Comparing Early Design Methods for Children

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ABSTRACT

This paper describes a study which compares the outcome of two early design methods for children: brainstorming and prototyping. The hypothesis is that children will uncover more design ideas when prototyping than when brainstorming, because prototyping requires the use of a wider range of Intelligences according to Gardner's Theory of Multiple Intelligences. The protocols were coded using Design Rationale Theory: distinguishing between Options (design solutions) and evaluation Criteria. The results show that as expected children provided more Options in sessions that appeal to a wider range of intelligences. However, unexpectedly children provided more Criteria in the session that appealed mostly to one intelligence.

Keywords

Design methods, children, brainstorming, prototyping, Theory of Multiple Intelligences, Design Rationale.

ACM Classification Keywords

H5.2 [**Information Interfaces And Presentation (E.G., HCI)**]: User Interfaces – *Evaluation/Methodoly, Prototyping, Theory and Methods, User-Centered Design*;

INTRODUCTION

How effective are existing design methods for children to participate?. Optimal performance of early design methods is often measured in terms of the role and involvement of the children [7, 20]. For example, Bekker et al. [2] presented a case study that examined whether the early design method KidReporter was suitable for the intended age group and provided the information that was expected. They assessed the outcome of the method in a qualitative manner.

The importance of a design method lies only partly in the appropriate involvement of the participants. For the design process, it is more important to assess the method on the exploration and expansion of a design space with the users. A measurement for design space exploration and expansion is the number of ideas that are produced in a design method. The more ideas are generated with a design method, the bigger the chance that the design space if fully explored and expanded.

Idea generation can be defined as generating solutions to design problems. In the early stages of design, Olson and Olson [16] and MacLean [18] found that discussions between designers can be analyzed in terms of Options [18] (or alternatives [16]) and Criteria. They found that designers explore the design rationale by bringing up Options for a design solution and evaluating those Options by questioning them and evaluating them with Criteria (further referred to as the QOC-model or Design Rationale Theory).

In this paper we present a study which compares the number of ideas generated in a discussion by ten year olds, depending on the kind of problem solving skills used in a creative session just before the discussion. Based on the ideas behind the Theory of Multiple Intelligences [9], we assume that methods that appeal to more intelligences, will lead to more ideas. The number of ideas discussed after a textual brainstorming session will be compared with the number of ideas discussed after a rapid prototyping session. The hypothesis is that children will generate more ideas after a rapid prototyping session than after a textual brainstorm, because textual brainstorming is mainly a linguistic exercise and rapid prototyping is more diverse in nature.

In contrast with other research examining children's participation in early design this paper describes a way to quantitatively compare design methods. Second, we describe the outcome of sessions using the QOC-model in the context of designing with children. While this approach has been used to describe design conversations with adults, we examine whether Design Rationale theory can also be used to describe design conversations by children. Finally, we explore whether the Theory of Multiple Intelligences provides a fruitful framework to predict the outcome of comparisons of different early design methods.

Below, first the Theory of Multiple Intelligences is explained and how it relates to design methods. Second, we will give an introduction into MacLean's QOC-model [16]. Then we will describe how we compared a brainstorm

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method and a rapid prototyping method with children in focus group sessions.

THEORY OF MULTIPLE INTELLIGENCES

Design has been described as a problem solving activity and as an experiential learning process [5, 21]. Thus, if designing is a problem solving activity, intelligence is required to design, as intelligence is also described as a problem-solving skill. [10].

The theory of intelligence that offers a collection of problem solving skills we use in designing is the Theory of Multiple Intelligences by H. Gardner [9]. Gardner distinguishes eight intelligences in the functioning of the human mind:

1. Linguistic
2. Logical-Mathematic
3. Musical
4. Visuo-Spatial
5. Bodily-Kinesthetic
6. Intrapersonal
7. Interpersonal
8. Naturalistic

Each intelligence is defined as an independent quality of the mind, and distinguishable in psychological and neurological terms. Some psychologists think the theory is problematic, since no measurement instrument has yet been developed that can satisfactorily observe the performance of an individual in a single intelligence. Many psychologists agree though that the theory opened up the discussion for a broader view on human intelligence, while current IQ measurements, like the Stanford Binet test, mainly focus on symbolic-logic skills. In education, the theory has become widely appreciated as an inspiration to develop a curriculum addressing the different intelligences[1].

