Challenges of Running Constructive Visualization Studies with Children

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Figure 1: Children participating in the study at a table, with tokens, pencils and rulers set to the side and a paper canvas to work on.

Abstract
Previous work has shown that physical materials such as simple plastic tokens can be used to study novices' rich and diverse processes of mapping abstract data to visual constructs [e.g. 2] which, in turn, can shed light onto sense-making processes and inform the design of visualization tools. Our research focuses on exploring children's approaches to visual mapping of abstract data. We have run a constructive vis study where we observed 7-11 year olds construct visualizations using physical tokens. While this study brought forth interesting findings, we also came across several methodological challenges related to the choice of data, study tasks, choice of material, and the study environment. We discuss how we approached these challenges in our study design and the questions this raises in the areas of pedagogy and physicalization.

Author Keywords
Constructive visualization; Data Physicalization; Visualization authoring; Visualization construction; Novices; Children.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Figure 2: A range of visualizations created by children from highly pictorial(top) to highly abstract(bottom)

Introduction

Data visualization can facilitate sense-making processes and problem solving. Recent work has investigated how novices engage in visual mapping processes as part of sense-making to better understand (1) the process itself and (2) how to facilitate it through visualization tools [2,3]. The simplicity of physical tokens features and use, and their flexibility, make them suitable for studies with visualization novices, as has been seen with previous studies applying the constructive visualization approach [1,2,7].

It is no coincident that children are taught numerical concepts using physical objects [7]. 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 surrogate objects [4]. However, apart from such studies on using tangible tokens to facilitate math education, we know surprisingly little about how children use visual representations as part of sense-making and problem solving. At a time where children are introduced to the concept of abstract data and even visualization tools such as Excel at an early age, this is a problem.

We have started to investigate children's visual mapping processes following a constructive vis approach using physical tokens. While we found physical tokens to be a suitable medium for rapidly engaging children into such vis construction tasks, running such studies with children is a challenge, and attention must be put on the choice of vis material, data, the study task and the study environment. Much more than in studies with adults these choices influence child participants' interpretation of and engagement in the tasks, which can influence study outcomes. We describe our experiences running a constructive vis study using physical tokens with children, and discuss how we approached methodological challenges and the questions these raise in this young research area.

Studying Children's Vis Construction

We conducted a study with 22 children aged 7-11 (11 female, 11 male). Study sessions were run at local after-school clubs with two children at a time to help them feel at ease, though they worked individually as we were interested in their personal approaches (see Fig. 1). Children were provided physical tokens in four different shapes and colors and a dataset to visualize (we chose relatable data, one set about pizza deliveries; one about trains). To motivate the activity, we told children a story about the data and said it was to be visualized using the tokens to communicate it to a younger child. The data was presented in a tabular form, a format familiar to children of this age. Datasets included quantitative, binary and categorical attributes. Once children had finished we asked them to explain their visualizations.

Methodological Challenges

When designing the above study, we encountered several methodological challenges. Below we discuss these challenges, how they manifested themselves in our study outcomes, and the questions they raise.

Vis Materials. Following the lead of previous constructive visualization studies [2] we decided to use physical tokens in our study as these allow the flexible creation of visual constructs without requiring prior knowledge (in comparison to current vis tools, that have not been designed with children in mind) or specific skills (in comparison to sketching). We also considered playdough

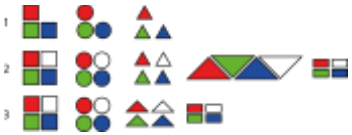

Figure 3: Revisions of the set of tokens to be used over time.

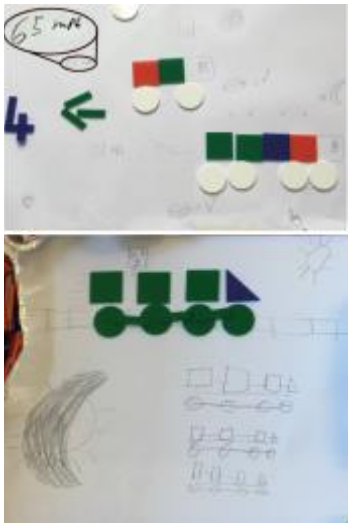

Figure 4: Pencil markings made by children ranging from numerical to pictorial.

for its flexibility, but, pilots showed that it encouraged highly playful behaviors (e.g. "baking" pizzas) leading away from the visualization activity. When designing a suitable token set we had to balance the number of colors and shapes to allow for flexibility while not overwhelming the children with too many choices. We went through three iterations (see Fig. 3) and tested different token sets with a group of adults first and only then with children to spare them frustrations due to basic usability issues [4]. For flexibility, we provided pencils for children to annotate their token constructions.

