Effects of Icon Concreteness and Complexity on Semantic Transparency: Younger vs. Older Users

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Abstract. The semantic transparency of icons in mobile devices was investigated using 48 icons for 12 mobile phone functions. Icons included original ones as well as icons specifically designed for experimental purposes. In order to determine the impact of age, each 10 younger and 10 older adults were examined. Having been acquainted with a reference function, participants had to decide for each of four icons shown on a display as fast as possible whether they represented the respective function. Speed and accuracy of responses were used as dependent variables. Though older adults generally responded slower than younger ones, the very same effects of icon concreteness and complexity showed up in both age groups. Real phone icons did not yield a better performance indicating a suboptimal design. Overall, use of icons in mobile devices in principle can be recommended for users within a wide range of age, *if* icon design obeys ergonomic rules.

Keywords: Icon recognition, mobile devices, ageing, concreteness, complexity.

1 Introduction

Small screen devices have evolved to be the most widespread consumer devices worldwide used in many daily life applications, in mobile communication, in the office sector as well as in the E-health domain. In view of the ever-shrinking screen size the use of icons gives a competitive edge over space consuming text information, especially on global markets since icons redundantize the need to adapt interfaces to different languages [1]. Besides requests for attractive information design, successful usage of icons requires conformance to usability demands and universal accessability. Users stemming from different age groups and having a different upbringing and domain knowledge should be able to recognize easily what the icon represents and what it means in the context in which it is used. This is especially important for people with visual and/or cognitive disabilities, whose information processing might be less developed.

There is a profound knowledge about critical icon characteristics which benefit fast and barrier free recognition and comprehension: abstractness, visual complexity and familiarity. Generally speaking, concrete icons are superior over abstract ones [2,3]. With increasing familiarity, however, the advantage of concreteness decreases [2,4]. In addition, identification of visually complex icons comes along with long recognition and encoding times [5]. Since most of these findings are based on the investigation of icons within traffic and office contexts it is not yet known whether they apply to the context of mobile devices.

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Though the far-reaching demographic change towards an increasingly ageing population entails an ever growing number of older people getting into contact with modern technology and though it is well known that ageing implies profound changes in sensory, physical, psychomotor and cognitive functioning [e.g. 6, 7] hardly any study in the past has investigated the impact of ageing on icon recognition. Distinct age-related differences in information processing speed [e.g. 6, 7, 8] and memory abilities [e.g. 7] have been reported when new and abstract information had to be memorized. In contrast, no age-related differences showed up when pictorial information was concrete and taken from familiar contexts [e.g. 9, 10]. Whether and to what extent these findings apply to icons and imply specific design requirements of elderly people is unclear so far. Possibly age-related deficits and associated obstacles for using mobile devices can be avoided by proper icon design. Therefore regard for elderly people and their requirements in the evaluation process is badly needed.

This study had therefore two major goals: (1) to find out whether icons in mobile devices are easy to understand and which icon features account for semantic transparency and (2) to ascertain whether age related performance differences show up in icon recognition in the field of mobile devices.

2 Method

As the recognition and identification of icons requires their correct assignment to a reference function, a semantic classification task was performed. Participants sequentially processed 12 tasks in each of which a reference function of mobile devices was paraphrased verbally. They had to decide for each icon as fast and unambiguous as possible whether it represented the respective function or not. Participants were equipped with two response keys representing confirmation and rejection. Within each task measurements were repeated four times per icon.

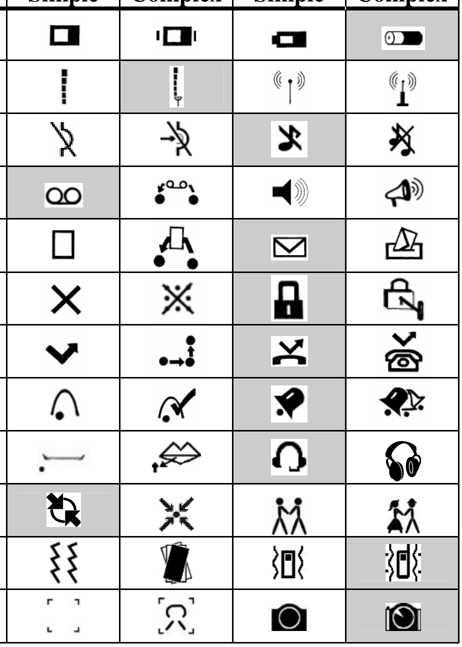
Variables. Three *independent variables* have been varied: (1) icon concreteness (abstract vs. concrete) (2) icon complexity (visually simple vs. visually complex), (3) participants'age (young vs. old). Icon concreteness and complexity were varied orthogonally resulting in four icon groups with the attributes abstract simple (AS), abstract complex (AC), concrete simple (CS) and concrete complex (CC). As each participant completed all combinations, the design consisted of two within-subject-variables (icon concreteness and complexity) and one between-subject-variable (age).