We will use the Theory of Multiple Intelligences to explore similarities and differences between design methods with children. To optimize a method according to the intelligences, we can distinguish between three processes during a design activity:

- Communication (i.e. to understand the instructions and to discuss the design ideas)
- Understanding of the product domain (for example musical applications require a different understanding than drawing applications)
- Performing the tasks specific to each design method (for example mood board creation vs role play).

Understanding the task and the communication of ideas, is associated with linguistic and logical skills. When working in the product domain, it depends on the particular design problem which skills are required, e.g. the design of a music player involves understanding of musical skills, whereas designing a dog-robot would involve naturalistic skills. The intelligences required to perform the method depend on the type of method, collage-making for example requires a certain level of a visuo-spatial intelligence, whereas role-play requires bodily-kinesthetic intelligence.

We are interested in the relation between the intelligences required for the method and the performance of the children in generating ideas with that method. Our hypothesis is that the more intelligences or skills involved in a particular design session with children, the more ideas will be generated for two reasons:

1. the more intelligences involved to solve the design problem, the more solutions will be triggered in one child; and
2. the more intelligences involved to solve the design problem, the more children will find the means to express their ideas.

THE MODEL OF QUESTIONS, OPTIONS AND CRITERIA

In early design sessions, we can involve children to explore and expand a given design space with their perceptions and values. In an explorative session, we expect that they will present their ideas and support them with arguments. MacLean at al. [16] explored a design space with designers. They analyzed discussions between designers in terms of Options (O) and Criteria (C). By creating an Options and Criteria diagram, designers are better able to formulate questions (Q) to come to more explicit design rationale. The QOC-diagram broadens up a design space, because it allows a more rigorous and elaborate evaluation of Options than the designers would otherwise consider. We will use the QOC analysis to measure the exploration of the design space by children.

The conversations on which MacLeans et al. and Olsons et al. base their findings are between professional designers. The conversations contain detailed Criteria on specific Options because they are held on a more concrete and detailed design level, like GUI-elements such as scrollbars and comboboxes [16]. In our study, we adapted the QOC-model to fit a discussion on early designs, allowing room for general concepts. Furthermore, the sessions are intended to collect user requirements; hence any specification of an option is potentially a user requirement. Thus, we re-defined the Criteria as specifications of Options, being statements that express:

- Numbers (e.g., you need two microphones)
- Locations (e.g., there is one at home)
- Functionality (e.g., you need to be able to talk secretly)
- Values (e.g., this is fun)

The Options were defined as “any object or technology mentioned by the children”.

With the QOC-model as a coding scheme, we can rephrase our hypothesis, by replacing “ideas” with Options and Criteria. This means that we think that the more intelligences are involved in a particular design method with children, the more Options and Criteria the children will bring forward.

HYPOTHESIS

To further refine our hypothesis we have to understand what intelligences are required to perform with particular design methods. We explained above that children need linguistic and probably logical intelligence for understanding the instructions and communicating their needs and ideas. Hence we assume these intelligences to be the absolute minimum of skills required. The intelligences involved in the product domain are open, as the children should be allowed to come up with any idea they think is appropriate, and any idea could involve any intelligence. The difference should be made in the method. Thus the difference in the type and number of intelligences required to apply various methods may lead to differences in the number of generated Options and Criteria

It should be noted that we do not intend to find a one on one relationship between the individual intelligences and a design method, we explore whether the Theory of Multiple Intelligences can serve as a framework for method optimization. To determine what intelligences are required for various design methods we related the skills required for a design method to the intelligences as described by Gardner's theory. To examine our assumptions we also asked nine professional designers (all having received a master's degree in user-system-interaction design) to conduct such an exercise. We offered them twenty-eight well described participatory design methods from literature [2, 6, 15, 17, 19] and the definitions of all eight intelligences.

We asked the designers to associate each method with the least number of intelligences required to perform the method as a participant. We asked for the minimum, because with some imagination it becomes possible that every method requires all intelligences. We wanted to define only those intelligences that are minimally needed to fulfill the tasks involved in a particular design method. If at least five designers would associate an intelligence with a design particular method, it was counted as a confirmed association.

The method associated with the minimal number of intelligences was a basic brainstorm as described by Osborne [19]. Osborne did not describe any other creative stimuli to come up with ideas, the intelligence associated with a plain brainstorm was the linguistic intelligence. The method associated with the largest number of intelligences was prototyping [17]. Prototyping was associated with the linguistic, bodily kinesthetic, visuo-spatial and interpersonal intelligence. Thus we expect more ideas, both in terms of Options and Criteria to be generated in a prototyping session than in a brainstorm session.

