International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:9, No:5, 2015

Triadic Relationship of Icon Design for Semi-Literate Communities

Peng-Hui Maffee Wan, Klarissa Ting Ting Chang, Rax Suen Chun Lung

Abstract**—** Icons, or pictorial and graphical objects, are commonly used in human-computer interaction (HCI) fields as the mediator in order to communicate information to users. Yet there has been little studies focusing on a majority of the world's population – semi-literate communities – in terms of the fundamental knowhow for designing icons for such population. In this study, two sets of icons belonging in different icon taxonomy – abstract and concrete – are designed for a mobile application for semi-literate agricultural communities. In this paper, we propose a triadic relationship of an icon, namely meaning, task and mental image, which inherits the triadic relationship of a sign. User testing with the application and a post-pilot questionnaire are conducted as the experimental approach in two rural villages in India. Icons belonging to concrete taxonomy perform better than abstract icons on the premise that the design of the icon fulfills the underlying rules of the proposed triadic relationship.

Keywords**—** icon, GUI, mobile app, semi-literate.

I. Introduction

Semi-literate communities refer to the group of people who have achieved an elementary level of ability in reading and writing. Although limited, this group has started to use technological devices, such as cellphones. There is currently over 5.9 billion cell phone users worldwide [1] with 87% global penetration, and close to 79% of subscribers are in developing countries [2]. News announced in March 2012 indicated that half of India's homes have cellphones, but not toilets [3]. The rate of smartphone adoption has grown exponentially each year at the early 21st century [4]. Yet there has been little investigation of cellphone applications in semi-literate communities. Any impact on this group, though seems trivial, is crucial.

By looking at the social-economic pyramid, semi-literate communities, occupying the middle of the pyramid (MOP), is the next biggest population after the group at the top pyramid. What needs to be considered from the perspective of this group is different from the typical users (e.g. literate and well-educated) in our daily lives, and has to be cultural and language independent.

An icon is defined as a graphical representation of concepts that symbolize computer actions [4]. Icon-based graphical user interface (GUI) has been widely used in cellphone applications. Despite its importance and potentials, yet there has been little studies focusing on designing icon-based GUI for semi-literate communities. Studies have recognized the value of imagery, and have recommended extensive use of graphics [12, 13, 14, 15] for designing for semi-literate communities. Moreover, icons have demonstrated their universal comprehensibility [5, 6, 7, 8] and are used extensively in interface design on the assumption that visual icons are capable of exceeding language barriers and of transforming meaning in compact representations [9, 10, 11].

It is fair to assume that an icon-based GUI is an appropriate approach while designing cellphone applications for semi-literate communities. The first objective of this study is to prove this assumption. Secondly, whether concrete or abstract icons have better icon performance is debatable. A lot of studies reveal that concrete icons perform better on a consistent basis than abstract ones [7, 16, 17, 18, 19, 20]. However, there are some studies posing opposed opinions in which abstract icons perform better than concrete ones [16, 21, 22]. Whichever is better, these studies have been conducted with literal and well-educated group, while little focus on semi-literate communities.

The objective of this study is to understand whether concrete or abstract icons perform better on mobile apps for semi-literate communities, and further investigate underlying design knowhow of that. The organization of this paper is as follows. In the section of background, existing related work on icon, icon-based GUI, and related works on semi-literate communities are discussed. The section of Experiment talks about the experimental approach on evaluating the icons, which includes a user-testing experiment, a questionnaire, data collection and analysis. The discussion of the data analysis of the GUI evaluation is depicted in the section of Discussion. The section of Conclusion concluded the study about the key findings, followed by the section of Limitation and Contribution.

II. Background

Designing an icon-based GUI for mobile apps for semi-literate communities, the next billion users, is the focus of this study. The related background studies are listed in the following section.

Peng-Hui Maffee Wan is with Department of Information Systems, National University of Singapore (e-mail: diswp@nus.edu.sg).
Klarissa Ting Ting Chang is with Department of Information Systems, National University of Singapore (e-mail: changtt@comp.nus.edu.sg).

A. Semi-literate Communities

Semi-literate communities have become the world's next biggest population other than the group at the top of the social-economic pyramid. Less than 50% of the adult population of the developing countries is literate, which is described as the ability to read and write with their native languages [23]. There is a big percentage of population is nonliterate or semi-literate. For example, 37.2% in India is illiterate, or at least textually-illiterate [24].

Semi-literate or nonliterate users are very different from the target users of typical GUI designs [25]. A GUI working perfectly for typical users may not be appropriate to semi-literate populations. Previous research shows that semi-literate or nonliterate populations tend to avoid complex functions while using cellphones, and use cellphones primarily for synchronous voice communications [26]. One study [27] interviews 79 subjects and 100 hours in India, Philippines, and South Africa and reveals several barriers to using existing text-based interfaces, including difficulties understanding or hierarchical structures, soft keys, scroll bars, nonnumeric inputs, and specialized terminology. [23] proposes an icon-based user interface so that low educated people can retrieve information from Internet, by composing their queries by means of selecting tools.