Overall, two *dependent variables* were surveyed: (1) The reaction time (RT) needed to verify or falsify whether any given icon represented a specific reference function or not was measured. RTs were defined to be the time interval from the onset of the icon until participant`s keystroke. RTs were assumed to be shorter, the less ambiguous an icon is with respect to a specific reference function. (2) The fraction of confirmatory responses per item (CR) was measured. CR was assumed to indicate the degree of semantic relatedness between an icon and a reference function. Since both dependent variables indicate differences in icons' appropriateness to represent a reference function, high interrelations between them were expected. It was unclear, however, whether sensitiveness of variables was the same for both ages.

Apparatus and Procedure. The experiment was run on a Pentium II computer with a 15' LCD screen (resolution: 72 dpi). Presentation of icons was controlled by a software program specifically developed for experimental purposes. Icons were shown subsequently in the screen center; within each trial they remained visible up to 6s until the participant responded, followed by a 1s inter-stimulus-interval. To ensure good legibility, icons were carefully scaled to a size of 32x32 Pixel. 8 icons were queried for each function: 4 target icons and 4 dummy icons taken from other functions. Dummy icons were used in order to balance the number of icons with positive and negative relations to the reference concept. All items were repeated four times and presented randomly within each task. In total, twelve blocks (one block per task) had to be completed. Within each block 32 trials had to be processed (in total 384 trials). Familiarizing participants with the task, a training block of 20 trials was presented in the beginning.

Table 1. Complete Icon Set of Twelve Target Functions (real icons are grey shaded)

Reference function	Abstract		Concrete	
	Simple	Complex	Simple	Complex
Battery charging level				
Net availability				
Dial tone silent				
Mailbox				
SMS				
Keylock				
Call diversion				
Alarm clock				
Headset				
Appointment				
Vibration				
Camera				



Participants. 20 participants volunteered in the experiment, 10 younger adults (19 - 29 years; M=21.6, SD=2.9) and 10 older adults (50 - 65 years; M= 55.5, SD=3.5). In order to reflect the ongoing aging processes within users of the active work force, we pursued a benchmark procedure and aimed at the "younger and healthy seniors". All of them were frequent phone and computer users.

Material. 48 icons were investigated in total (Table 1). Icons were assigned to 12 different mobile phone reference functions. Each function was represented by four icons – one each abstract simple, abstract complex, concrete simple and concrete complex. Furthermore one of the four icons each was a real icon taken from a marketable mobile phone. The remaining icons were specifically designed for experimental purposes. Real mobile phone icons were used in order to control for age dependent differences in the expertise and familiarity of icon use. Selection of real icons was guided by the goal to represent each of the four icon combination (AS, AC, CS, CC) with equal frequency. However, no perfect equipartition was achieved since the majority of real mobile phone icons belong to the CS group. The 36 fictitious icons were generated by carefully filling up those categories of icon concreteness and icon complexity not represented by real mobile phone icons so far.

Prestudy. To obtain suggestions for the development of fictitious mobile phone icons the sign production method was employed [11]. 30 participants (16 female, 14 male, 13-53 years) were requested to submit suggestions for the graphical representation of 12 different reference functions. The classification of the real and fictitious mobile phone icons with respect to their visual complexity and concreteness, respectively, was validated in a second step. 60 participants (14 female, 36 male, 21-35 years) rated all icons according to their degree of concreteness and complexity on 5-step-scales each. A value of 1 (5) was assigned to very abstract and very simple (highly concrete and highly complex) icons. Table 2 shows the mean concreteness and complexity ratings. By means of ANOVAs it was ensured that ratings differed in accordance with the requirements of each experimental condition (Table 2).

Table 2. Mean Ratings (M) and Standard Deviations (SD) for Icon Concreteness and Complexity in Each Experimental Condition

	Type of Icon									
	AC		AS		CS		CC			
Icon Characteristic	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*(3,44)*	Bonferroni
Concreteness	1.6	0.3	1.7	0.4	3.5	0.5	3.9	0.4	102,3	AC, AS < CS, CC
Complexity	2.1	0.4	3.3	0.3	2.4	0.2	3.6	0.4	53,6	CS, AS < CC, AC

*$p<0.001$

3 Results

Outcomes were analyzed by means of 3-way repeated measures ANOVA. User age was treated as between-subject variable. Dummies were not included in the evaluation. The significance level was set at 5%.