METHOD

Focus group setting

To uncover Options and Criteria, we need to analyze conversations about design. Hence, we combined a brainstorming session and a prototyping session with a focus group setting. A comparison of the discussions in the focus group sessions on the number of Options and Criteria stated, should validate our hypothesis.

To enable children to explain their designs a focus group setup was chosen. In a focus group the dynamic interaction of five children will elicit more information than a one-on-one interview because there is less emphasis on the adult-child relationship. The children are less likely to respond in ways the researcher desires and because the aim of a focus group is to discover the children's view of their world the session will have a high face validity [13].

However, an exploratory focus group setting also has a disadvantage: cognitive tuning. Cognitive tuning is the effect that participants start to tune into each others mindset for comprehension and apprehension. As a consequence they become less capable of generating their own individual ideas [8]. To avoid cognitive tuning, the creative part of the focus group discussion should be performed individually.

Design Case

A telecommunication company provided two design cases for a device for children in a primary school. The goal of the design cases was to establish live communication between a child at home and the class in school in the case that a child is too ill or too immobile to come to school. We asked the children to create a device located in class and/or at home. The device was intended for two common class situations: in one situation the children are collaborating in small groups and in the other situation the teacher is actively teaching a lesson to the entire class.

Children

Literature shows that doing focus groups with children is best done with a maximum of five children [13], hence we composed groups of five children. For the results reported in this article, four groups of five ten-year-old children participated in the study (a total of twenty children). All groups were of a mixed gender composition. All children were in grade five in a Dutch primary school. Two primary schools, one from Hilversum and one from Eindhoven took part in the study, each providing two groups of five children.

Within-subject design

There are many other variables that could influence the results, for example the time of the day, the combination of characters, the number of girls and boys. To avoid a strong influence of these variables on the results, we decided on a within-subject design. Therefore each group of five children went through both a brainstorm and a prototyping session. A typical session would have the following setup:

1. General introduction
2. Introduction of the first case
3. Instructions for the written brainstorm
4. Individually performing a written brainstorm
5. Group discussion on the results of the brainstorm
6. Introduction of the second case
7. Instructions for the rapid prototyping session
8. Individual creation of a prototype
9. Group discussion on the resulting prototypes
10. Rounding off

To avoid influence of order and of case, we performed the sessions in the four possible variations of method (brainstorm or prototyping) and case (group work setting or teaching setting) illustrated in table 1:

Methods → Cases ↓	Brainstorm 1st Prototyping 2nd	Prototyping 1st Brainstorm 2nd
Teaching 1st Group 2nd	Brainstorm on Teaching Prototyping for Group work	Prototyping for Teaching Brainstorm on Group work
Group 1st Teaching 2nd	Brainstorm on Group work Prototyping for Teaching	Prototyping for Group work Brainstorm on Teaching

Table 1: Overview of all the possible combinations of cases and methods dealt with in a focus group session.

Time allocated for brainstorming and prototyping

Initially, the children had fifteen minutes to come up with ideas or a description in each creative sessions. However, a pilot study with adults showed that fifteen minutes of brainstorming was too long. After five to ten minutes the participants felt they were finished and could not come up with more ideas. For the prototyping session they felt they did not have enough time and could not finish or implement all their ideas. Basically, they explained, because it takes more time to “cut and glue” your ideas than to write them up.

The purpose of the study was to compare the methods. Although allowing more time for one method than for the other method causes an inequality in time for generating ideas, we decided that our criterion for finishing the method should be more compliant with how much time the participants needed to finish the method satisfactorily. Therefore we decided to shorten the time for the brainstorm with five minutes and to lengthen the time for the prototyping sessions with five minutes. Our studies with the children showed that the majority of the group members finished their brainstorm and their prototyping activities within that time.

Each session was recorded using video and audio recording devices. For the video recording we used a mobile usability lab consisting of two digital cameras, a video mixer, and an mpeg encoder connected to a laptop via usb. The participants were sitting next to each other, in a circle. The two cameras recorded the session from opposite sides, such that the combined picture showed two half circles, each showing half of the group. The video was recorded with audio, captured by one of the cameras.

A pilot study showed that one distant microphone on a camera does not provide the quality required to transcribe all the children’s statements. To score the verbal statements of the children we required clear recordings of each individual child. Therefore we also used a wireless audio recording system. Each child was equipped with a wireless microphone and a broadcasting device. The recording setup consisted of a rack-system containing the microphone receivers and an audio mixing device. Each audio signal was recorded on a single track. The result was six synchronized tracks (five children and the moderator) being stored on a computer in the lossless WAV format.

