al. reflected on the process and proposed four guidelines for the design of tangible interfaces for the classroom. (1) Make it easy to collaborate by using physical props and physical sizes. (2) Consider how different interfaces emphasize different actions. (3) Understand that superficial design changes can affect physical interactions in very different ways. (4) Instead of focusing on polished products, use open low-tech solutions. These guidelines could be adopted in different contexts such as the home environment.

Culturally, storytelling has been a powerful method to communicate emotions, values, and social skills [38]. To facilitate and complement this process, Wallbaum et al. developed an interactive tangible modular toolkit that enables the re-creation of different narratives using a multi-modal user interface [105]. They see their tangible interactive kit as an approach toward allowing emotion-based storytelling to blend with personal expression and support that tangible, interactive storytelling has the potential to act as a mediating artifact to enhance the already existing practice of storytelling between parents and children.

A qualitative study about data sculptures in an educational context [80], presented over twenty different data sculpture examples and discussed the most remarkable design strategies followed by our undergraduate design students. In addition, the paper described the aspects of physical properties, affordances, interactivity and play, then discussed the value of data sculptures in the current information aesthetics movement as a potential way to engage lay people in understanding complex data insights.

5.3 Visualizing data at home

In this study we saw how children are capable to visualize their own data to communicate findings about themselves outside a school environment. This opens the opportunity to explore collaboration at home using visualization to engage families into exploring or understanding different aspects at home (planning activities, home budget, food, chores, etc.) Involving all members of the family including young children.

Wang et al. explore data edibilization [108], the process of encoding data with edible materials, as a novel approach to leverage multiple sensory channels to convey data stories.

"What Made Me" [41] is a participatory art piece exploring the fundamentals of what shapes us as individuals. Through a visual system that uses colour, line and grid composition, the project invites the participants to answer five simple questions about themselves. A different colored thread represents each question, and relevant words can be connected to answer each question. Throughout the event, a visual data map emerges. Ultimately, the participants become the creators of a colourful art piece.

5.3.1 Constructive visualization for data exploration

Previous work has shown that physical materials such as simple plastic tokens can be used to study non-expert's processes of mapping abstract data to visual constructs [57]. Children are taught numerical concepts using physical objects [114]. Studies show that they use such objects to support offloading cognition, allowing the child to process more information, and to provide conceptual metaphors which help the child understand certain concepts by highlighting parallels between the concept and the objects [74]. Constructive visualization is an approach that is being used to introduce data visualization to non experts [55][56]. Therefore, this approach can be used to involve young children in data exploration.

Thudt et al.'s work [103] explores the constructive paradigm using physical materials in a real-world personal setting, focusing specifically on its potential for supporting self-reflection. Their qualitative study investigates the construction of personal physicalizations in people's domestic environments. It contributes an understanding of the integration of self reflection in the physicalization process.

5.3.2 Encouraging to visualize personal data

Visualizing personal data can be a powerful tool to encourage children to explore their own lives. During this study we were able to see how children identified key aspects about themselves and were able to communicate them to other people.

"Dear Data" [72] is a year-long, analog data drawing project by Giorgia Lupi and Stefanie Posavec, two award-winning information designers living on different sides of the Atlantic. By collecting and hand drawing their personal data and sending it to each other in the form of postcards, they became friends. Same authors also worked on the project "Observe, collect, draw" [73] a visual journal that teaches a general audience how to collect and draw their own personal data. It is a guided diary to learn how to notice and record the minutiae of our lives, and how to use data as a material for our creations.

Studying what students learn with personal data physicalization [83], collecting data about themselves and representing this data in physical forms, students were able to i) learn about data visualization, ii) design creatively; and iii) learn about themselves.

Embedded personal physicalizations [68] have the potential to help people leverage the massive amounts of personal data that they collect in their everyday lives. They offer dynamic, actuated physical representations of data that can help families gain awareness insights, participate in collective decision-making activities, reflect on their behaviors, and change their habits

Thudt et al. [103] outline how the benefits of manual construction, personalization, and presence in everyday life can be transferred to a variety of digital and physical systems.

Chapter 6

Conclusion

In this chapter, We review our research questions and research contributions. We then discuss the limitations of this study and future work to extend this research.

