Customizing Developmentally Situated Design (DSD) Cards: Informing Designers about Preschoolers' Spatial Learning

Gökçe Elif Baykal
Design, Technology and Society
Koç University, Istanbul, Turkey
gbaykal13@ku.edu.tr

Tilbe Göksun
Department of Psychology
Koç University, Istanbul, Turkey
tgoksun@ku.edu.tr

Asım Evren Yantaç
Arçelik Research Center for Creative Industries
Koç University, Istanbul, Turkey
eyantac@ku.edu.tr

ABSTRACT

To date, developmental needs and abilities of children under 4 years old have been insufficiently taken into account at the early stages of technology design. Bekker and Antle [6] created developmentally situated design (DSD) cards as a design tool to inform children's technology designers about children's development starting from 5 years of age. In this paper, we describe how we customized DSD cards for a specific developmental skill (i.e., spatial learning) of children between 2- and 4-year-olds for tangible interaction design. The cards were evaluated after a user study in which 19 participants from different backgrounds used the cards in three design workshops. Our analysis of observational notes and online survey identify and discuss how specific card features support or limit use by our participants. We draw on our findings to set forth design considerations and possible refinements that make age specific knowledge about very young children's spatial learning to inform technologies based on tangible interaction.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; D.2.2 [Design Tools and Techniques]: Object-oriented design methods.

Author Keywords

Design tools; design methods; child development; child-computer interaction.

INTRODUCTION

This paper describes the customization of a card-based design tool to support interdisciplinary design team in taking into account very young children's spatial abilities and skills during the early design stage of a tangible system for learning. It has long been highlighted in design approaches such as participatory design [25] and child-centered design [13, 10] that, in early design, designers should involve children as participants of a design process or they need to use analytical methods and tools to elicit evidence-based knowledge about children's abilities and needs to inform the design [6].

When it comes to designing with and for children younger than 4 years old there are only a few methods or tools found in the child-computer interaction (CCI) field that involve these very young people to inform interaction design choices [16, 21, 19]. It is mostly very difficult to elicit verbal feedback from this age group to inform the design [16]. In CCI, informing age-appropriate technologies responsive to very young children's learning process remains as a wicked design space. Despite the challenges, techniques such as Wizard of Oz [21], or hands-on tools such as intervention with manipulatives [21, 5, 4] began to be adapted to observe on-task behaviors of children under 4 years old. Still, those studies reported that even 4-year-old children have difficulty in involving participatory techniques such as using drawing [4], Fictional Inquiry or Comicboarding [18] to generate and communicate a design idea, or Wizard of Oz to finish the tasks which need precise toy movements [21]. There is also a wealth of emerging theoretical knowledge about the early cognitive developmental abilities and skills of the intended age group. Then, how can we make this age specific knowledge in cognitive developmental studies readily accessible to designers?

Based on a similar quest, Bekker and Antle [6] created Developmentally Situated Design (DSD) cards that make information about children's developmental stages, ages, and abilities available throughout the design process [6]. Other studies also evaluated card-based design tools and reported their usefulness in particular at early design stage [9, 12, 7]. Still, none of these approaches have focused on delivering knowledge about the developmental abilities of children younger than 4 years old. By targeting this age group, this study contributes to the evaluation and further development of the DSD cards to be applied in wicked design problems. The contribution of this paper consists in the customization of the content of DSD cards relying on; (1) incorporating the literature review in a specific learning domain in cognitive development field (i.e., spatial learning), which is found critical in particular between 2 and 4 years old [20], along with (2) supporting the content with concrete examples and empirical results elicited from our observational case study which we have conducted with 2- to 4-year-old children to gain in-depth insight into their spa-

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tial skills (i.e., mental rotation skills) and ability levels while interacting with tangibles (i.e., tangram and Froebel Gifts).

In this paper, we present the customized design of DSD cards, which are a set of 32 cards (4 developmental concepts on spatial learning x 4 learning processes x 2 age segments). We evaluated cards after three user studies in which 19 researchers and practitioners with different backgrounds (i.e., developmental psychology, interaction design, industrial design, game design, and children's media) used the cards for brainstorming, idea generation and constraining the design idea of a prospective tangible system for spatial learning. We also present suggestions for customized design of the DSD cards, and a discussion of strengths and weaknesses of our approach.