The advantage of separate audio tracks is that although children often talk at the same time, the tracks can be analyzed individually. Furthermore the quality of the signal benefits greatly from being so closely mounted to the source – the child’s mouth. Even in noisy environments, the quality of the audio signal remained good enough for transcription.

The audio tracks were transcribed using the audio editor Audacity [24]. One of the authors and one research assistant took care of the transcriptions. The transcriptions contained a timestamp for each utterance, a number indicating the speaker and a code to indicate overlapping speech. Comments of the transcriber on an utterance were noted between square brackets; for example [laugh] for laughter, [unint] for unintelligible or [takes picture] when the moderator took a picture of the prototype).

ANALYSIS

We checked the inter-coder reliability by performing an any-two agreement on the session transcripts. Furthermore we checked whether the groups of children were comparable in terms of their intelligence profiles according the Theory of Multiple Intelligences.

Any-two agreement

Several measures are available to determine reliability: Cohen’s kappa and the any-two-agreement measure. Cohen’s kappa [4] is one of the commonly used measures that estimate the proportion of agreement between two evaluators after correcting for the proportion of chance agreement. However, Cohen’s kappa is based on each evaluator classifying the same observation points. In the case of free detection of Options and Criteria evaluators may not have observed the same amount of items to be coded thus resulting in different observation points. Therefore, similar to Hertzum and Jacobsen[14] who determined the reliability of problem detection, the any-two agreement measure was used. To determine the reliability of the proposed coding scheme two of the authors of this paper independently coded both the prototyping and the brainstorming session of one group of five children.

The Options and Criteria were coded with numbers. The numbering indicated to which Option a Criterion belonged. In the conversation, we observed Options and Criteria, repetitions of Options and Criteria and Option-Criteria connections. Therefore the possible outcomes of the comparison were:

1. both observers coded the phrase the same, being new or being a repetition (agreement)
2. only one observer coded a phrase as new (disagreement), while the other did not code it
3. only one observer coded a phrase as a repetition (disagreement), while the other did not code it
4. the observers did not agree on an option or criterion as being new or being a repetition (disagreement)
5. one observer coded a phrase as an option, while the other coded the phrase as a criterion (disagreement)
6. the observers did not agree on the relationship between a criterion and an option (disagreement)

In the any-two analysis, situation (5) never occurred. Furthermore the number of missed repetitions (3) was not included in the disagreements. When composing the design-space of Options and Criteria, a repetition does not add new information to the design-space. Hence if one observer did not score anything where the other scored a repetition, no information is lost.

Table 2 shows that the agreements between the 2 coders is fairly good, compared to other any-two agreements found in the literature. For example, the range of any-two agreement values described in Hertzum and Jacobsen [14] lies between 5% and 65%. This means that the coding scheme should be considered fairly reliable, independent of the researcher using it.

Out-come	Agree-ment (1)	Unique A (2)	Unique B (2)	Disagree-ment about repetition (4)	Disagree-ment about link C and O (6)
100 %	54,5%	7,3%	17,3%	8,7%	12,2%

Table 2: The outcomes of the any-two agreement of two coders (A and B).

Profiles of Multiple Intelligences

The Teele's Inventory of Multiple Intelligences (TIMI, [23]) creates a profile of a child in terms of the dominance of the intelligences as identified by Gardner [9]. The test has been validated by test-retest validation. Furthermore it is used in an increasing number of primary schools in and outside the USA. It is used to understand what kind of learning activities would suit a child best. As we have based our hypothesis on which activities would suit the intelligences of the children best, an extremely deviant group profile of multiple intelligences would be a confounding factor to our results. For example in the case that none of the children would associate themselves with the linguistic intelligence, could have a strong influence on the results.

The TIMI consists of fifty-six pictures, offered to the children as a pair-wise comparison. Each picture is associated with one of the intelligences. The children are asked to tick which picture suits them best. They are explicitly instructed not to choose the picture representing what they would like to do most, but to indicate which picture is the best representation of their current behavior. The results are an overview of the four intelligences the children associate themselves with dominantly.