6.1 Research Contributions

In this thesis, We provide three research contributions:

- C1: A description of how young children associate their mappings with their reflections on their data.

  In chapter 5 section 5.2, we discussed how young children communicate the insights from their visualizations after understanding, interpreting and applying their mapping throughout the study discussed in section 5.1.

- C2: A list of interactions young children use to get insights from their visualization.

In chapter 5 section 5.2.1, we described the most common interactions that young children used to derive insights throughout the study.

- C3: A discussion of benefits and challenges of working with young children to study visualization.

  In chapter 5, we discussed the opportunities in future developments to engage young children in data visualization. In chapter 6, section 6.3, We describe the limitations and challenges encountered throughout the study.

These research contributions develop the responses to the research questions that directed the study and our research which is described in this thesis.

6.2 Addressing Research Questions

In chapter 1, we presented our main research question: **How do young children engage in a constructive physicalization process to support understanding of self?** In order to develop a comprehensive answer to this main question, We separated it into four sub-questions. we discuss the responses to these questions as informed by the results and discussion of the home study findings.

Q1: How do young children understand, interpret and apply the concept of mapping?

After introducing young children to a scale to measure their level of emotion, the children quickly picked up the idea that placing more beads in their bracelets meant they were extremely happy or unhappy depending on the colour they chose to represent that emotion. As the children got familiar with the concept of mapping they kept the consistency of their mapping throughout the first week. However, the consistency of their mapping changed throughout the second week as they had more freedom to create their own mapping. Overall, young children were able to understand and interpret the concept of mapping. In terms of applying the mapping, young children are more consistent when they have a specific mapping they can reference to construct their tokens.

Q2: How do young children construct a visualization over time? How do they read and understand their visualization?

While having a constraint and specific reference to map their tokens, young children where consistent with their constructions. After having more range of materials to use to map their emotions on the second week, they started to apply different visual variables from the materials to map and construct their tokens. However, their constructions were less consistent with their mappings. Although the consistency of their mapping changed throughout the study, young children were able to read their visualizations and understand the meaning of their tokens. Over time, participants were able to update their visualizations either by updating their design choices or adding more dimensions to their visualizations.

Q3: How do young children communicate the insights they gained from their visualization?

Our data analysis revealed that the most common interaction for young children to get and communicate insights from their visualization is to physically move tokens around the visualization environment. This is to point out details about their tokens, and to compare tokens side by side. In terms of recalling information from their visualizations, children are more likely to provide more detailed information the same day they create them than a few days later. In particular, when they had more freedom to create their own mappings during the second week.

Q4: How can researchers and designers use young children's existing relationships with personal data and their preferences for data visualization to engage young children in the design of future in-home data visualization?

After analysing young children's existing relationships with personal data and their constructions of data visualization we discussed different approaches that could help engaging young children in the design of future in-home data visualization such as dynamic and tangible visualization interfaces, the use of constructive visualization and the collections and representation of personal data.

Those four sub-questions develop the main question that guided this research: **How do young children engage in a constructive physicalization process to support understanding of self?**

Our exploratory study revealed that young children in our study are active learners who quickly got familiar with the concept of mapping and were able to read and understand their visualization. After having more range of materials to map their tokens, they were able to apply different visual variables from the materials to map and construct their tokens. They were able to update their visualizations over time either by updating their design choices or adding more dimensions to their visualizations. Interacting with their visualizations while communicating with others, the young children in our study were able to understand different aspects of their daily activities and about themselves.

6.3 Limitations and Future Work

In this section we describe the limitations of the study and the challenges of engaging young children in data visualization activities.

6.3.1 Limitations of the study

The study was conducted during the COVID-19 pandemic, starting at the beginning of the year 2020. During this period of time travelling and gathering restrictions were put into place with the purpose of protecting the public health. As a consequence, the planning and execution related to this study was affected and had to adapt thus making it different from other studies like ours. For instance, original plans included traditional recruitment strategies and a workshop format in which participants would be in a controlled environment with the researchers. In person format had the purpose of observing and documenting the study while the participants engaged in the planned activities. However, due to the restrictions placed by the pandemic, our study moved to a remote, virtual and individual format which required researchers to rely on caregivers to document and further provide their observations. Likewise, video calls were necessary to conduct the interviews, as well as the use of other technology-related resources like video recordings, storage in a shared repository with access for the participants and the research team, and digital guides and forms.