Although not focusing on cellphones, studies have been done on GUIs for low-literacy users in the context of Automatic Teller Machines (ATM). Results from the studies reveal that low-literacy people prefer an icon-based ATM interface over a speech-based interface [28, 29, 30].

Some studies have been done regard to speech-based interfaces to access information services for semi-literate communities. Such as VoiKiosk – a system provides a voice-based kiosk solution for people in rural areas [31] and StoryBank – a system distributes digital stories within an Indian village [32]. [33] investigates the media needs of low-income mobile users in a South Africa township. The study discovers not only the community interested in developmental information, but are also just as interested in sharing local music or videos. The uses for such a system are much wider than researchers might previously have imagined.

B. Triadic Relationship

A sign is a device that conducts specific information or meaning. It is defined as "something that stands to someone for something in some respect or capacity" [34]. The sign itself is the production of a three-way relation between the representation (which represents), the sign's object (which is represented) and its interpretant (the process of interpretation). The triadic relationship of a sign is described in Fig 1 [35]. A sign is generally composed of textual and pictorial objects, in which the pictorial object is commonly referred as an icon.

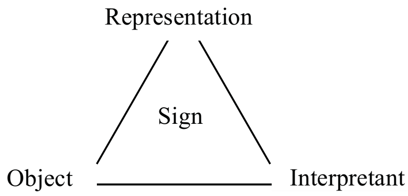


Fig 1. A triadic relationship of a sign [35].

When a designer designs an icon, he/she is trying to use the icon to convey what he/she intends to convert [36], in many cases, the task and its functionality. Correspondingly, when the user interacts with an icon, he/she is required to guess what the icon is intended to convey – the meaning of an icon. An icon can represent both the referent and its attributes, association and states [9]. One major advantage of an icon-based interface is that icons are easily recognized [37], and help users memorize and recognize functions available within an application [38]. Moreover, ideally, icons used in an interface should activate the appropriate mental images in the users. Mental images or imagery has been discussed in design and psychology related fields [39, 40, 41]. There are many factors which may influence the performance of an icon-based GUI, and its icons. The inevitable difference between the mental image of the designer and the user is one [42].

Mapping from Nadin's [35] idea of the triadic relationship of a sign, a triadic relationship of an icon – a three-way relationship between the meaning, the task and the mental image - is proposed for the use of this study (see Fig 2). A sign's representation maps to an icon's meaning; a sign's object maps to an icon's task and lastly a sign's interpretant maps to an icon's mental image.

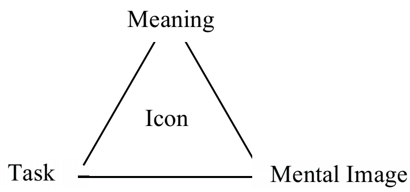


Fig 2. A triadic relationship of an icon.

C. Icon Taxonomy

Several studies have been posed on icon design strategy. The effects on icon design on HCI is discussed in [22, 43], where icon characteristics are investigated to determine the speed and accuracy of icon identification.

Classification of icons by type is known as icon taxonomy [49]. Many researchers have used an icon taxonomy to measure the effectiveness of different icon types as it offers a methodical framework for assessment [6, 18]. Although many researchers employ similar principles to classify icons, some researchers identify more categories than others. Differences also exist in researcher's inclusion. Amongst various classifications, the most common icon taxonomy – abstract and concrete - is categorized according to their physical form.

An abstract icon depicts abstract elements such as metaphysical arrows, shapes and arbitrary shapes. An abstract icon often needs learning to be understood as its meaning is assigned [44, 45, 46]. A concrete icon (can be considered a merger of Roger's [21] resemblance, exemplar and symbolic icon types) is an icon that only depicts physical items that exist in the real world such as a file or scissors [44, 47, 48].

Concrete icons are thought to be easiest to interpret as they allow people to apply their everyday knowledge, about the objects depicted by them, in order to make inferences about the function of the icon [49]. Conversely, abstract icons are likely to represent information using graphical features such as arrows or lines and consequently have less obvious connection with their real world referents [50].

Research has shown that user respond more quickly and accurately to concrete icons than to abstract icons, thus supporting the idea that a pictorial or visually obvious symbol will be most easily understood by a user [16, 17, 18, 19, 20]. Stammers [49] found that even when users preferred concrete icons for a function, they did not always respond more quickly or accurately than they did with abstract icons. However, the performance of these two sets is not culture independent. Korean subjects perform significantly better in the set of concrete icons while American subjects show the opposite tendencies. But no significant differences in preference according to icon style are found [51]. No matter which cultural background users have, the more details an icon contains and the more concrete an icon is, the more it is correctly interpreted [7].

III. Experiment

Two stages - one user testing with the experimental mobile app and one post-pilot questionnaire – were included in the experiment.

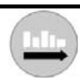
A. Experimental App

An Android mobile app with pure icon-based GUI was implemented and used as the experimental tool. The mobile app is designed for local farmers to report pest incidences and share pest-related information. Agriculture is chosen as the context for the reason that a lot of rural farmers are semi-literate and pest management is a crucial problem in their real life. There are six selective icons in the app, including profile, report, alert, timeline, advice and search.

