

Designing Icons on User Interfaces for 4-6 year Old Children

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Abstract—A new generation of children, called “digital natives”, live in a world where technology is forever being used in their daily lives. Digital media, such as games and applications, are increasingly being designed with kids in mind. However, interface and icon design for kids are not just a matter of simplification or scaling-up buttons. Children should not be dumbed down during the design process. Given that children’s cognitive abilities vary at different ages, it’s imperative to avoid assumption of an icon or image will be targeting all ages. Designing for a 4-year-old may not be age appropriate for a 7-year-old. This paper discusses how to design icons for children from 4 to 6, on user interfaces, by investigating cognitive development theory and applying the concept of user-centered design into children-centered design. Along with that, it will compare different user interfaces on different media platforms like applications, games, and websites for kids. With the children’s unique characteristics at different ages in mind, designers can address age-appropriate design to those characteristics.

Keywords-icon design; children; cognitive development.

I. INTRODUCTION

Many media research studies have shown that children have become a large user group for digital products such as websites, applications, and video games. A report from Common Sense Media in 2013 pointed out that 72% of children under 8 years old in the United States own a mobile device for a different purpose [1]. Under such circumstance, younger users need more appropriate interface design. However, as some studies have pointed out, it is not hard to find general guidelines for interface design, but only a few have responded to the development world of today’s children [2][3][4][5]. We cannot design for children just based on intuition or memories from adult’s childhood [6]. The new generation of children thinks and processes information fundamentally different from their predecessors [7]. A study from Andrew Large and Jamshid Beheshti suggested that specific interface design guidelines are required for kids rather than just relying on general design guidelines [4].

When working with children, they do not always follow the strict requirements of experimental procedures, so the completion rates and data collection of this subject pool are usually not ideal [8]. This problem makes interface design for these “digital natives [7]” more challenging for designers. To crack this hard nut, designers should better understand their intended small-age users’ characteristics [10]. Piaget’s theory about the four stages of cognitive development may

help us know why children behave differently at different age.

The purpose of this paper is to employ findings from literature review to investigate some specific guidelines for icon and interface design for 4 to 6 year old by adopting children’s cognitive development theory and user-centered design concept. The main reason to choose this age group is that they have been missing from most literature [8]. Lots of relevant studies focus on children older than 7 year old.

There are mainly three parts in this paper. Section II discusses the importance of icon and interface design for children; design for children is different from design for adults. According to Piaget’s development stage theory, Section III explains why design icon and interface for children should take different age segments into account. Section IV lists some problems in current icon design for children and attempts to incorporate user-centered design concept in the procedure of design for children users. Other than that, it provides some specific guidelines for icon and interface design for children.

II. ICON AND INTERFACE DESIGN IS IMPORTANT FOR CHILDREN AND SHOULD BE DIFFERENT FROM DESIGN FOR ADULTS

When we own a new electronic device such as PC, iPad or smartphone, the way we interact with an unknown system is through activating the icons or other visual indicators on the graphic user interface (GUI). The term icon originates from a Greek word *eikon*, which refers to likeness, image or portrait. In the field of computer science, an icon is a small picture of symbol that represents a program, command, file, directory or device [9]. Usually, users can activate an icon on the graphic user interface (GUI) through a mouse, pointer, finger or voice commands. Icon interface has been extensively used on various smart devices because it has compact universal pictographic representations of functionality [11] and confronts fewer language obstacles [12]. Many studies have pointed out that children and young adults tend to rely on visual indication or visual cues rather than textual information [3][13][14][15]. Some researchers from Taiwan measured 104 children’s information search efficiency of finding icons (databases) in the virtual environment. The final statistical analyses demonstrated that children’s searching efficiency improves through using the graphical interface, compared to using text-focused interface [3]. Children at 4-6 year old still have poor reading ability, so appropriate icon and interface design are important for

them to easily retrieval information from digital products such as website, game, and application [16].