Another limitation was recruitment. The initial strategy was to approach places where children gather typically like preschools and community centers; however new strategies were implemented and even though remote participation broaden the reach of the participants, before it was considered only local and later became country wide, recruitment was challenging because we didn't get many responses from our call for participants as we expected. Moreover, two of the participants stopped communicating with us, thus loosing them as participants, and some others required frequent nudging from the research team to keep them engaged. As a result, the study took longer than we had anticipated.

Lastly, time was a variable of limitation as well. The time available from the participants to conduct the study was heavily affected by their personal and particular challenges and changes due the pandemic. Likewise, this created some resistance from the participants to fully engage or even agree to participate in the study. Consequently, data collection from participants was not consistent nor constant. For example, some participants were unable to submit the daily video recordings, instead they submitted written notes. Similarly, most participants did not submit the entire collection of the study data, although we anticipated this behaviour given the circumstances of the study and the pandemic situation.

6.3.2 Engaging young children in future data visualizations

This thesis was motivated by the desire to gain a better understanding of how young children interpret data, construct visualizations and interact with them, and how these interactions affect what they learn, reflect upon, and communicate.

After observing how young children construct and interact with their visualizations to communicate their insights, we believe that future visualization interfaces that would involve children to create their own visualizations can offer a diverse range of visual variables for them to map their data including haptic variables such as resistance, friction, and temperature that can be used to augment visual variables. As we observed that young children can note more dimensions in the context of the data that they are collecting, it is important to also consider creating adaptive visualization interfaces that would allow children to freely update the mapping of their visualization to better communicate the data they are analyzing.

Visualizing personal data can be a powerful tool to encourage children to explore their own lives. Through this study, we observed how children are able to visualize their own data to communicate things about themselves outside of the school setting. This opens the opportunity to explore collaboration at home using visualization to engage families into exploring or understanding different aspects at home (planning activities, home budget, food, chores, etc.) Involving all members of the family including young children. Hence, future research could also consider constructive visualization as an effective approach to introduce data visualization to young children at home in order to engage them in data exploration. This approach can create tangible visualization interfaces so young children can learn, communicate and collaborate more easily with others. Considering the aspects of physical properties, affordances, interactivity and play, of the materials as a potential way to engage lay people in understanding complex data insights.

Future physicalization processes can be rolled out to young children and parents at home trough a handout with detailed instructions and means to contact the researcher in case of doubt. In a more controlled environment, the physicalization process can be introduced with workshops were the parents and the children can actively participate in the process while it is explained and mediated by the team of researchers.

When introducing this approach to children and their parents, it is essential to take into consideration the challenges of working with children in a constructive visualization study listed by Bishop et. al. [7], which takes into account the materials, tasks, and environment of these activities. We should also consider the potential consequences of introducing new habits among children and the possibility of generating a misconstrued interpretation of the process without appropriate guidance that might affect the future relationship between people and data.

6.4 Conclusion

This study was an exploration of how young children are able to understand the concept of mapping data to abstract representations, how they construct visualizations and interact with them, and how these interactions affect what they learn, reflect on, and communicate to others.

We learned that young children are active learners and quickly became familiar with the concept of mapping and were able to read and understand their visualizations. Often, children did not need reference to the mapping they created at the beginning of the week to map their tokens in their visualization environment. With a broader range of materials at their disposal, they were able to use different visual variables from the materials to map and construct their tokens. Over time, they have been able to update their visualizations either by changing their design choices or by adding more dimensions to them. After young children had more freedom to create their mapping, however, we found that it was difficult for them to recall the corresponding position of a token they mapped at the end of a week even though they were able to recall its general concept.

For young children, the most common way to communicate insights gained from their visualizations is to physically move tokens around the visualization environment to illustrate details about their tokens, and to compare tokens side by side. Young children are more likely to provide more detailed information concerning their visualizations on the same day that they create them than a few days later. Particularly during the phase of our study where they were given more freedom to design their own mappings. By interacting with their visualizations while communicating with others, young children were able to gain a deeper understanding of their daily activities and themselves.