Since we based our hypothesis on addressing the multiple intelligences of children, we asked them to fill in the TIMI individually. This test was performed apart from the focus group sessions. Table 3 provides an overview of the results. Each column indicates the number of children for that group that associated themselves with the types of intelligences. The numbers do not always add up to twenty (four dominant intelligences vs. five children). Some children scored an equal number of associations for a subset of the intelligences. For those intelligences, dominance becomes indistinguishable. The table represents therefore the intelligences that received the four highest scores in the test. For example, if a child scored eight times for intelligence A, six times for intelligence B, five times for C, and four times for intelligence C ***and*** D, both C and D are included in the overview.

	Group 1	Group 2	Group 3	Group 4
Linguistic	4	3	3	
Logical	2	2	2	1
Visuo-Spatial	3	3	3	4
Musical	5	4	1	3
Kinesthetic	5	5	5	5
Intrapersonal	1		2	3
Interpersonal	5	5	5	5

Table 3: An overview of the dominant intelligences per session, showing the number of children that associated themselves with those intelligences.

This table shows that in each group at least six or more different intelligences are among the dominant intelligences of the children. That means that sufficient intelligences are present in each group to exclude a bias in the results from a "specialist" group, featuring only one or two intelligences. All children associated themselves with the kinesthetic and the interpersonal intelligence, which is coherent with the common view in developmental psychology on children of around ten [3].

Figure 1: Children working on the inventory of Multiple Intelligences

RESULTS

So far the protocols of 4 groups of five children have been coded. Table 4 provides an overview of the number of Options and Criteria that were mentioned by the 4 groups.

The results show that as expected all teams mention more Options after the prototyping activity than after the brainstorming activity. However, unexpectedly, except for session 4, all the teams mention less Criteria after the prototyping activity than after the brainstorming activity.

	Prototyping			Brainstorming		
	Opt	*Crit*	*Total*	*Opt*	*Crit*	*Total*
Session 1	46	69	115	34	150	184
Session 2	39	114	153	30	121	151
Session 3	47	93	140	42	109	151
Session 4	45	151	196	43	123	166

Table 4: the number of Options and Criteria per session. The double lined cells indicate which activity was performed first in the session.

The differences found are rather small for session 2 and 4, possibly due to an order effect. If we look at the total number of Options and Criteria together, a trend could be that the second activity elicits more data points than the first activity. In session one and three the brainstorm activity was performed second, in session two and four, the prototyping activity was performed second. If we take a look at the data in that perspective, after the second activity the children expressed a higher total number of Options and Criteria than after the first. Because we equally distributed the order of the activities over the sessions, we can safely assume that the structural differences are a consequence of the activities. However, the order effect is clear and could be responsible for the smaller differences in options and criteria for brainstorming and prototyping found in the sessions 2 and 4.

From the qualitative data we expect to find more differences between the two conditions. For example in the prototyping condition, the children were more likely to use reference words with which they –visible on the video tape– pointed at parts of their work. In the brainstorming condition they could not do that, which might have led to the larger number of Criteria. Figure 2 shows a part of a transcript to illustrate what types of Options and Criteria were provided by children after a prototyping session.

E: well, what did you make?

3: **This[O1]** is a kind of a *broadcasting[C1.1]* **device[O1],** actually **it[O1]** *consists of three parts[C1.2]*, and I have only one. **This[O2]** is let's say the **receiver[O2],** and then I needed another piece of carton which would be **the screen [O3]...**

E: hm hm

3: ...and then there is, let's say **a camera[O4]** *that records the teacher[C4.1]* and **this[O2]** *will receive that[C2.1]* and that will go via **this[O2]** to that **TV[O5],** to **that screen[O3]**

Figure 2: A piece of transcript after a prototyping session where E stands for Experimenter, and 3 indicates child 3 talking. **[O#]** codes an option, *[C#.#]* codes a criterion.

DISCUSSION

To measure the effectiveness of early design methods, we started with developing a framework based on the Theory of Multiple Intelligences to compare methods. As this framework is considered fruitful in selecting educational exercises for children in primary schools, we looked for evidence that the same approach would work in comparing design methods to involve children. The two methods applied in the study were selected based on the assessment on the number of intelligences to which the methods appeal. Our selection was confirmed by the application of the framework by 9 professional designers. The framework can be used as a tool to compare design methods on their expected output effectiveness.

To measure whether the expected effectiveness of early design methods is reflected in the output of the design sessions, we first developed the means to generate comparable output of different methods, by using a focus group setup. Furthermore we developed a basic measurement instrument to detect the differences in the output of the design methods. The first results showed that this setup is successful in detecting differences in terms of Options and Criteria.