When kids open a website or an application, they think in the different ways as adults [3][17][18]. Adults use websites and applications to find information, do shopping, and communicate with friends, etc. Meanwhile, most of the kids consider digital media as a way to entertain themselves [19]. Jakob Nielsen found that lots of usability aspects apply for both kids and adults. Meanwhile, he also discovered that there are some different aspects. Table I [20] in his study summarizes the main similarities and differences in user behavior between children and adults when they use websites. It illustrates how children and adults think and behave differently as they use digital products. For instance, look at the seventh column in the first row, when users confront multiple or redundant navigations on user interface, children feel more confused. Then in the row that says Back button in the first column, it shows young kids barely use that icon, yet older kids and adults are relying on it. Those comparisons just indicate that younger children have a different interpretation to the same design than older children and adults. In addition to that, designers should also consider children’s immature cognitive development, and void experience of association to produce high recognizable and age-appropriate icon design for them.

A. Immature Executive Function

Neuroscience scholars discovered that the executive functions controlled by the frontal lobes allow adults to concentrate on relevant information on user interface and filter irrelevant information [21]. Children aged from 3 to 8 have relatively immature executive functions and short-term memory [22], which hinder their ability to have a good command of interpreting the icon and visual cues on graphic interface as adults do. Hence, children may not be able to recognize some icons that we adults take for granted.

B. Void Experience of Associating Icon Metaphor

A study from National Taichung University of Education found that the users’ prior experiences could contribute to storing images and build up conceptual neural networks in our brain [22]. When an icon delivers a message, adult users can retrieve their previous long-term memory to interpret it. However, due to the void experience, children user would have difficulty associating the icon metaphors with the real objects. For example, we adults are quite familiar with the save icon (Figure 1), which we still frequently used in the Microsoft Word software (Figure 2). Most of adults can recognize this icon because it is widely used on websites and applications. However, the image of this save icon is a 3.5-inch floppy disk (Figure 3), the primary means of backing up files or transferring them between computers in the 1990s. We are no longer using this storage device. Apparently, children today cannot recognize this icon without training because floppy disk does not exist in their world. Therefore, it is important for adults and designers to avoid assuming that children’s world experiences and adult experiences are comparable, with regard to icon metaphor association. Children will feel quite confused if this assumption is

TABLE I. MAIN SIMILARITIES AND DIFFERENCES IN USER BEHAVIOR BETWEEN CHILDREN AND ADULTS [20]

	Children	Adults
Goal in visiting websites	Entertainment	Getting things done Communication/community
First reactions	Quick to judge site (and to leave if no good)	Quick to judge site (and to leave if no good)
Willingness to wait	Want instant gratification	Limited patience
Following UI conventions	Preferred	Preferred
User control	Preferred	Preferred
Exploratory behavior	Like to try many options Mine-sweeping the screen	Stick to main path
Multiple/redundant navigation	Very confusing	Slightly confusing
Back button	Not used (young kids) Relied on (older kids)	Relied on
Reading	Not at all (youngest kids) Tentative (young kids) Scanning (older kids)	Scanning
Readability level	Each user’s grade level	8 th to 10 th grade text for broad consumer audiences
Real-life metaphors e.g., spatial navigation	Very helpful for pre-readers	Often distracting or too clunky for online UI
Font size	14 point (young kids) 12 point (older kids)	10 point (up to 14 point for seniors)
Physical limitations	Slow typists Poor mouse control	None (unless disabled)
Scrolling	Avoid (young kids) Some (older kids)	Some
Animation and sound	Liked	Usually disliked
Advertising and promotions	Can’t distinguish from real content	Ads avoided (banner blindness); promos viewed skeptically
Disclosing private info	Usually aware of issues: hesitant to enter info	Often recklessly willing to give out personal info
Age-targeted design	Crucial, with very fine-grained distinctions between age groups	Unimportant for most sites (except to accommodate seniors)
Search	Bigger reliance on bookmarks than search, but older kids do search	Main entry point to the Web search



Figure 1. Save icon.

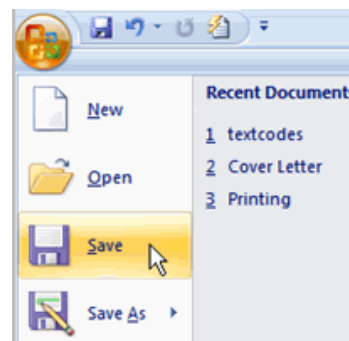


Figure 2. Save icon on Microsoft Word interface.