BACKGROUND AND RELATED WORK

This study is derived from the need for translating early spatial learning theories and our case study findings to the interdisciplinary design team of a tangible learning game. As part of a larger project, this paper is built on card-based design tools, suggested to bridge between theory in child development and practices in interaction design for children. In this section, we focus mainly on the customization of the DSD cards along with a brief background information about early spatial learning and child-tangible interaction (CTI) for early learning.

Developmentally Situated Design (DSD) Cards

Cards are one form of design approaches to make academic or conceptual knowledge accurately and concisely presented to designers [6, 9]. Based on Antle's [1] attempt to inform design through creating child-personas in the absence of children in the design process, Bekker and Antle [6] carried this approach a step forward and developed the DSD card tool to provide an easy compilation of child development knowledge for designers.The DSD cards contain age specific information (including three age periods; 5-6, 7-9, 10-12) about children's development in four domains (cognitive, social, emotional, and physical). The cards support designers in creating child personas and design concepts. The DSD cards are effective in providing easy access to theoretical knowledge; enabling to search or browse information related to the design goal or the target age group; using at different stages of design (e.g., brainstorming, inspiration and idea generation) [6]. (The original cards are available at www.antle.iat.sfu.ca/DSD)

The DSD cards inspired development of other card-based design tools such as *Tango Cards*, making design knowledge about tangible learning games accessible to designers [9]. Furthermore, the DSD cards were incorporated into lectures for teaching how to design for children to interaction design students who have no knowledge about child development [12, 7].

Early Spatial Learning

Spatial learning and thinking skills at early years are essential for a variety of everyday tasks, such as packing a toy box, cutting equal slices of cake for a group of people, or remembering where an object is by cue learning [26]. Longitudinal studies showed that early spatial experiences have significant impact on school readiness and child's further STEAM (science, technology, engineering, arts and mathematics) skills [26].

There is evidence that children's early interactions with manipulatives such as block building activities, shape games, and playing with puzzles facilitate *mental rotation* skills (i.e., imagining the change in orientation or direction of objects in mind) [27]. Children who play with puzzles more between 2 and 4 years have better spatial transformation ability than their peers when they are 4.5-years-old [20]. Thus, mental rotation skills in spatial learning are malleable and durable if they are trained before 4 years of age [26].

Employing various spatial tools such as *gesture* (e.g., pointing) [11] and *narrative* (e.g., storytelling) [8] has a scaffolding effect on spatial visualization, construction and rotation skills when incorporated into the block building activities. Moreover, guided-play has an effective role for promoting early spatial learning when compared to free play or didactic play activities with tangible objects [14]. Theories and suggested tools for early spatial learning given here can provide a useful framework for informing tangible interaction design choices to leverage young children's spatial learning activities with manipulatives.

Child-Tangible Interaction (CTI) for Learning

CTI as a framework introduced by Antle [1] in child-computer interaction field points out that tangible interaction combining physical and digital platforms together have a great potential for enhancing young children's learning [23, 22], and cognitive development [2], especially because it enables embodied and spatial interaction more than other interfaces [2]. The types of tangible user interfaces that are suggested for young children's learning blend the advantages of physical objects with digital affordances [23]. Thus, these tangible interactions were basically inspired by block building activities [24, 28]. Moreover, integrating narrative and gesture are defined as typical learning domains that tangible user interfaces might enhance [22]. Still, spatial problem solving which relates to hands-on action, manipulation, and rotation skills is defined as one of the knowledge gaps in CTI research [1, 2, 19]. These tools also need to be explored for facilitating very young children's early spatial learning. A detailed review about the tangible interaction systems that blend the advantages of physical and digital worlds that might serve children's spatial learning will be presented in another study. Based on the complementary nature of CTI framework in child-computer interaction and spatial learning concepts and tools in cognitive developmental studies, here we present how we customized the content of the DSD cards regarding our wicked design problem.