B. Variables

Two sets of icons were implemented with the same function for the application. One set of icons belongs to the concrete icon composition and another one belongs to the abstract composition (see Table I).

TABLE I
TNITS SETS OF ICONS

	Profile	Report	Alert	Timeline	Advice	Search
Concrete						
Abstract						

These icons are designed by a professional graphics designer and categorized by three other professional graphics designers.

C. Objective

We assume that icons falling in certain taxonomy (whether concrete or abstract) are more suitable for designing icon-based GUI for cellphone applications for semi-literate communities. Corresponding design guidelines related to the proposed triadic relationship are expected to be discovered as well.

D. Participants

A total of 57 semi-literate farmers in India – 28 from farming villages in Pabal and 29 from villages in Nasik – participated and completed the experiment voluntarily. None of the participants had knowledge of the objective of the experiment prior to the experiment. Participants were asked to complete assigned tasks using the experimental application and corresponding questionnaire.

E. Materials

Two experimental materials – an Android phone application with two different sets of icons only GUI (See Fig 3) and a questionnaire – were included in the experiment. Three tasks occupied with either low (see Table II) or high task complexities (see Table III) were evenly and randomly assigned to the participants.

Fig 3. The experimental app with two different sets of icons.

TABLE II
TASKS IN LOW COMPLEXITY

Task name	Task description	Concrete icon required	Abstract icon required
T_{1L}	Report any pest		
T_{2L}	Find any pest alert		
T_{3L}	Find any advice about pest control		

TABLE III
TASKS IN HIGH COMPLEXITY

Task name	Task description	Concrete icon required	Abstract icon required
T_{1H}	Report an observation of mealy but on grapes		
T_{2H}	Find a pest alert from Pune		
T_{3H}	Check out the report for mealy bugs on grape 2 days ago, and find an advice about removing mealy bugs from grapes.		

The questions regard to how strongly did the participants agree (strongly disagree to strongly agree, in 5 scales) on the pairing of the meaning and the icon were asked in the questionnaire.

F. Procedure

Participants were asked to accomplish three tasks with the experimental cellphone application, followed by the questionnaire. The detail of the procedure is described in the sequel:

A 5-10 minutes brief introduction and asking general questions (e.g. name, age and family income

Introduction of the experimental application. Participants were told how to use a touch-screen Android phone, including menu button and back button.

Participants were assigned Android cellphones with pre-installed experimental application. The icons of the application can be either in concrete or abstract. Participants were asked to explore the experimental application for 5 to 7 minutes.

Participants were asked to complete their assigned tasks, one at a time. The time limit for completing each task was 4 minutes and the total time limit for completing three tasks were 12 minutes. The task was considered incomplete if the participants failed to accomplish it within the time limit.

Participants were asked to complete the questionnaire after finishing the three assigned tasks.

The procedure was conducted verbally in the local language (Hindi) of the participants.

G. Results and Analysis

Both quantitative and qualitative results were collected from the experiment for further analysis. Five quantitative results – task completion rate, assumed obtained goal rate, task completion time, number of prompts requires and number of errors - were collected from the process while participants working on the tasks with experimental application. One qualitative result was collected from the questionnaire.

For the quantitative results, the data at four levels were collected and analyzed, which are at the overall level (L_O), the level in low task complexity (L_L), the level in high task complexity (L_H), the level of task 1 (L_{T1}), the level of task 2 (L_{T2}) and the level of task 3 (L_{T3}).

The numbers with higher values are marked with underlines for the tables in this section.

- *Task completion rate*

Task completion rate is the percentage of the participant who successfully finished the given tasks in the experiment. The task was also considered incomplete if failed or withdrawn.

The average task completion rate at L_O of the concrete set of icons is 85.06% while that of the abstract set of icons is 64.29%. The average task completion rate at L_L of the concrete set of icons is 44.83% while that of the abstract set of icons is 27.38%. The average task completion rate at L_H of the concrete set of icons is 40.23% while that of the abstract set of icons is 36.9% (see Table IV).

TABLE IV
TASKS COMPLETION RATE

	Concrete	Abstract
L_O	85.06%	64.29%
L_L	44.83%	27.38%
L_H	40.23%	36.90%

Regard to the level of the task, the average task completion rate at L_{T1} of the concrete set of icons is 79.81%, while that at L_{T2} is 89.66% and that at L_{T3} is 86.21%. The average task completion rate at L_{T1} of the abstract set of icons is 85.71%, while that at L_{T2} is 50.00% and that at L_{T3} is 57.14% (see Table V).

TABLE V
TASKS COMPLETION AT THE TASK LEVEL

	Concrete	Abstract
L_{T1}	79.31%	85.71%
L_{T2}	89.66%	50.00%
L_{T3}	86.21%	57.14%

Participants successfully completed more tasks while using the experimental application with the concrete set of icons than the abstract set at L_O, L_L, L_H, L_{T2} and L_{T3}. Participants successfully completed more tasks while using the experimental application with the abstract set of icons than the concrete set at L_{T1}.