Figure 3. Floppy disk.

applied in the design for them. The icon metaphors used in interface should be familiar to children and connect to the physical world [20][23].

III. WHY ICON AND INTERFACE DESIGN FOR CHILDREN SHOULD CONSIDER DIFFERENT AGE RANGES

Children undergo dramatic physiological and cognitive changes as they grow up [3][24]. Children at different age segments have different user characteristics. Adult's mental and physical situation usually remain pretty stable in the long term. Shneiderman argued that any design should be built upon an understanding of its target users. He also stated that age group and gender should be considered as important user characteristics alongside education, ethic, personality, training and so forth [3][25]. In addition, Sultan Idris Education University did a study on children's ability to design icons based on the given tasks, the finding shows younger and older children have a different understanding of the same icon representation and their meaning. Children under 8 year old have difficulty in recognizing even some simple icons like undo icon and move-to-first-page icon [26]. Figure 4 in this study report shows children interpret a given word differently according to their age [26]. It reveals that age plays an important role in icon recognition and visual information perception ability.

According to Piaget's theory [27][28][29], children have four stages of cognitive development: the sensorimotor stage (0-2 years), preoperational stage (2-7 years), concrete operational stage (7-11 years), and formal operational stage (adolescence through adulthood). Most children under 2 and half years old have few experiences with standard input devices like mouse trackball and keyboard to interact with technology. And children older than 14 years old have entered into puberty and are likely to behave as adults [30]. However, children aged 4-6 year old are in the development process of the preoperational stage, and they begin to develop various cognitive skills, such as language, memory, imagination and so forth. But they are unable to understand concrete logic yet, so they tend to know this world only through making connections between events and phenomena. Their ability to process information mentally is still very limited [8]. Statement from Piaget and Inhelder and Piaget [28][31] also identified that the children aged 2 to 4 like to

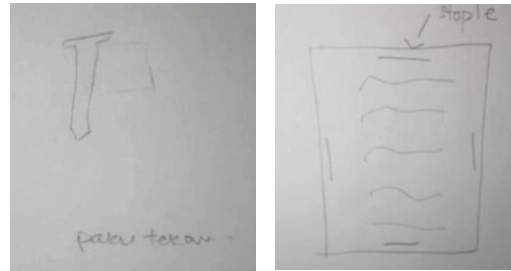


Figure 4. A girl aged 5 years old (left) and a girl aged 11 years old (right) interpretate of a giving word "paste" [26].

engage in symbolic play, such as pretend play. It means they start to use symbolic representations. Later, children at preoperational stage achieve an important cognitive milestone when they behave better at language expression, draw and play [8]. Making use of symbol such as icons on user interface for children at this age group will help them get the hang of smart devices and understand things faster and efficient.

IV. HOW TO DESIGN ICON FOR 4 TO 6 YEAR OLD

Though there exist many studies and guidelines of user interface design, most of them still focus on adult users, only a small amount of them have taken children youthfulness as user characteristic [3][32]. This situation is typical in touch-screen interface designed for children. A study from Romania noticed that only a few works had addressed children's interaction behavior with touch-screen devices. Most existing touch interactions are designed for a generic user population. Those designers just assumed that all users could be able to target small graphical items precisely, and drag and drop them smoothly and effortlessly on the screen interface [8]. Nevertheless, as the study pointed out, children's touch interaction patterns are different from adults. Children have smaller finger size, and their motor and cognitive ability are limited in accordance with their age and developmental stage [8][32][33][34]. In fact, small children are more complicated than they appear initially [24]. Designers should avoid dumbing down their young users by simply enlarging the icon size and brightening the color in UI design. Therefore, specific interface design guidelines are required for small-age children, rather than just relying on general design guidelines [3]. If needed, designers can also actively include the young user themselves in the design process.