PROBLEM STATEMENT: CUSTOMIZATION OF THE DSD CARDS

Our goal for customizing DSD cards was to deliver knowledge about early spatial learning as a domain in cognitive development and translate the results of our case study to the participants of our user studies. We customized DSD cards that could be used to easily inform designers about mental

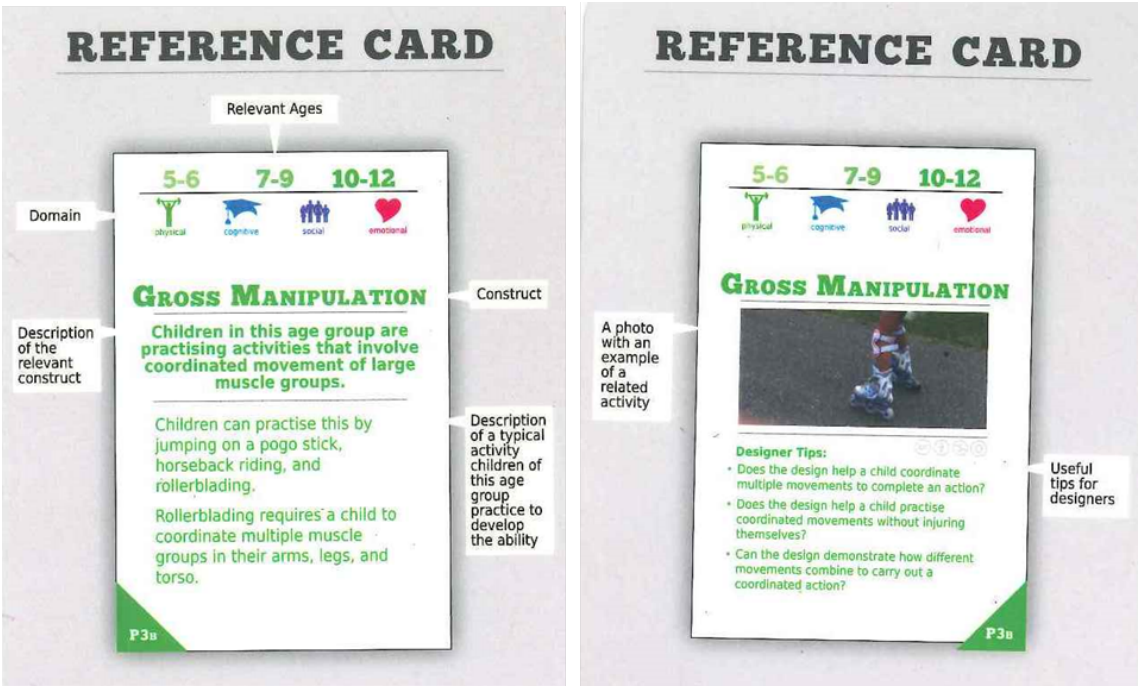


Figure 1. Reference to the original DSD cards created by Bekker and Antle, 2013.

rotation skills and ability levels of children between 2 and 4 years old. We also included spatial tools (i.e., gesture, narrative, guided-play) and intervention techniques (i.e., block building activities, preschool embedded figure test) found in cognitive developmental research. These tools and techniques that facilitate mental rotation skills of very young children are included to provide inspiration for a tangible learning game.

Given that design methods and techniques in CTI for early learning are yet to be developed, the target users of the DSD cards that we have customized for were the design team members with different expertise (i.e., developmental psychology, interaction design, industrial design, game design, and children's media) who came together to work on a tangible interaction design solution. However, we customized DSD cards with possible future target users (e.g., practitioners, parents) in mind.

Customized DSD Card Design

One of the authors in this paper first used the original DSD cards when participated at the "Designing Tangibles for Children: One Day Hands-On Workshop" at Interaction Design and Children Conference (IDC'16) organized by [3]. Then we conducted a literature review of research about design cards including works used DSD cards as a tool [9, 12, 7, 17]. Although we customized the content, we kept the main design rationale of the DSD card template created by Bekker and Antle including size and layout (see Figure 1). Our final customized design was a set of 32 cards (4 developmental concepts on spatial learning x 4 learning processes x 2 age segments). A PDF copy can be downloaded from https://happern.ku.edu.tr/tangible-interactions-for-early-spatial-learning/

Developing Card Content

As being said, our priority to customize the DSD cards was to inform our participants about early spatial learning (i.e., mental rotation) and to translate our results of our case study. Building on design considerations presented in the previous work [6, 9] we have customized the DSD cards by following their suggestions. To include appropriate amount of information we excluded the topics that are not directly related to development of spatial skills. The topics that are addressed by in the original card set included cognitive, emotional, social, physical development of children. Since our design goal focuses on spatial skills as a specific domain in cognitive development, we elaborated the concepts in this specific domain knowledge (i.e., mental rotation). Thus, we first began customizing the topics in the cards by tailoring the theoretical concepts related to spatial skills (i.e., mental rotation) along with the scaffolding intervention tools (i.e., narrative, gesture, guided-play) for this particular skill. To make searching and browsing the information easier we modified the icons as visual identifiers for each concept. We compiled these concepts as the main topics of our customized card set (see Figure 2).