From this exploration of physical visualizations constructed by young children we conclude that involving young children in data visualization exercises helps them explore creative ways of communicating and reflecting. We believe that future visualization interfaces can offer a variety of visual variables that children can use to map data, including haptic variables such as resistance, friction, and temperature. As young children can observe more dimensions in the context of the data they are collecting, it is important to provide them with the ability to freely update the mapping of their visualization to better communicate the data they are analyzing. Considering constructive visualization as an effective method of engaging young children in data exploration, future researchers may develop tangible visualization interfaces that will help young children engage in learning, communication, and collaboration more effectively.

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Appendix A

Study Handout

In this appendix a present the Study Handout document that was mailed to each participant with all the instructions to follow throughout the study.

Visualization of everyday data in a family setting - Study Handout

Study overview

Objective:

The purpose of this study is to understand how collecting and representing personal data helps children reflect on their experiences by creating objects (or tokens) that represent their emotions on daily activities, using provided arts and craft material.

Description:

During the study, children and parents/guardians will perform a series of exercises and document the progress in a diary template.

Who is going to participate:

- Children age 4-6
- Parents or guardians

NOTE: This study is designed to be performed by **one child** and his/her family.

What do parents/guardians need for this study:

- Smartphone or any video and audio recording device.
- A device (computer, tablet, phone) with the Zoom video conferencing software installed.
- Internet access.

What will be provided for this study:

- A kit of arts and craft materials
- Several plastic containers
- A Google slide template for the diary

Duration of the study:

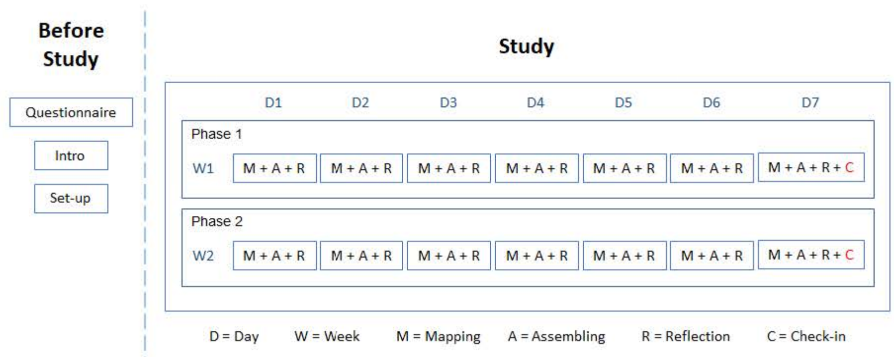
2 Weeks

Figure A.1: Study Handout page 1

Structure of the study:

The table below summarizes the structure of the study.

- D1 to D7 indicate the day of the week (for example, if the study starts on a Wednesday then D1 is Wednesday, D2 is Thursday, etc..)
- W1 stands fo Week 1 and W2 for Week 2
- Each day of each week consists of a series of phases, indicated with the letters M (for Mapping phase), A (for Assembling phase), R (for Reflection phase), and C (for Check-in phase)



1

Figure A.2: Study Handout page 1

Before the study

Before the study begins, as parent/guardian of the child please select **4 activities** that your child performs frequently. **2** from the list on the right and **2** from the list on the left:

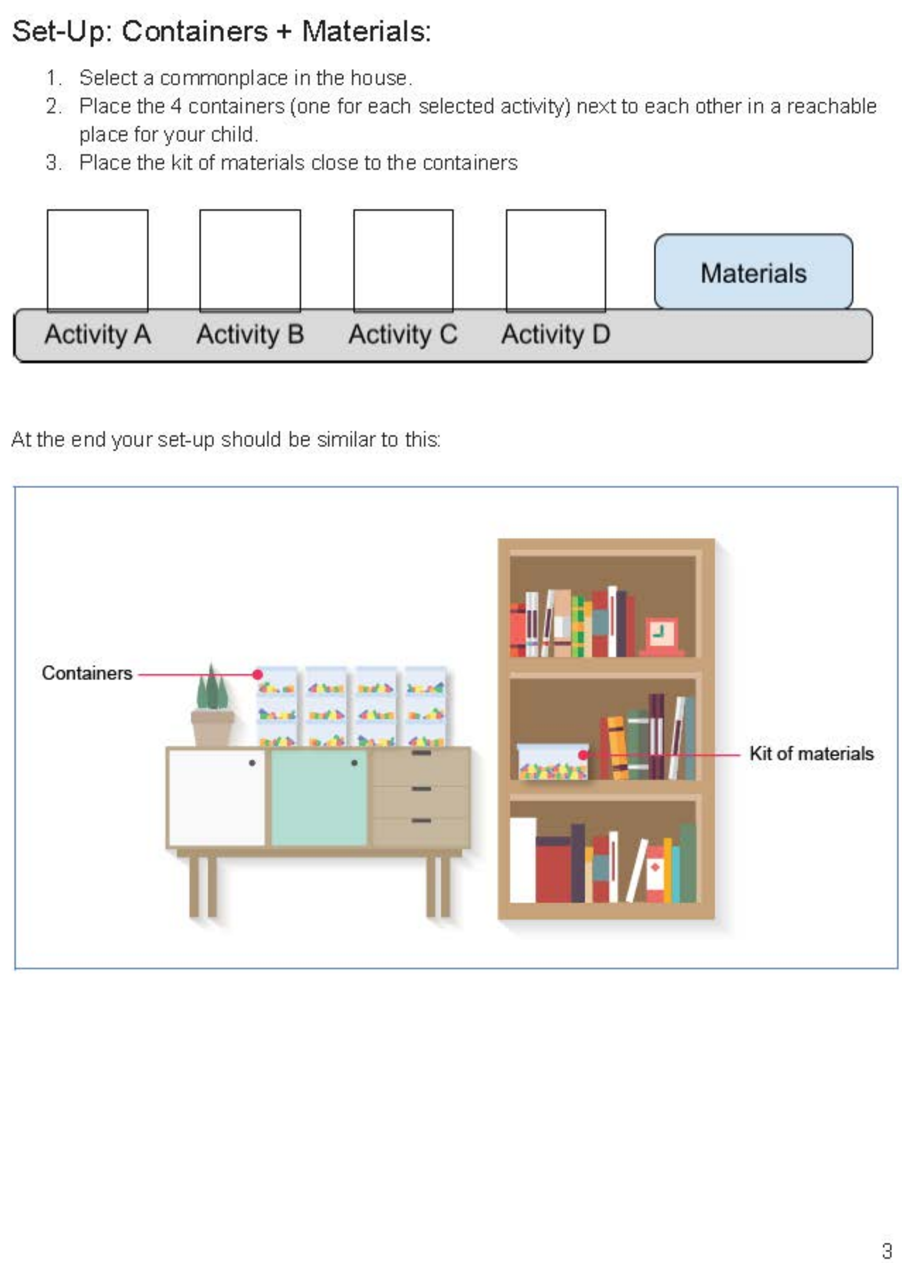
Please select **any two** activities from the list below	Please select **any two** activities from the list below
❏ Reading a book	❏ Brushing teeth
❏ Cooking/baking	❏ Taking a bath
❏ Playing with toys	❏ Washing hands
❏ Playing outdoors	❏ Tidying up a room / put away toys
❏ Playing video games	❏ Taking care of pet
❏ Watching TV and/or online videos	❏ Making the bed
❏ Painting/Drawing	❏ Clearing the table
❏ Doing arts & crafts	❏ Having lunch/dinner
❏ Playing an instrument	❏ Going grocery shopping
❏ Gardening	❏ Other: ______________________
❏ Doing sports / exercises / yoga	
❏ Other: ______________________	

Intro:

Before the study begins we will set a remote meeting (1-hour approximately) with you to walk you through the study and have a short introduction with your child.