Icon and interface design for children can incorporate the concept of "User-centered design". Most designers are familiar with the term "User-centered design"(UCD). Donald Norman's research laboratory at the University of California, San Diego, originated the term 'user-centered design' (UCD) in the 1980s. The role of the designer in the user-centered design is to facilitate task for users, to make sure that users can use the product as intended, and with a minimum effort to learn how to use it [35]. Table II lists the four phases of the UCD process. A rule for user-centered design practices is that no design suits all users. Designers should design based

on the knowledge of the target users [4]. However, as Shneiderman argued [10], it is less common to find in practice that small-age users are being considered in the interface design guidelines. Sabina Idler, who is the founder of UXkids, mentioned the notion of child-centered design (CCD). She recommends designers to take what we have learned from UCD and to apply it to design for kids [36]. Based on the concept of UCD, and Sabina’s explanation of CCD, Figure 5 demonstrates the five phases of icon design for children. The first step is to have an idea; then designers should conduct some field research to understand their children user characteristics. Next, it is time for designers to produce design solution for a particular product. After that, usability testing is required to make the design evaluation and designers can modify their design based on the feedback from children users.

A. Field and User Research

Having a good understanding of target user’s needs is an evitable part of the design process. If users are preschoolers who have limited language expression and cognitive ability, designers should do more research on characteristics of children users. In this case, understanding the cognitive psychology at various age stages could help designers put themselves into children’s shoes.

1) *Children from Age 4 to 6 are in the Preoperational Stage:* According to Piaget’s theory of cognitive development, children aged 4 to 6 are in the preoperational stage (2-6 years). Piaget developed term “Preoperational” for children who don’t understand concrete logic yet and can only see objects and people from their perspective [24]. They are starting to have the ability to communicate via simple language and use symbols such as words, numbers, and images to represent real objects [6]. But kids at this stage are in the process of learning how to think abstractly, so they still are having trouble articulating thoughts and behaviors clearly. Hence, even if some icons and symbols are universally understood for adults, they make no sense in children’s minds. So, designers ought to think twice before using any icons and symbols that adults take for granted.

2) *Children Privacy and Parental Consent:* Before conducting the on-site research or test for children, one thing should be kept in mind is that many countries have strict regulations about collecting personal data from kids younger than 13. Designers and researchers are required to obtain parental or guardian consent before conducting any testing. In the United States, detailed explanations of the rules could be found in the U.S. Children’s Online Privacy Protection Act (COPPA) laws [24]. Apart from getting permission, it is highly recommended to let the parents understand your research objectives [37].

B. Produce Design Solution

When designing icon graphics for 4 to 6 year old, the following aspects should be taken into account. The design concept can be applied to the user interface on different platforms.

TABLE II. FOUR PHASES OF USER-CENTERED DESIGN

User-centered Design Phases	
<i>Specify the context of use</i>	Identify target user, what they will use it for, under what conditions
<i>Specify requirements</i>	Identify user goals or business requirements
<i>Create Design Solutions</i>	Realize rough concepts to complete design
<i>Evaluate Design</i>	Conduct usability testing with actual users

1) *Icon Graphics Should Match User’s Mental Models:* Icon metaphor should depend on user familiar mental models, for the purpose of reducing cognitive effort [3]. In other words, icon design should remind the user of real objects that they are already known [12] [38]. Many studies [39][40][41][42] shows that concrete icon sets tend to be more visually complex than abstract icons since the detailed interpretation of real world objects would allow users to access their existing knowledge and life experience related to these items to infer meaning. However, icon design should avoid being too complex, as it will increase the extra processing time for user to recognize [43]. Jeeves [3] example found that metaphors are related to age and culture. Chinese Academy of Science did a research about how the development of visual attention aged from children to adult affects interface design [44], the finding use series of data to point out that children participants need significant longer reaction time on user interface than adolescence and adult participants.

In addition, for children who usually don’t have much life experience and haven’t received icon recognition training, learning a new set of visualized symbols is much difficult than recognizing images they observe in daily life. According to the study from Nation Taipei University of Technology [45], a design guideline is using icons based upon simplified images that relevant to children’s real life experience, as they can easily perceive the actual meaning on the user interface database. Figure 6, the screen shot of TV icons from website Sprout and CBeebies for preschoolers, is an example in practice. The biggest difference in these two icon graphics is that the right one has