In order to implement a clear information architecture supported through relevant tips and concise examples, we translated the findings of the case study we have conducted with children prior to this study. The aim of our case study was to gain in-depth insight into children's mental rotation skills when interacting with tangibles (i.e., tangram and Froebel Gifts) in a guided-play context provided with a story [x]. We recruited 14 parent-child (children between 26-and 43-months of age) and observed children's on-task behaviors along with the gesture and narrative feedback they required from their

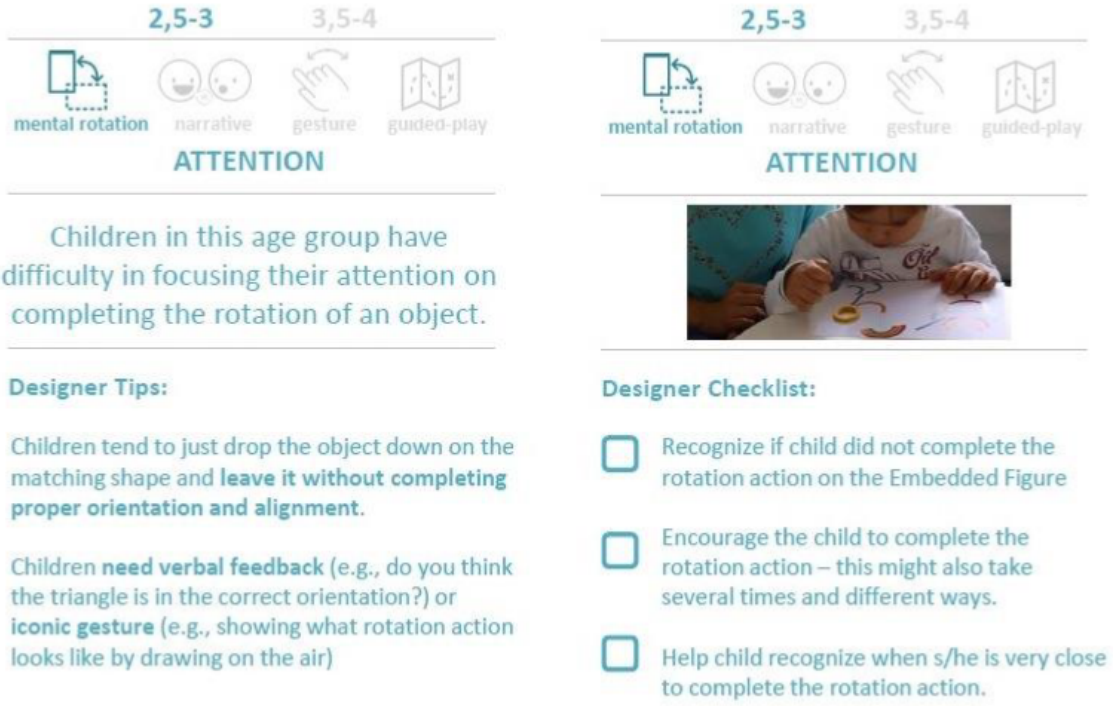


Figure 2. A customized DSD card. Front (on the left) and back (on the right) side.

parents to solve the mental-rotation tasks embedded into the stories. Our results showed that children between 26 and 34 months old required more time, gesture and narrative input from the parent whereas the children older than 34 months old did not have any difficulty on-task. Thus, we developed the card content relevant to two age segments; according to age specific abilities and needs of 2.5-3 and 3.5-4 year olds as two groups.

In the original DSD cards, the topics were framed and described with headers (see Figure 1). For instance the headers in cognitive development were Attention, Problem Solving, Information Processing, and Instructions. We kept these headers in our customized cards to categorize, define and describe our findings retrieved from our case study. We also provided picture examples from our case study that were relevant to the topic and the header on each card. We also kept the sub-header titled *Design Tips* in the original set and customized the information under this section based on the literature review and our case study. In addition, to assure a more clear information architecture we included a new sub-header. We titled this section *Designer Check-list* in which reminding prospects were presented. Another distinctive element in our customized cards was the bold-written keywords highlighted in the sentences (see Figure 2). By including these distinguishing visual elements we aimed to support the ease of access to knowledge in the cards. The cards were useful to translate the results of our case study concisely and adequately to our interdisciplinary design workshop participants. In the next section, we describe the methods we used to present the customized DSD cards to our participants.