- *Assumed obtained goal rate*

Assumed obtained goal rate is the percentage of participants who thought they successfully completed the given tasks in the experiment.

The average assumed obtained goal rate at L_O of the concrete set of icons is 95.40% while that of the abstract set of icons is 79.76%. The average assumed obtained goal rate at L_L of the concrete set of icons is 49.43% while that of the abstract set of icons is 42.86%. The average assumed obtained goal rate at L_H of the concrete set of icons is 45.98% while that of the abstract set of icons is 36.9% (see Table VI).

TABLE VI
ASSUMED OBTAINED GOAL RATE

	Concrete	Abstract
L_O	95.40%	79.76%
L_L	49.43%	42.86%
L_H	45.98%	36.90%

Regard to the level of the task, the average assumed obtained goal rate at L_{T1} of the concrete set of icons is 93.10%, while that at L_{T2} is 96.55% and that at L_{T3} is 96.55%. The average assumed obtained goal rate at L_{T1} of the abstract set of icons is 89.29%, while that at L_{T2} is 71.43% and that at L_{T3} is 78.57% (see Table VII).

TABLE VII
ASSUMED OBTAINED GOAL RATE AT THE TASK LEVEL

	Concrete	Abstract
L_{T1}	93.10%	89.29%
L_{T2}	96.55%	71.43%
L_{T3}	96.55%	78.57%

Participants thought they successfully completed more tasks while using the experimental application with the concrete set of icons than the abstract set at L_O, L_L, L_H, L_{T1}, L_{T2} and L_{T3}.

- *Completion time*

The completion time is how much time participants spent on finishing the given tasks (in seconds), successfully or not. If the participant failed to complete the assigned task within the time limit (4 minutes), he/she would be told to stop the task, and the completion time of such task would be recorded as 240 seconds.

The average completion time at L_O of the concrete set of icons is 58.02 seconds while that of the abstract set of icons is 80.71 seconds. The average completion time at L_L of the concrete set of icons is 53.89 seconds while that of the abstract set of icons is 63.57 seconds. The average completion time at L_H of the concrete set of icons is 62.45 seconds while that of the abstract set of icons is 97.86 seconds (see Table VIII).

TABLE VIII
COMPLETION TIME

	Concrete	Abstract
L_O	58.02	80.71
L_L	53.89	63.57
L_H	62.45	97.86

Regard to the level of the task, the average completion time at L_{T1} of the concrete set of icons is 71.86 seconds, while that at L_{T2} is 38.69 seconds and that at L_{T3} is 63.52 seconds. The average completion time at L_{T1} of the abstract set of icons is 73.18 seconds, while that at L_{T2} is 99.00 seconds and that at L_{T3} is 69.96 seconds (see Table IX).

TABLE IX
COMPLETION TIME AT THE TASK LEVEL

	Concrete	Abstract
L_{T1}	71.86	73.18
L_{T2}	38.69	99.00
L_{T3}	63.52	69.96

Participants spent less time finishing the tasks while using the experimental application with the concrete set of icons than the abstract set at L_O, L_L, L_H, L_{T1}, L_{T2} and L_{T3}.

- *Number of prompts required*

Number of prompts required is how many times the participants asked for reminders/prompts while working on the given tasks in the experiment.

The average number of prompts required at L_O of the concrete set of icons is 1.91 times while that of the abstract set of icons is 2.25 times. The average number of prompts required at L_L of the concrete set of icons is 1.84 times while that of the abstract set of icons is 2.33 times. The average number of prompts required at L_H of the concrete set of icons is 2.05 times while that of the abstract set of icons is 2.17 times (see Table X).

TABLE X
NUMBER OF PROMPTS REQUIRED

	Concrete	Abstract
L_O	1.94	2.25
L_L	1.84	2.33
L_H	2.05	2.17

Regard to the level of the task, the average number of prompts required at L_{T1} of the concrete set of icons is 2.48 times, while that at L_{T2} is 1.24 times and that at L_{T3} is 2.10 times. The average number of prompts required at L_{T1} of the abstract set of icons is 3.18 times, while that at L_{T2} is 2.18 times and that at L_{T3} is 1.39 times (see Table XI).

TABLE XI
NUMBER OF PROMPTS REQUIRED AT THE TASK LEVEL

	Concrete	Abstract
L_{T1}	2.48	3.18
L_{T2}	1.24	2.18
L_{T3}	2.10	1.39

Participants requested fewer prompts while using the experimental application with the concrete set of icons than the abstract set at L_O, L_L, L_H, L_{T1} and L_{T2}. Participants requested fewer prompts while using the experimental application with the abstract set of icons than the concrete set at L_{T3}.

- *Number of errors*

Number of errors is how many time the participant made mistakes while working on the given tasks in the experiment.

The average number of errors at L_O of the concrete set of icons is 2.33 times while that of the abstract set of icons is 2.43 times. The average number of errors at L_L of the concrete set of icons is 1.87 times while that of the abstract set of icons is 2.31 times. The average number of errors at L_H of the concrete set of icons is 2.55 times while that of the abstract set of icons is 2.83 times (see Table XII).