2

Figure A.3: Study Handout page 3



Set-Up: Containers + Materials:

1. Select a commonplace in the house.
2. Place the 4 containers (one for each selected activity) next to each other in a reachable place for your child.
3. Place the kit of materials close to the containers

At the end your set-up should be similar to this:

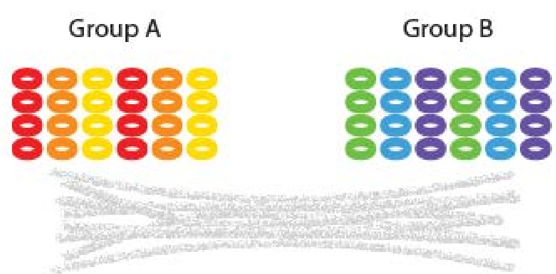
3

Figure A.4: Study Handout page 1

Phase 1: Introduction to Mapping [Week 1]

During Week 1 of the study your child will create a mapping by associating beads to emotions and building tokens (objects) using these beads and fuzzy sticks, that they ill then place in containers.

Kit of Materials: Beads + Fuzzy Sticks



Creating the Mapping [Day 1 - Introduction to the study]

You will go through the following four steps together with the researcher, as part of the introductory session for the study.

- **Step 1: Association of the colour group to the type of emotion**
  Ask your child to choose which group of coloured beads (Group A or Group B) they associate with being "Happy" and which group they associate with being "Not Happy".

- **Step 2: Creating two basic tokens**
  Ask your child to pick a fuzzy stick and thread it through a bead from the group he/she chose to associate with being "Happy". This will be a **token** that represents "Being Happy".

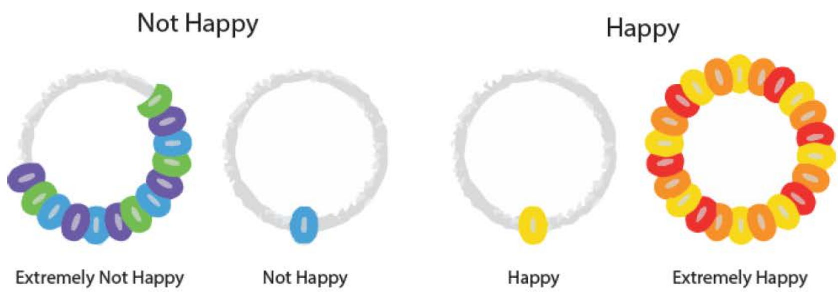
  Do the same for the group he/she chose to associate with being "Not Happy"

- **Step 3: Creating two more tokens based on the level/intensity of the emotion**
  Ask your child to use as many beads from the group of beads associated with being "Happy" as they want, and to thread them through one fuzzy stick to show you what "Being extremely happy" looks like.

4

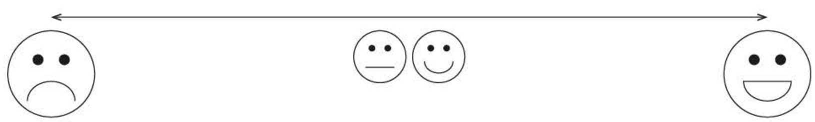
Figure A.5: Study Handout page 5

Do the same to represent "Being extremely not happy", by using as many beads in the group he/she associated with being "Not Happy" as they want and one fuzzy stick.



This image is an example of this exercise and does not mean the child has to do the same.

- **Step 4: Display the Mapping**
  Tape the tokens to the sheet showing the scale of level of happiness in the corresponding order.



Place this mapping in a place visible to your child and close to the containers for each activity, so that he/she can refer to it later during the study.

Figure A.6: Study Handout page 6

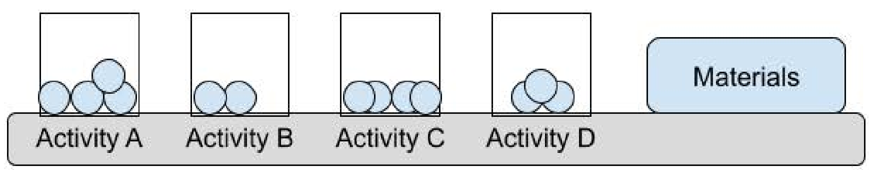
Assembling [Day 1 to Day 7]

Instructions:

Every time your child finishes one of the activities, he/she will create a token that represents how "Happy" or "Not Happy" they felt using the mapping they created as a reference. They will then place this new token in the container corresponding to the activity they just did.

Frequency: The representation can be done any time after the activity is finished and ideally will be done before starting another of the selected activities. If your child does an activity several times a day he/she is encouraged to create one token for each occurence of the activity.

Note that your child is not required to perform all activities every day but it is expected that your child will perform the four activities that were selected frequently during the week.