METHOD

To test and evaluate the customized DSD cards, we first conducted user studies through workshops and then an online survey with the workshop participants. For user studies, we invited practitioners and researchers from different backgrounds. Then, for evaluation of the cards, we conducted an online post-workshop survey with the participants. Here, the procedure and materials of the user studies and online post-workshop survey are described.

Participants

We wanted to recruit participants with knowledge in different fields; psychology (i.e., cognitive and developmental psychology), design (i.e., interaction, industrial, UX, game), and experience in children's media industry (e.g., television, children's books) and early childhood education. Along with personal invitations we made an open call for the workshop. We also wanted to invite people who have tangible interaction design experience in particular, however we were unable to find someone. In total, 19 experts (18 females and 1 male) volunteered to participate in the workshops (e.g., 2 interaction designers, 3 industrial designers, 3 UX designers, 2 game designers, 1 computer engineer, 2 children's media professionals, 2 CG artists, 1 scriptwriter, and 3 researchers in cognitive development). Our recruitment priority was to balance participants' background knowledge (10 designers and 9 non-designers), so we did not seek for a gender balance in participation. Every participant were invited to all workshops, however only 3 participants could attend them all. Still, in every workshop at least 7 and at most 12 people participated. So that, in every

team work at least two people from different fields of experience have collaborated. We shared the post-workshop online survey with all 19 participants after three workshops were completed. Sixteen participants filled out the online survey until the deadline.

Procedure

We conducted user studies in three whole-day workshops. The workshops took place at a collaborative working space. One of the authors of this paper facilitated the workshops. The aim of the user studies was twofold: (1) to generate ideas for a tangible interaction design to support very young children's mental rotation abilities and develop a design brief for a future prototype; (2) to improve our customization of the DSD cards as a design tool and use them in the further workshops with game designers. In this paper, we only focus on describing the procedure for the use and evaluation of the customized DSD cards. The DSD cards were used in the workshops in three levels of design:

- 1st Day: Brainstorming and inspiration;
- 2nd Day: Concept development and idea generation through a persona;
- 3rd Day: Constraining and detailing the design idea.

In every workshop we first began introducing and presenting the DSD cards (see Figure 1) along with a 10-minute introduction to spatial skills of young children and examples of tangible user interfaces for learning to the participants in case someone new joins to the workshop. Another reason for a short introduction is because previous work emphasized that [9] a certain level of knowledge about the domain specific concepts is necessary for designers to use the cards effectively. The brief information about the DSD cards included how designers can make use of the content of the cards [i.e., (1) headers - mental rotation, storytelling, gesture and guided-play; (2) subheaders - attention, problem solving, instructions, information processing; (3) Designer Tips and (4) Designer Checklist] to inform about children's age specific spatial skills and abilities (see Figure 1). The participants had the hard copies of card sets throughout the whole workshop.

The participants divided into groups. In each group, we ensured that there were at least two people from different backgrounds collaborated as a team. We assigned each team a task for a target age (i.e., 2.5-3 or 3.5-4 year olds). We provided teams the set of cards relevant to their target age. As a workshop structure we employed "opening and closing" as a method used in gamestorming [15] to orchestrate between the three levels of design in the workshops. By doing so, we prepared tasks to be completed, discussed and presented in half a day. The output of each task preceded and prepared the next step. In other words, the work presented by each team in every half day established the frame of reference for the subsequent session's design task. For example, the output of the brainstorming sessions in the 1st day has set the context of the persona created in the 2nd day for concept development and idea generation. In turn, the output of the ideation activities in the 2nd day has laid out the themes and design ideas



Figure 3. The customized DSD cards being used by member of our interdisciplinary design team.

that were elaborated in the 3rd day. This method helped us in two ways: First, no matter if a participant has joined or left the workshop at some point, the tasks could be carried out sufficiently by the team members in the next session. Second, the DSD cards could be used at different levels of the design process throughout the whole workshops.