TABLE XII
NUMBER OF ERRORS

	Concrete	Abstract
L_O	2.33	2.43
L_L	1.87	2.31
L_H	2.55	2.83

Regard to the level of the task, the average number of errors at L_{T1} of the concrete set of icons is 2.66 times, while that at L_{T2} is 1.38 times and that at L_{T3} is 2.97 times. The average number of errors at L_{T1} of the abstract set of icons is 2.39 times, while that at L_{T2} is 2.50 times and that at L_{T3} is 2.39 times (see Table XIII).

TABLE XIII
NUMBER OF ERRORS AT THE TASK LEVEL

	Concrete	Abstract
L_{T1}	2.66	2.39
L_{T2}	1.38	2.50
L_{T3}	2.97	2.39

Participants made fewer errors while using the experimental application with the concrete set of icons than the abstract set at L_O, L_L, L_H, and L_{T2}. Participants made fewer errors while using the experimental application with the abstract set of icons than the concrete set at L_{T1} and L_{T3}.

- *Qualitative result*

Participants were asked to answer on how strongly they agree on the pairing of the meaning and the icon. From scale 1 to 5, the option of strongly disagree is 1 and the option of strong agree is 5. The results were the average answers from the participants (see Table XIV). The higher the number, the stronger the participants agreed on the pairing of the meaning and the icon.

TABLE XIV
RESULTS OF THE QUESTIONNAIRE

	Profile ($p<0.05$)	Report ($p<0.05$)	Alert ($p>0.05$)	Timelin e($p<0.0$ 5)	Advice ($p<0.05$)	Search ($p<0.05$)
Concrete	 4.18	 4.18	 4.16	 3.29	 3.96	 4.14
Abstract	 3.46	 3.47	 4.21	 2.39	 3.23	 2.59

Participants agree more on the pairing of the meaning of the icon of the concrete set of profile, report, timeline, advice and search. And the differences between the concrete and abstract icon is significant ($p < 0.05$). They agree more on the pairing of the meaning of the icon of the abstract icon of alert. And the differences between the concrete and abstract icon is not significant ($p > 0.05$).

IV. DISCUSSION

Overall, the concrete set of icons performs better than the abstract set of icons, on both user testing and questionnaire, while testing with semi-literate communities. The result is consistent the studies in the related fields [16, 17, 18, 19, 20].

The concrete set of icons performs better on task completion at L_O, L_L, L_H, L_{T2} and L_{T3}, assumed obtained goal rate at L_O, L_L, L_H, L_{T1}, L_{T2} and L_{T3}, task completion time at L_O, L_L, L_H and L_{T2}, number of prompts required at L_O, L_L, L_H, L_{T1} and L_{T2}, and number of errors at L_O, L_L, L_H and L_{T2}, while comparing to the abstract set of icons. Better performance means better task completion and assumed goal rate, less prompts required, shorter completion time and less errors.

The abstract set of icons perform better on task completion rate at L_{T1}, task completion time at L_{T1} and L_{T3}, number of prompts required at L_{T3}, and number of errors at L_{T1} and L_{T3}, while comparing to the concrete set of icons.

Regard to the pairing of the meaning and the icon, the concrete icon of profile, report, timeline, advice and search perform better than the abstract ones, while the abstract icon of alert performs better than the concrete one.

Recapping, a proposed triadic relationship of an icon (see Fig 2) for semi-literate communities includes the meaning, the mental image. Upon participants seeing an icon, three mapping processes is conducted in their minds – the mapping between the icon and its meaning, the mapping between the icon and its corresponding task and the mapping between the icon and the participant's mental image (see Fig 2). Some underlying phenomena are needed to be discussed for the occurrences where abstract icons perform better than concrete ones. The detail is discussed in the sequel.

- *Task 1*

The description of the task 1 is to report the incidence of pests. Participants were expected to use same icons for both low and high task complexities.

The notion of the task itself is rather novel to the participants. Although the participants were familiar with the idea of seeing a pest on the crops, the concept of "reporting" is comparably new.

From the results of the questionnaire, we understand that participants did not have much difficulty linking the meaning to the icon of report, while concrete icon (4.18) did perform better than abstract one (3.47) (see Table XIV).

The representation of the concrete icon of report is a pen, a piece of paper and a clipboard. The representation of the abstract icon of report is a symbolized paper, few lines and a check mark symbol (see Fig 4). While the participants tried to accomplish task 1, what they needed to do in order to finish the task was clicking the report icon, followed by clicking a binary icon – "pest observed" or "pest not observed". Based on the result that abstract report icon performed better than the concrete one at L_{T1} on the task completion rate (see Table V) and number of errors (see Table XIII), we can conclude that the abstract icon of report (with the mark symbol) has a stronger linkage with its corresponding task (clicking a binary icon), hence has a stronger linkage with the mental image to the participants than the concrete one (with pen, paper and clipboard).

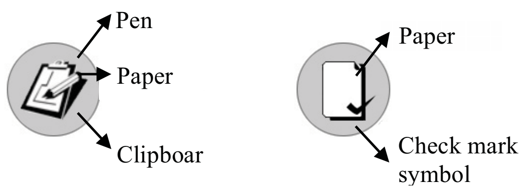


Fig 4. Representation of concrete (left) and abstract (right) report icons.