At the end of the day, take a picture of the containers and fill in the diary template for that day.

Because tokens are added to their corresponding containers daily, the number of tokens in each container will increase progressively.

6

Figure A.7: Study Handout page 7

Daily Reflection [Day 1 to Day 7]

This will be performed at the end of each day of the study.

Instructions:

1. Place the recording device in a place where you can capture both your child and the set-up, and start recording.
2. Ask your child the following questions:
    - Ask your child to show you the tokens they created today.
    - Then ask him/her to show you where on the scale they would place their token based on the emotion this token represents (how happy or not happy). It is a good idea to refer to the sheet with the mapping you created together on Day 1.
    - Finally, ask them to explain the reasons why they placed their token at that specific location on the emotion scale (e.g., why did you put it here [point to token] and not elsewhere?).

    NOTE: In case you speak more than one language at home, please either do the exercise in English or provide a translation in English during the session.
3. Stop recording.
4. Log the video in the shared folder.

Weekly Check-in [Day 7]

Instructions:

This will be performed over a remote 30 minutes session with a researcher via Zoom. You and your child must be present for the session.

1. Place your device/laptop in a place where you can capture both your child and the set-up before the start of the session.
2. The researcher will ask the following questions to your child:
    - Can you tell me which activity you did the most this week?
    - Looking at your jars can you tell me how you felt <doing activity> this week?
    - Pick one of the tokens you created (one at a time if he/she wants to show several tokens); where would you place it on the scale (reference the sheet with the mapping)? Do you remember why you felt that way?
    - Can you take one token from two different activity containers and tell me if the emotions associated with them are different or the same? How do you know?

    NOTE: In case you speak more than one language at home, please either do the exercise in English or provide a translation in English during the session.
3. After these questions, the researcher will have a short interview with you to talk about what happened during the week.

7

Figure A.8: Study Handout page 8

Phase 2: [Week 2]

In the second week of the study, your child will keep creating tokens that represent their emotions when conducting activities, however, now they will be able to use more material and have more freedom in terms of which mappings they will follow.

Kit of materials: (The rest of the container **after removing all fuzzy sticks and beads**)

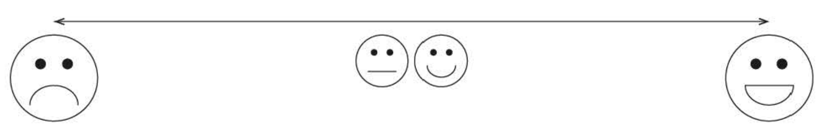
Creating the Mapping [Day 1]

Using the new kit of materials, we are going to repeat the process of Creating the Mapping in Phase 1.

- **Step 1: Creating two basic tokens**
  Ask your child between all the materials in the kit, what would they use to associate with being"Happy" and what would they associate with being "Not Happy"?
  Because they have more freedom in terms of materials to use, this time the tokens can be made using the materials provided in the kit and any other physical material found in-home (such as home supplies) or in nature (such as small marbles and wood chips). A token can be made using a single piece of material, or by combining several as long as these are put together to form a single object.

- **Step 2: Creating two more tokens based on the level/intensity of the emotion**
  Ask your child to use as many materials as they want to show you what "Being extremely happy" looks like. Then repeat the exercise and ask your child to use as many materials as they want to show you what "Being extremely not happy" looks like.

- **Step 3: Display the mapping:**
  Tape the tokens to the sheet showing the scale of level of happiness in the corresponding order.



Place this mapping in a place visible to the child and close to the containers for each activity.

Figure A.9: Study Handout page 9

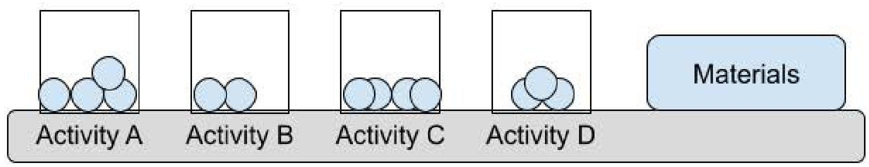
Assembling [Day 1 to 7]

Instructions:

Every time your child finishes one of the activities, he/she will create a token that represents how "Happy" or "Not Happy" they felt using the mapping they created as a reference. They will then place this new token in the container corresponding to the activity they just did.