Data Collection and Analysis

We captured video and audio recordings while the teams were presenting their work to each other. At the end of each presentation, the participants were asked to discuss the usefulness of the customized DSD cards orally and indicate areas for improvement. We also took observational notes during the design sessions, presentations and discussions. With the help of the video and audio recordings, and handwritten notes, we prepared an online post-design questionnaire to understand how the participants used the DSD cards in their interdisciplinary design process. While preparing our questionnaire, we also used findings and design considerations pointed in previous research [6, 9] to provide evidence of themes reported on card use. We used Qualtrics as an online platform to create and distribute our survey, and to collect and analyze individual responses of the participants. Fifteen closed and 1 open-ended questions were asked to extract information about support and limitations of; 1) the design, 2) the content, and 3) the use of the customized DSD cards along with participants' suggestions for improvements. The qualitative analysis of data from post-design online survey and observational notes supported the validity of our methods. The descriptive statistics of the data extracted from online survey were analyzed and presented with the observational notes taken during the workshops.

RESULTS

In the survey, participants were first asked about their prior experience with the intended age group. Half of the 16 respondents of our survey informed that they had prior experience with children between 2 and 4 years old either in their professional or personal environments, whereas the other half informed that they had not. When it comes to the familiarity with the concepts in the domain knowledge of spatial skills the

majority of the respondents (11/16) of the post-workshop survey defined themselves being familiar with the subject prior to the workshop. However, this result contradicts with our workshop observations. During the workshop none of the participants indicated knowing the concepts and theories before and they were glad to be informed. This might be linked with the informative effect of the cards. Participants were also asked to rate the use of DSDcards on a Likert scale. All of the respondents found the customized DSD cards useful as a design tool (9/16 respondents found highly useful and 7/16 found moderately useful). Most of the participants (11/16 respondents) found the information in the cards easy to understand, whereas some of them (5/16 respondents) found the information a little detailed and complex to understand.

In addition, participants were asked to evaluate how they used the cards in their design activities. The questions included how they found different elements of information in the content and the design of the cards. They were asked to rank the given elements from the strongest to the weakest. Here, we first present the results for the general use of the cards in the design process, and than present the evaluations for the content and the design features of the cards.

The Card Use

To understand the purpose of using the cards during the design process we first asked participants to rank their intentions for using the cards from most to least, with (1) being intended most. The online survey results showed that the cards were mostly used to (1) get informed about, (2) validate or confirm, (3) reminded about the spatial skills and ability levels of children. In our observational notes, one of the design teams also informed that they applied the cards when the team members had a conflicting idea about a design solution.

To evaluate the design activities that the cards were mostly employed, we asked participants to rank the phases of design in which the DSD cards were applied most, with (1) being employed most: (1) during the inspiration gathering, brainstorming and kick off to brainstorming; (2) after brainstorming, while generating a design idea; equally when being decided to switch a design idea; (3) while elaborating on and detailing a design idea.

To describe the way how the design teams have used the cards throughout the whole design work, we asked the participants to select a definition that explained best for their overall card use. The responses showed that, with (1) being most likely selected, (1) they first carefully familiarized with the cards, quickly read through all the cards, then browsed and picked out the card that contains information that they are looking for; (2) they first read carefully all the information in detail in the cards, they sorted and grouped the cards to outline their design rationale, they used all the cards throughout the whole design work; (3) they skimmed and scanned through the information roughly, and this information have been enough for them throughout their design work. Next, we present the evaluations for the content information in the cards that supported and limited the card use.

The Content

The content of the cards were evaluated according to the informative elements displayed in Figures 1 and 2, and described under *Developing Card Content*: subsection above. We asked the participants to rank or select the information type that they found the most or least useful in the content of the cards. The survey data revealed the following information about the content.

Among all informative elements *textual examples* and *bold-written keywords* were found more helpful to get familiar and informed about the concepts as well as serving as a quick reminder whenever needed. The respondents also noted that *textual examples* retrieved from the case studies were more useful than the *descriptions* under the *Design Tips* for participants to understand the domain specific concepts and the spatial thinking skills and ability levels of very young children. We observed that participants used *bold-written keywords* as a guide to develop design ideas, whereas the *textual examples* were mostly used to formatively evaluate the design ideas. Furthermore, descriptions in long sentences were also found hard to skim and scan the information. *Bold-written keywords* were again found to be more useful than the *descriptions*, in the sense that they help to distinguish and retrieve a particular card that includes a concept that had been realized or discussed before.

According to the responses, the hierarchy of the information and the wordy descriptions are the features that need to be further improved to aid the understanding of the content. For sorting or grouping the cards, participants mostly used the *Titles*. It was followed by the *Bold-written keywords* and *Designer Check-list*. The information architecture has also links with the design features of the card. The results for the evaluation of the design elements are presented below.