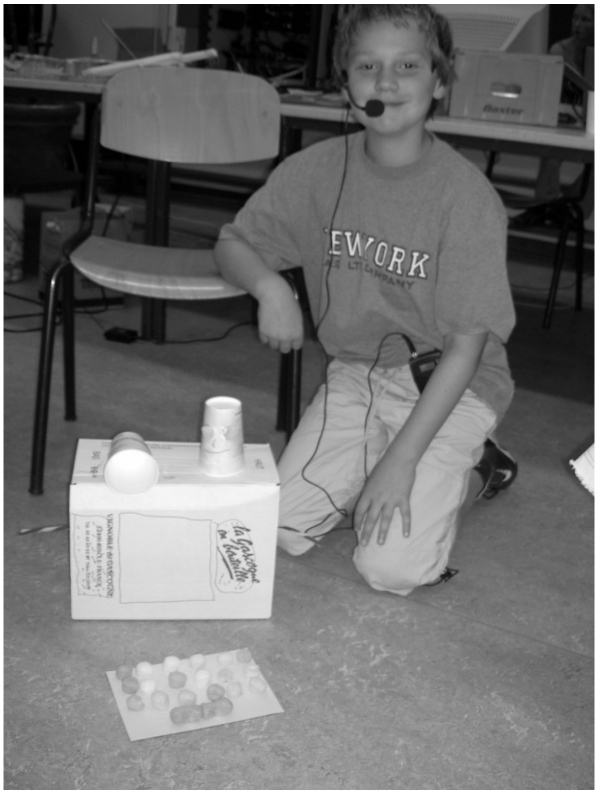

Figure 3: One of the ten-year-olds, wearing a head mounted wireless microphone demonstrating his rapid prototype

On the basis of the available data, we found evidence for the part of our hypothesis that the more intelligences involved in the design activity, the more Options are generated in a group of children. An explanation for the higher number of Criteria after the brainstorming activity is that in the case of the prototypes, more Criteria are probably implicit in the design of the prototypes. When implicit information is obvious, it is a manner of good communication to state only the relevant [11], hence in the discussion about the prototypes, some Criteria are not explicitly mentioned.

FUTURE WORK

So far the data of only four teams has been analyzed. By the time of the conference the data of the other four teams will have been analyzed to determine whether the same trends will be visible based on the behavior of more groups.

Furthermore, we have to look into the data more qualitatively to understand the informational value of the Options and Criteria for each condition. For example by looking at the difference between design related criteria and context related criteria. Compare for example statements like "it has to have five buttons" [design related] and "the shape of the device makes sense only when the teacher is drinking coffee" [context related].

This study has made a first step in exploring the applicability of a framework for design methods based on the Theory of Multiple Intelligences. The framework is applied to predict the effectiveness of early design methods. Future studies could explore the relationship between expected effectiveness and the Multiple Intelligences further, for example in younger children, or in adults.

For this study we started from the basic idea that the more information elicited the better. An understanding of the quality of the data is also interesting to determine more in depth the effectiveness of design activities for a design process. Shah and Vargas [22] proposed four measures to assess the effectiveness of ideation activities: Quantity, Quality, Novelty and Variety. If we can apply their ideas on the data provided by the children, we can examine more in depth the effectiveness of a design activity with children.

CONCLUSION

The study described in this paper examined the applicability of Design Rationale Theory on design conversations by children and the use of the Theory of Multiple Intelligences as a framework for comparing early design methods.

The results show that Design Rationale Theory can be used to describe design discussions by children. Two coders were able to analyze the data with an acceptable amount of agreement. This means that the coding scheme with Options and Criteria can be used to quantify (part of) the outcome of design sessions with children.

The results also show that using the Theory of Multiple Intelligence as a framework to compare methods provides a basis for interesting hypotheses. As expected children mentioned more Options after the prototyping activity than after the brainstorming activity. However, unexpectedly after the prototyping activity the children mentioned fewer Criterions than after the brainstorming activity. The videotapes show that the prototypes allow children to refer to aspects of the design without having to explicate them verbally. This factor also contributes to the fact that children mention fewer Criteria in the prototyping session.

In summary, the children participating in our study were better able to explore the design space in terms of Options after the prototyping activity. However, they provided more Criteria after the brainstorming activity. Future research focusing on more detailed analysis of the protocols and comparison of other design methods should shed further light on the relative costs and benefits of using early design methods with children.

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