- *Task 3*

The description of the task 3 is to find an advice about pest control. Participants were expected to use the icon of advice for task in low complexity and use the icon of timeline for task in high complexity.

From the results of the questionnaire, we understand that participants did not have much difficulty linking the meaning to the concrete icon of advice (3.96) and abstract icon of advice (3.23), while the concrete icon performs better than the abstract one (see Table XIV).

The representation of the concrete icon of advice is a person and a paper. The representation of the abstract icon of advice is two white dialogue boxes and one black dialogue box (see Fig 5). These are the required icons for task 3 in low complexity. While the participants tried to finish task 3 in low complexity, what they needed to do in order to finish the task is to find a pest report, which looked similar to a dialogue box on a cellphone screen.

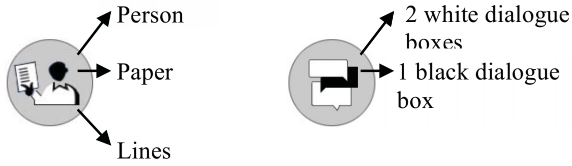


Fig 5. Representation of concrete (left) and abstract (right) advice icons.

The similarity of the representation of the task and the abstract advice icon can explain why participants requested more prompts and made fewer errors for task 3 in low complexity while using abstract icon than concrete one. We can conclude that the abstract advice icon (with the dialogue boxes) has a stronger linkage with its corresponding task (dialogue boxes on screen), hence has a stronger linkage with the mental image to the participants than the concrete one (with person, pen and lines).

Participants do have similar experiences in recording crop growth in a notebook or a diary, so they do understand the concept of recording incidences over time. But the task of finding an advice or report in a chronologically record is rather novel and arbitrary to the participants.

From the results of the questionnaire, we understand that participants did not have much difficulty linking the meaning to the concrete icon of timeline (3.29). But the participants did show difficulties linking the meaning to the abstract icon of the timeline (2.39). The result of the abstract icon of timeline is the lowest value in the qualitative data (see Table XIV).

The representation of the concrete icon of timeline is a calendar. The representation of the abstract icon of timeline is several dialogue boxes and a unidirectional arrow (see Fig 6). These are the required icons for task 3 in high complexity. In order to accomplish task 3 in high complexity, the participants had to use scroll bars to locate a certain pest advice in the past. The concept of a scroll bar might be rather novel to the participants, but the appearance of a scroll bar definitely looks similar as a unidirectional arrow. Although the concept of a calendar is more acceptable to the semi-literate communities and has better linkage to the meaning of "timeline" than the abstract icon, it has little connection linking to the task.

Fig 6. Representation of concrete (left) and abstract (right) timeline icons.

The similarity of the representation of the task and the abstract advice icon can explain why participants requested more prompts and made fewer errors for task 3 in high complexity while using abstract icon than concrete one. We can conclude that the abstract timeline icon (with the unidirectional arrow) has a stronger linkage with its corresponding task (scroll bar), hence has a stronger linkage with the mental image to the participants than the concrete one (with the calendar).

The alert icon

Other than the icon of alert, the rest of the icons perform better with the concrete composition than the abstract one. However, the difference is minor and insignificant, while the concrete icon of alert is 4.16 and the abstract icon is 4.21 ($p > 0.05$, see Table XIV). Besides, for the task (task 2) which requires the icon of alert, the concrete one performed better than the abstract one on all the quantitative results.

Both of the concrete and abstract icons of the alert do share one similarity – a symbol of a pest. With this similarity and all quantitative and qualitative results, we can simply conclude that the appearance of the symbol of a pest plays the main role on linking the triadic relationship of the icon of alert – the meaning, the mental image and the task.

While tasks completion rates were higher, more time as well as more external assistance was required. We attribute this to the fact that users required significant prompting, encouragement, and time to press any key as they were nervous that they might "break" or "spoil" the phone [12].

V. Conclusion

The goal of this study is to 1) understand whether concrete or abstract icons perform better, and 2) comprehend the underlying phenomena on the triadic relationship of an icon (see Fig 2) while designing icon-based GUI mobile app for semi-literate communities.

Two sets of icons (six each), concrete and abstract composition, are used as the experimental GUI. A user-testing with the experimental application and a questionnaire were conducted in India with local farmers.

Based on the quantitative and qualitative results, we can conclude that, in general, icons with the concrete composition perform better than the abstract one, for icon-based cellphone GUI in semi-literate communities. This finding reveals the universal comprehensibility of icons. Hence we can conclude that an icon-based GUI is appropriate for cellphone application for semi-literate communities. However, not all concrete icons are more appropriate than abstract ones in such occurrences. When a designer designs an icon, he/she has to consider thoroughly within its triadic relationship - the meaning, the task and the mental image. An abstract icon could perform better than a concrete one if the design of it fulfills the icon's triadic relationship (see Fig 2). Based on the discussion, the most influential factor amongst the triadic relationship is the mapping between the icon and the task.