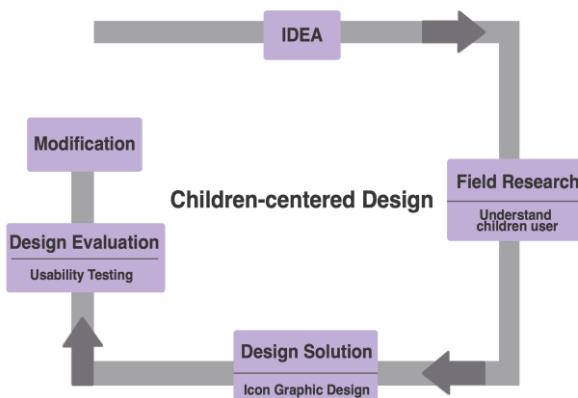


Figure 5. Children-centered design phases.

two television antennas. Those antennas are not matched with nowadays children’s mental model because the truth is we no longer use TV with antennas and have not for quite a long time. Most of the kids nowadays are watching the TV in Figure 8 at home or school rather than the counterpart with antennas. Though the antenna makes the TV icon “childish” and more kid-friendly, it is at odds with children user’s sense of rightness, and result in a low recognizability.

2) *Semantic Distance*: Semantic distance in interface design means the closeness between the icon and the function it represents [39]. When designing interface for children, icon graphic should match its function to avoid misunderstanding. Some researchers agreed that semantic distance plays an important role in determining interpretability [38][39][46]. Townsend [2] also recommended in his research that icon designed for children user should “clearly depict, indicate and distinguish a program’s commands and operations” and “should suggest and indicate a command intention rather than just duplicate or represent a particular pictorial form.” Currently, some icons designed for children users tend to be looking good but not accurately matching the meaning of function [3]. For instance, the two icons represent the game section in Figure 8, the graphic in the right one is a wheel with an arrow on it, and the left one is a game console. Apparently, most kids today know what a game console looks like, this graphic let them easily remind of video gameplay experience in real life. However, the wheel graphic does not accurately match the video game concept. Children may play wheel spin game in real life, but this cannot represent various kinds of video games in their mind. As a result, icon graphics need to be carefully selected, accurately matched with the label text to avoid any misinterpretations [3] for children users.

3) *Maintain Visual Hierarchy on User Interface*: Color combination and color contrast on user interface would significantly influence the visual search performance of user [43]. Studies [47][48][49] show that proper use of color could enhance the graphical display effectiveness, which can lead to fewer search times for user. Children at the preoperational stage prefer bold and primary colors and high contrast in graphic layouts [50], because bright colors immediately catch their attention [3] and trigger their interest to explore. But some studies also stated that incorporate too much color into a user interface could be counterproductive, as it may generate a “fruit salad” look [49] feeling to the user. At the same time, it could also slow down children user’s visual search time on the interface. In the example shown in Figure 9, Webkinz Jr. is a website design for kids aged 3 to 6, to play learning games online. You can tell from the picture that designers intend to use lots of bright colors to attract children’s attention of exploring. Also, the four icons at the bottom are quite colorful. However, the visual hierarchy on the interface is not evident, which makes children under 6 years old have trouble navigating it. Screenshot in Figure 10 is a good iconic interface design. It is an early math application for preschoolers, named Eggy



Figure 6. TV icon on children website Sprout (left) and CBeebies (right).



Figure 7. Children watching TV.



Figure 8. Game icon on children website Sprout (left) and PBSkids (right).

Subtract to 20. The color on the interface is bright enough, and the graphic design is kid-friendly. The icons on *Eggy Subtract to 20* maintain have high color contrast with the background. For children user, it is easier for them to complete visual search and further navigate to the contents they want. Hence, user interface design for children should incorporate an appropriate amount of color and high contrast to increase visual search efficiency [43].

4) *Indication of Icon Clickability*: Children love feedback, such as animation and sound when they interact with the game or application. A study result from University of Calgary [2] argued that animated icons are easier to decipher the meaning than static images for children. Children show an obvious preference for the moving icons. So incorporating animated icons in a user interface for children could have a merit. The click animation in Figure 11 is a good illustration of this point. When the mouse cursor moves to the icon, the animation appears to give children users feedback and attract their attention. It uses a children-friendly way to indicate that icon is clickable.

C. Design Evaluation-Usability Testing with Children



Figure 9. User interface of website Webkinz. Jr.



Figure 10. Screen shot of early math application- Eggy Subtract to 20.