The resulting visualizations were surprisingly detailed and varied given the limited token set, and span a continuum of abstract visual representations and data-driven pictorial constructs (see Fig. 2, 4 & 5). Children rated the handling of tokens as easy. However, also due to the tediousness of working with the tokens, some children, especially those with the more elaborate pictorial visualizations decided not to represent the entire data set. Further vis studies with children should investigate the use of other materials (e.g., lego, pencil & paper, and playdough) to see how these influence children's mapping processes, their engagement and visualization outcomes.

Data. W we tried to provide a relatable data topic to children while still including a variety of attribute types. However, the data topic may have influenced the character of children's visualizations: 5/8 children who used the pizza dataset created more pictorial visualizations, compared to 6/14 children using the train dataset. Children working with the pizza data often remarked at the similarity of tokens to pizza toppings, for example, the red circle tokens similarity to pepperoni toppings. The ease with which children could find such visual parallels between data and tokens may have influenced their visual mapping process. The tabular presentation of the data may also have affected children's visual representations. In 5/11 cases, the more abstract token-based visualizations followed a table layout (see Fig.4, bottom). Lastly, the data types influenced the form of children's token-based visualizations. All children found creative ways of using the abstract visuals given by the tokens, e.g., showing the number of train carriages. However, we found that children frequently turned toward literary visuals (e.g. iconic pictures or digits) to represent more abstract data that is not directly visible in the real world (e.g. time and speed; see Fig.4. top left).

Three aspects require further investigation: 1) How do parallels between real-world concepts inherent in the data and the vis materials influence children's visual mappings? 2) How does a (tabular) data presentation influence children's constructed visualizations? and 3) How to guide the visualization of more abstract attribute types (e.g., temporal data or relations)?

Task. We deliberately chose to provide children an open-ended task, without specific questions to answer through their visualization. We wanted to see if they would come up with their own questions and focus their visualizations around these. While all children provided a general overview of the dataset (some included less data points than others), and could point out min and max values within their visualization, children did not think of "slicing and dicing" the data: none of them juxtaposed attributes to answer specific questions. Future vis studies with children should investigate how children's vis construction differs if given more targeted tasks, and how we can provide prompts to encourage children to interrogate the data in more versatile ways.

Environment. It turned out that when running studies with children, the study environment is crucial. After-school clubs encourage free-form and playful activities, and our child participants were in a playful mindset when creating their token-based visualizations. They could also hear and see their peers doing other things

Figure 5: Further visualizations created by children from highly abstract(top) to highly pictorial (bottom)

outside which provided some distraction. Running the same study in a classroom environment may have influenced children's exploration of the data and, ultimately, their construction of the visualizations. Study tasks should be constructed to fit with the environment they are presented in, preferably by working closely with staff members. We are currently exploring vis activities in more focused classroom environments, also investigating how to run vis construction tasks with larger groups of children.

Eliciting Reflections. We ran sessions with two children at a time to try and create a setup where children would reflect on their vis construction process through discussion. However, during activities, few discussions occurred. While children would readily answer questions about their design choices and, when asked, explain their visualizations to each other, it was difficult to get them to reflect on their visual mapping process. Indeed, even for adults, it can be difficult to reflect on internal processes if the task is quite novel. We need to further investigate methods (e.g., through think aloud) to initiate discussion and reflection among children during and after the vis process.

Conclusion

The area of vis for young audiences is still quite young. We have found constructive vis approaches using physical tokens to be a promising way to investigating how children visually map abstract data, potentially informing the design of visualization tools for children. The physical tokens allowed children to construct visualizations with ease while providing room for creativity. However, on a methodological level we encountered several challenges mainly regarding the choice of vis material and data, the nature of the visualization task, and the study environment. Our paper is an early reflection on how choices along these dimensions may change children's visual mapping and outcomes. Based on this we hope to stimulate a debate on how to engage children into visualization activities - for research, pedagogical purposes and beyond.

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