What reveals in this study is that, in most cases, icons are designed only fulfilling one segment of the triadic relationship, e.g. mapping with the meaning. But such icon lacks the consideration of mapping with the task and/or the mental image may lead to a complete opposite outcome, in particular for semi-literate communities. Semi-literate communities do not have exposure to technological objects in their daily lives. Their mental image while seeing an icon is influenced by the corresponding task of the icon. Such process is very different from typical GUI users. Although it may seem trivial, the task-oriented designing approach for an icon-based GUI opens a new door to designing for semi-literate communities.

VI. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

VII. Limitations and Contributions

Not all icons were tested with the experimental application. Icons of profile and search were only tested with the questionnaire. Besides, 57 participants in a single country may not be sufficient, more participants in multiple countries with different languages are expected in the future studies.

Designing for icon-based cellphone GUI for semi-literate communities is an innovative topic. As the gradually popularization of cellphones (in particular smartphones) in semi-literate communities, the topic is worth noticing and has great values in both academic and industry. Design guidelines regard to the triadic relationship of the icon is also expected in future studies.

Designers have used to design for literate users. These users often have vivid knowledge to innovative technological objects. Such group also adapts to new GUIs quite easily. The boundaries between concrete and abstract icons become ambiguous and fuzzy for these users. From the perspective of design, designing for semi-literate users forces the designers to rethink from the point of users. Because semi-literate users have difficulties adapting to new GUIs, a GUI and its icons have to be well designed to have a good performance. We are also surprised to learn that how fast a semi-literate user can learn to use a mobile app that he/she has not seen or used before. We suspect the familiarity of the content also helps to bridge the learning gap. This study brings new thoughts to both icon-based GUI design and designing application for semi-literate communities.

Acknowledgment

This is a technology project under the Center of Social Media Innovations for Communities (COSMIC), supported by the Interactive Digital Media Programme Office and hosted by the National Research Foundation.

REFERENCES

[1] ITU. Measuring the Information Society: The ICT Development Index. *International Telecommunications Union*, 2012.

[2] UNCTAD. Information economy report: science and technology for development - The new paradigm of ICT. *United Nation Conference on Trade and Development*, 2012.

[3] Half of India's homes have cellphones, but not toilets. http://www.thehindu.com/news/national/article2992061.ece, 2012.

[4] Garcia, M., Badre, A. N., and Stasko, J. T. Development and validation of icons varying in their abstractness. *Interacting with Computers 6*, (1994), 191-211.

[5] Schroder, S., and Ziefle, M. Effects of icon concreteness and complexity on semantic transparency: younger vs. older users. Presented at conference, *ICCHP '08 Proceedings of the 11th international conference on Computers Helping People with Special Needs*. 2008.

[6] Gittins, D. Icon-based human-computer interaction. *International Journal of Man Machine Studies 24,* (1986), 519-543.

[7] McDougall, S. J. P., Curry, M. B., and de Bruijn, O. Exploring the effects of icon characteristics on user performance: The role of icon concreteness, complexity and distinctiveness. *Journal of Experimental Psychology: Applied 6,* 3 (2000), 291-306.

[8] Caplin, S. *Icon design: Graphics Icons in Computer Interface Design*. Cassell, 2001.

[9] Havelock, E. A. *Prologue to Greek Literacy*. University of Cincinnati Press, 1971.

[10] Grisedale, S., Graves, M., and Grunsteidel, A. Designing a graphical user interface for healthcare workers in rural India. *Presented at conference, Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI)* (1997).

[11] Parikh, T., Ghosh, K., and Chavan, A. Design considerations for a financial management system for rural, semi-literate users. *Proceedings of the ACM Conference on Human Computer Factors in Computer Systems* (CHI) (2003).

[12] Medhi, I., Sagar, A., and Toyama, K. Text-Free user interfaces for illiterate and semiliterate users. *Inf. Technol. Int. Devel 4*, 1 (2007), 37-50.

[13] Arend, U., Muthig, K.-P., and Wandmacher, J. Evidence for global feature superiority in menu selection by icons. *Behavior and Information Technology 6*, (1987), 411-426.

[14] Rogers, Y., and Oborne, D. J. Pictorial communication of abstract verbs in related to human-computer interaction. *British Journal of Pshychology 78*, (1987), 99-112.

[15] Stammer, R. B., George, D. A., and Carey, M. S. *An Evaluation of Abstract and Concrete Icons for A CAD Package*. In E. D. Megaw, ed., Contemporary ergonomics. Taylor & Francis, 1989.

[16] Stammer, R. B., and Hoffman, J. Transfer between icon sets and ratings of icon concreteness and appropriatness. *Proceedings of the Human Factors Society 35th Annual Meeting*. Santa Monica, (1991).

[17] Stotts, D. B. The usefulness of icons on the computer interface: Effect of graphical abstraction and functional representation on experienced and novice users. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting*. Santa Monica, (1998).

[18] Rogers, Y. Icons at the interface: their underfulness. *Interacting with Computers 1*, (1989), 105-117.