Figure 11. CBeebies Icon Animation.

For designers, it is highly recommended to get feedback from children about your design and make some proper modifications. In Human-Computer Interaction (HCI) field, we usually use usability testing to do evaluation. This notion initially focused on adults [51][52], later children’s different requirement became noticeable, and it leads to more children-centered methods in usability testing. In a study from Malaysia [51], some researchers attempted to find out issues that have been overlooked in performing testing with children. They point out that some testers, especially younger ones, seemed to have trouble communicating with children.

As we know, usually children are taught to not to trust strangers easily. When you first meet a kid, it is suggested to establish relationships by engaging him or her into some small talk to find out more about each other. Topics like birthday, favorite computer games, or favorite subjects at school [30] could trigger children’s interest. Other than that, some children are quite introverted, and not willing to talk too much. In this case, a good way is to use “friendship pairs” [37] during the communication with children. Friendship pairs in conducting research refers to obtaining information from participants, by speaking to their outgoing peers who know about their experience of using any websites or apps. However, even the children users are willing to talk to the tester; another challenge is that they can be very unpredictable regarding actions and behaviors [51]. And most of the children aged from 4 to 6 year old are still not ready to sit at task and follow directions from an adult. Besides, children at this age stage usually have difficulty expressing their likes and dislikes in words [30]. Under this circumstance, we could apply observation in the evaluation process. When children users are sighing, smiling or sliding under the table, it can indicate they like or dislike your design to a certain degree.

As for some other aspects, such as preparation, lab environment and so on need to be taken care during the usability testing with children, we can use Figure 12 and Figure 13 from previous studies [46][51] about usability testing with children to summarize the specific guidelines for testers.

V. CONCLUSION

This paper attempts to investigate some guidelines for icon and interface design for 4 to 6 year olds by analyzing children user characteristics, incorporating Piaget’s development stages theory and user-centered design concept. The design procedures could be summarized as having an idea, conducting field research, producing design solution, doing design evaluation by usability testing, and making some modifications. In general, based on findings from different studies, design icon on interface for children should strike a balance between a plain, unimaginative but functional design and a colorful and animated design.

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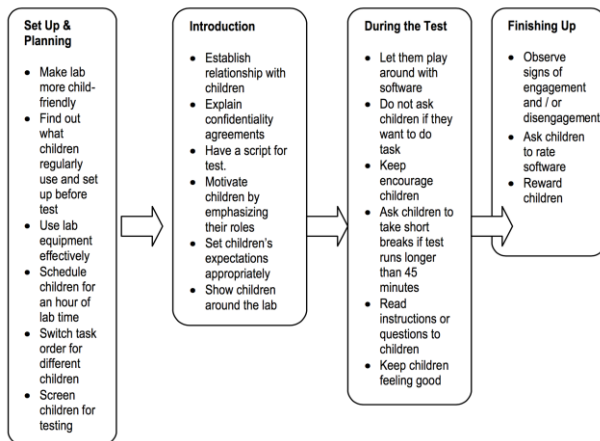


Figure 12. Guidelines from Hanna, Ridsen and Alexander [30][51].

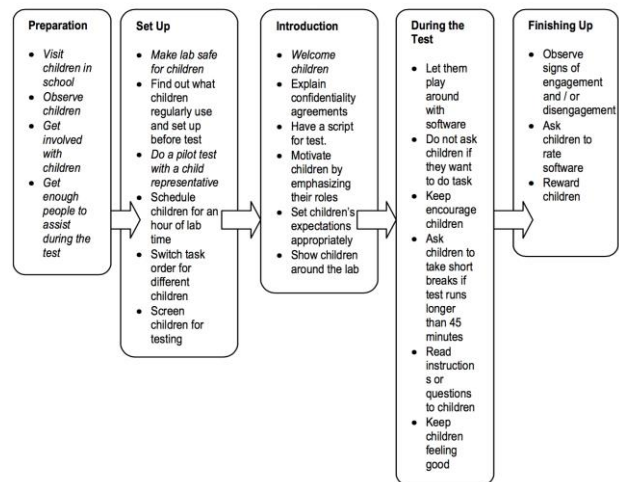


Figure 13. Additional steps in usability testing with children [51].