The Design

The design elements of the cards that were evaluated included the tangibility, two-sided use, font size, color coding, use of the picture examples and icons. The results for evaluations of the card design occurred in the participants' spontaneous speeches or behaviors during the workshop or as an additional suggestion for improvement defined in the online survey.

Most of the participants mentioned the usefulness of the physicality of the cards, which enables grabbing, pointing, sorting, or grouping. The blank bullet point signs next to the *Designer Check-list* also reinforced the use of physicality of the cards as a reference. Some participants filled the blanks to show if they could find a solution for that particular design problem. However, one of the key suggestions for design was the difficulty of keeping track of the information in both sides of a card at a time. The participants mentioned the adversity in browsing or processing an information on the front side while trying to keep an eye on the *Designer Checklist* relevant to their design problem. Participants also noted that the number of cards (16 cards for one age segment) was too much as another challenge against information processing. A common suggestion was to reduce the number of cards as well as the amount of information within a card. Participants emphasized that they would prefer bold and punchy keywords with larger font size

which would help to capture the information during a fast-paced ideation. We now discuss the results about the strengths and weaknesses needs to be taken further consideration.

DISCUSSION

Based on our study findings together with our participants' implications for improvement we suggest several considerations for the customization of the DSD cards. We believe these considerations will contribute to further improvements for customizing the DSD cards to inform children's technology designer and support their use with more effective design flow.

The survey results showed that the participants used the cards to get informed in early fuzzy stages of a design activity more than to validate and remind about the concepts in the later stages. As a result, there are two main issues to be considered: 1) to improve the information processing of the card content, and 2) to reinforce and facilitate the card use at different stages of a design activity.

Insights for the Information Processing of the Cards

In parallel to the previous research [9, 7], our results showed that extraction and simplification of the theoretical and academic knowledge is one of the key elements that needs to be considered in order to support the information processing in the cards. Based on our observations and as spontaneously remarked by our participants during the workshops, the concrete examples about age specific skills that we have extracted from our case study has been more useful to aid the understanding of the information than descriptions. Thus, conducting a case study with the intended age group feeds the content in various ways; provides real life examples for skills and ability levels of children, valuable insights about unexpected on-task behaviors of children to be implemented into the *Designer Tips*, inspiration about ways to tailor suggested tools or intervention techniques into the design implementation.

Another issue regarding the simplification of the content is the participants' familiarity with the information given in the content. For instance, unfamiliarity with the concepts about spatial skills made designers' use the cards less. For example, P11 with interaction design background said that *"if we have a psychologist in the team we preferred to ask directly to the expert rather than looking at the cards to check and confirm the information, because there were too much information."* On the contrary, the participants with psychology background or having a general idea around the concepts, indicated they read the cards in detail and used them when a designer asked a question. Thus, there is a clash between the level of knowledge of the participant and the amount of information needed and extracted from the cards. This result also goes in line with [9]. In addition to the previous research, our study showed that the domain experts in psychology and the designers who have small children were more interested in reading the information in detail than the designers with no prior experience with children in our workshops. This observation implies that the DSD cards in the original format might not be effective enough to support designers' use without refinements, but they can be sufficient guidelines for people who are already knowledgeable to collaborate with designers of children's technology to find a common vocabulary to reach a common understanding. The cards may also serve well as a parental guideline providing information about domain specific developmental areas or playful learning environments.

However, the main goal of the DSD cards is to make the knowledge readily accessible to technology designers in the absence of children, parents or experts with domain knowledge. Our suggestions for refinements to support information processing lies in the implementing more effective and usable information architecture in the cards which is adjusted for different levels of a design process which we present in detail below.

Insights for Reinforcing the Card Use at Different Levels

As the results showed, regardless of what design phase the participants have joined in the workshop they used the cards mostly during their inspiration gathering, brainstorming and kick off to brainstorming stage of a particular design activity. Their purpose of using the cards was more likely to gather information rather than a constant reminder or source of validation for the refinements throughout the whole design process. In order to secure the card use at all phases of design process, we basically suggest to allocate information and implement information architecture relevant to the design stage.

Implementing effective information hierarchy

For ensuring a clear information hierarchy, segments in the content such as topics, headers, sub-headers (i.e., Designer Tips and Designer Check-list) along with textual and visual examples were implemented as suggested in the previous study [9]. However, as indicated in our observational notes and survey results participants explicitly mentioned, the difficulty in finding concise information within full sentences under Designer Tips and Designer Check-list during their idea generation or constraining stages. The bold-written keywords were more supportive than full sentences especially while browsing, selecting and communicating information shorthand. Keywords were also one of the key elements to bookmark a card for inspiring and/or discussing ideas. Most of the participants indicated that they would prefer seeing the keywords only.