Frequency: The representation can be done any time after the activity is finished and ideally will be done before starting another of the selected activities. If your child does an activity several times a day he/she is encouraged to create one token for each occurence of the activity.

Note that your child is not required to perform all activities every day but it is expected that your child will perform the four activities that were selected frequently during the week.



At the end of the day, take a picture of the containers and fill in the diary template for that day.

Because tokens are added to their corresponding containers daily, the number of tokens in each container will increase progressively.

Figure A.10: Study Handout page 10

Daily reflection

This will be performed at the end of each day of the study.

Instructions:

1. Place the recording device in a place where you can capture your child and the set-up and start recording.

2. Ask the below questions to your child: (it is fine if they do not answer all questions)
    a. How did you feel today during <activities the child did>?
    b. Can you show me what you created?
    c. Pick one of the tokens you created (one at a time if multiple were created); where would you place it on the scale (reference the sheet with the mapping)? Do you remember why you felt that way?
    d. *Ask questions about comparing some of the objects your child built (ask what applies, by pointing at different objects):*
        i. Why are these two objects similar?
        ii. Why is this one different from the others? What does it mean?
        iii. Why is this <point at token> bigger than this <point at similar token>?
        iv. Why is this <colour>?
        v. Why does this one have <material> different from the previous?

    NOTE: Please be mindful that the research team understands English. We do not require the child to speak English but it helps if you follow their reply with an English translation in the recording
    e. Stop recording.

3. In the slide deck of your diary, type in answers to the following questions:
    a. Did your child do/say anything that you found surprising while building their tokens?
    b. Did your child express any thoughts about representing his/her emotions?
    c. Was your child willing to represent his/her emotions every time?
    d. Additional comments.

4. Log recordings, pictures, answers and comments to the diary template for that day.

NOTE: You will agree with the researcher on a few days that the researcher will virtually join you and your child for the session, to assess progress and answer questions you might have.

Figure A.11: Study Handout page 11

Weekly Check-in

This will be performed once a week on day 7 (D7) over a remote 30 minutes session. You and your child must be present in the session.

Instructions:

1. Place the laptop in a place where you can capture both your child and the set-up before the start of the session.

2. The researcher will ask the following questions to your child:
    a. Can you tell me which activity you did the most this week?
    b. Looking at your jars can you tell me how you felt <doing activity> this week?
    c. Pick one of the tokens you created (one at a time if he/she wants to show several tokens); where would you place it on the scale (reference the sheet with the mapping)? Do you remember why you felt that way?
    d. Can you take one token from two different activity containers and tell me if the emotions associated with them are different or the same? How do you know?
    e. Between what you did last week (using only fuzzy sticks and beads) and what you did this week (using different materials), which one did you prefer? Why?

    NOTE: In case you speak more than one language at home, please either do the exercise in English or provide a translation in English during the session.

3. After these questions, the researcher will have a short interview with you to talk about what happened during the week, and wrap-up the study.

4. After the session, in the slide deck of your diary, answer the following questions:
    a. What are your thoughts about the reflection of your child about his/her week?
    b. What are your thoughts about the process of representing your child's emotions during this week?
    c. Additional comments.

5. Log answers and comments to the diary template.

Figure A.12: Study Handout page 12

Please note the estimated time the participants (child and parent/guardian) will spend during the study:

Task	Estimated Time	Frequency	Participant
Phase 1			
Intro + Creating the Mapping	1-hour	Once	Parent + Child
Assembling	~5 minutes	Every time after completing one activity.	Child
Daily Reflection	~5 minutes	Once every day	Parent + Child
Filling the Diary	~5 minutes	Once every day	Parent
Weekly Check-in	~30 minutes	Once	Parent + Child
Phase 2			
Creating the Mapping	~30 minutes	Once	Parent + Child
Assembling	~10 minutes	Every time after completing one activity.	Child
Daily Reflection	~5 minutes	Once every day	Parent + Child
Filling the Diary	~5 minutes	Once every day	Parent
Weekly Check-in	~30 minutes	Once	Parent + Child

12

Figure A.13: Study Handout page 13