[19] Santa, M., Debasis, S., Satya, R. D., et al. Language independent icon-based interface for accessing internet. *Advanced in Computing and Communications 191*, 3 (2011), 172-182.

[20] Statistics, UNESCO Institue for. http://www.uis.unesco.org/literacy/Pages/adult-youth-literacy-data-viz.aspx.

[21] Cooper, A., and Reimann, R. *About Face 2.0, The Essentials of Interaction Design*. Wiley Publishing, 2003.

[22] Chipchase, J. *Understanding Non-Literacy as A Barrier to Mobile Phone Communication*, 2005.

[23] Indrani, M., Somani, P., Emma, B., et al. Designing mobile interfaces for novie and low-literacy users. *ACM Transactions on Computer-Human Interaction 18*, 1 (2011), 2-28.

[24] Ivatury, G. Harnessing technology to transform financial services for the poor. *Small Enterpr. Devel. 15*, 4 (2004), 25-30.

[25] Thatcher, A., Shaik, F., and Zimmerman, C. Attitudes of semi-literate and literate bank account holders to the use of automatic teller machines (ATM*). Int. J. Industrial Ergonomics 35*, (2005), 15-30.

[26] Thatcher, A., Mahlangu, S., and Zimmerman, C. Accessibility of ATMs for the functionality illiterate through icon-based interfaces. *Behav. Inf. Technol. 25*, 1 (2006), 65-81.

[27] Sheetal, K. A., Arun, K., Amit, A. N., et al. User-generated content creation and dissemination in rural areas. *USC Annenberg School for Communication & Journalism 6*, 2 (2010), 21-37.

[28] Frohlich, D. M., Rachovides, D., Riga, K., et al. Storybank: mobile digital storytelling in a development context, *Human Factors Computing Systems (CHI '09),* (2009), 1761-1770.

[29] Andrew, M., Gary, M., and Richard, H. Making the link - providing mobile media for novice communities in the developing world. *International Journal of Human-Computer Studies 69*, (2011), 647-657.

[30] Peierce, C. S. *Collected Papers*. Harvard University Press, 1931.

[31] Nadin, M. Interface design: a semiotic paradigm. *Semiotica 69*, 3/4 (1998), 269-302.

[32] Buchanan, R. Declaration by design: rhetoric, argument, and demonstration in design practice. *Design Issues 2*, 1 (1985), 4-22.

[33] Shneiderman, B. *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Addision-Wesley, 1997.

[34] Siau, K. Human-computer interaction: the effect of application domain knowledge on icon visualization. *J. of Computer Information Systems 45*, 3 (2005), 53-62.

[35] Kosslyn, S. M. Scanning visual Images: some structural imagination, *Perception and Psychophysics*, 1979.

[36] Miller, A. *Imagery in Scientific Thought*. MIT Press, 1986.

[37] Anderson, J. R. *Cognitive Psychology and Its Implications*, 1990.

[38] Norman, D. *Things That Make Us Smart*. Addison-Wesley, 1993.

[39] Blankenbergers, S., and Hahn, K. Effects of icon design on human-computer interaction*. International Journal of Man Machine Studies 35*, (1991), 363-377.

[40] Isherwood, S. J., McDougall, S. J. P., and Curry, M. B. Icon identification in context: the changing role of icon characteristics with user experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society 49*, 3 (2007), 465-478.

[41] Wang, H.-F., Hung, S.-H., and Liao, C.-C. A survey on of icon taxonomy used in the interface design. *14th European conference on Cognitive Ergonomics*. London, 2007.

[42] Lodding, K. N. Iconic interfacing. *IEEE Computer Graphics and Applications 3*, 2 (1983), 11-20.

[43] Blattner, M. A., Sumikawa, D. A., and Greenberg, R. A. Earcons and icons: their structure and common design principles. *Human-computer interactions 4, 1* (1989), 11-40.

[44] Purchase, H. Defining multimedia*. IEEE Multimedia 5*, 1 (1998), 8-15.

[45] Lidwell, W., Holden, K., and Butler, J. *Universal Principles of Design*. Rockport Publishers, 2003.

[46] Moyes, J., and Jordan, P. W. Icon design and its effect on guessability, learnability and experienced user performance. *People and Computers VIII* (1993), 49-59.

[47] Sarah, I. Graphics and semantics: the relationship between what is seen and what is meant in icon design. *Engin. Psychol. and Cog. Ergonomics* (2009), 197-205.

[48] Kim, J. H., and Lee, K. P. Cultural difference and mobile phone interface design: icon recognition according to level of abstraction, *MobileHCI'05*, 2005.

[49] Pappachan, P., and Ziefle, M. Cultural Influences on the comprehensibility of icons in mobile-computer interaction. *Behavior and Information Technology 47*, 4 (2008), 331-337.

[50] Satchell, C., and Ziefle, M. The smart phone as globalizing icon of the early 21st century. http://www.ucd.smartinternet.com.au/Documents/MobilePhone_Globalizing.pdf, 2010.

[51] Ferguson, A., and Brown, W. Standard symbols - using the iso test method. In P. T. McCabe, ed., *Contemporary Ergonomics*. Taylor & Francis, 2003.