Another difficulty that limited the effective use of information hierarchy was two-sided presentation (Designer Tips on the front and Designer Check-List on the back) of the cards. P14 (a UX desginer) said *"it was hard to keep track of the information on back and front of the cards at the same time. Instead of back-and-front sided use, the cards could be designed with the same size but foldable. It might allow an accordion style expansion in which we could have one or two or even three pages on one side at the same time. It might also help the users to fold and hide, or unfold and open pages with the required information whenever needed."* P13 (a developmental psychologist) collaborating in the same group added that *"In doing so, all the pages would allow to contain information from different fields as a complementary knowledge for the topic. For instance, while the first page would present the information about target age's developmental needs and abilities in a specific area (e.g., recognizing basic shapes is an emergent skill at this age), the second page would inform about a media or*

technology platform that might serve that skill (e.g., tangible objects with haptic feedback), and interactional tips would complement those information in two fields on the third page (e.g., embodied interactions and experiences afforded by TUI can scaffold an effective learning of basic shapes for children at this age)." Other groups agreed on the need for cards that also includes suggestions for age-appropriate technologies, platforms or feedback affordances that might serve as complementary tools for such developmental processes, and on increasing detailing level in further design phases. Thus, we suggest to refine both sides of the cards as follows.

Adjust the Information for Different Design Levels

Some designers mentioned that the design considerations in question format given in the Designer Check-list has limited the creativity and freedom needed for the brainstorming session. Therefore, the Designer Tips and Designer Check-List can split in different cards for using at different stages of a design process. The latter can be provided in the idea generation and refinement stages rather than brainstorming. For the earlier stage of the design only a refined version of Designer Tips might accompany the brainstorming session. We suggest to refine the Designer Tips by providing keywords and examples only on one side for supporting the usage as quick reminder, bookmarking, or getting inspiration. The descriptions of the keywords can be presented at the back of the cards. So that the designer can easily access to it for informing, validating and confirming the information whenever needed. Similarly Designer Check-list can be refined having only keywords and examples on one side for reminding, determining, bookmarking ideas for outlining the design problem and Check-list at the back to confirm if the design team is on the right track. As being said, examples are the most effective information to help understanding the concepts when one is not knowledgeable about the topic. Thus, finding ways to augment the examples on each card is another important element to be considered.

Augmenting examples with distinguishing visual elements

Our participants indicated that they would prefer seeing more picture examples on the cards. Moreover, the participants who had no prior experience with very young children asked to see some videos from the case studies to get more insight into what a child at that specific age period would behave like different from older ones. However, in the questionnaire participants also responded that they did not use picture examples on the cards to bookmark an information. This goes in parallel with the finding that the picture examples were much less used than the text side in Deng et al.'s study [9]. In order to augment the examples visually in the cards, we suggest implementing QR code on the cards that opens video showing prominent examples for age specific abilities and skills in the particular developmental domain. One UX designer suggested using color to gain information about the ability level in a specific skill of the target age group (e.g., ability to rotate an object precisely). To avoid a wordy full sentence, for instance, color shades presented in a palette might represent the less or further developed states of a particular skill within that age. Such visual solutions can facilitate processing information on the cards faster and more effectively.

CONCLUSION

We customized and used DSD cards which were originally created by [6] as a knowledge transfer vehicle in a domain specific design space targeting children younger than 4 years old. Based on our user study findings and experience, we present general considerations for the customization of the DSD cards for informing children's technology designers and developers. The customization of the DSD cards is not only necessary when targeting users at different age groups within different design spaces, but also while using at different stages of a larger technology design process. Thus, this study not only contributes to a design practice in a specific domain knowledge, but inspires any type of complex domain space with a wicked design problem or extreme target groups. As future work, we will revise the cards relying on the the findings and feedback from our user study, and reevaluate the customized cards in participatory design workshops which enable the participants to contribute to the customization in design-in-use studies, and later in Game-Jam sessions which have real-life constraints. Moreover, a further study that compares the customized DSD cards with another age specific cards would be helpful to validate not only the effectiveness of our customized cards, but also contribute to better design considerations for age specific card-based design tools in general.

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