3.1 Effects of Icon Characteristics

Icon Concreteness. Whereas no effect of icon concreteness on RT was observed (F<1), a significant main effect showed up with respect to CR (F(1,18)=204.5,

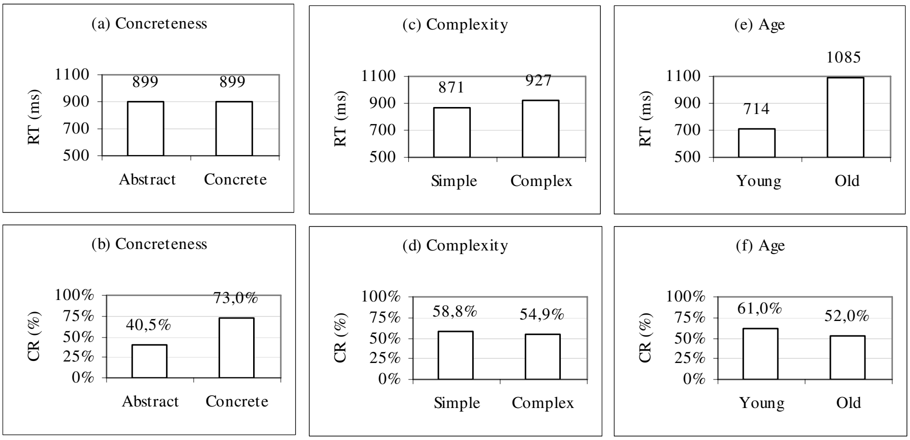


Fig. 1. Mean Reactions Times (upper row) and Confirmative Responses (lower row) for Each Factor Level of Icon Concreteness, Icon Complexity and Age

$p<0.001$). Abstract icons were confirmed in only 40.5% (SD=0.03), concrete icons in contrast in 73.2% (SD=0.03) of all cases (Figure 1a-b).

Icon Complexity. Just the contrary effects were observed for icon complexity: Whereas no significant difference occurred with respect to the fraction of confirmative responses reaction time differed significantly ($F(1,18)=37.8$, $p<0.001$). The evaluation of visually complex icons required about 56 ms more time than visually simple icons (Figure 1c-d). An interaction of the two main factors was observed for CR: Whereas for abstract icons CR did not differ between simple and complex variants they were significantly higher for concrete and visually simple icons than for concrete icons which were visually complex ($F(1,18)=7.4$, $p<0.05$).

3.2 Effects of Users' Age

RTs in both age groups differed significantly ($F(1,18)=14.7$, $p<0.01$): Compared to young adults who needed 713.7 ms (SD=283.2) to respond older adults reacted more slowly (M=1084.6 ms; SD=534.3). Also, the fraction of CR in general was higher (though non significant) for young than for older adults (Figure 1 e-f). In spite of quantitative differences, the very same effects of icon concreteness and icon complexity showed up in young and old adults. Thus, concrete-simple icons were superior in both age groups. In order to rule out familiarity effects (higher presence of real phone icons), effects were re-calculated for fictitious icons only. Again significantly shorter RTs were observed for visually simple icons ($F(1,18)=26.3$, $p<0.001$) and more affirmative responses for concrete icons ($F(1,18)=152.9$; $p<0.001$). A high accordance of responses among the two age groups was also observed on the level of individual targets (Table 3).

Table 3. Icons with the Highest Fraction of Confirmative Responses in Each Task (Icons Stemming from Real Phones are Gray Shaded)

Reference Function	Icon with Highest Fraction of Confirmative Responses		Reference Function	Icon with Highest Fraction of Confirmative Responses	
	Young Adults	Old Adults		Young Adults	Old Adults
Battery charging level			Call diversion		
	100.0%	90.0%		95.0%	82.5%
Net availability			Alarm clock		
	100.0%	82.5%		90.0%	75.0%
Dial tone silent			Headset		
	95.0%	77.5%		57.5%	10.0%
Mailbox			Appointment		
	67,5%	52.5%		97.5%	87.5%
SMS			Vibration		
	97.5%	95.,0%		90.0%	82.5%
Keylock			Camera		
	80.0%	60.0%		77.5%	77.5%

Icon preferences between young and old adults differed for only 2 tasks (mailbox and vibration). In the remaining 10 tasks the same icons performed better in both age groups. Whereas each one of these 10 icons was concrete-complex (alarm clock) and abstract-concrete (net availability), 8 of them were concrete and simple (battery charging level, dial tone silent, SMS, key lock, call diversion, headset, appointment, camera). Real mobile phone icons performed best in both age groups in the majority of the tasks (net availability, dial tone silent, SMS, key lock, call diversion and headset). Surprisingly the fictitious icons performed better than their real counterparts in 4 tasks (battery charging level, alarm clock, appointment, camera). In general real mobile phone icons tended to perform worse whenever attributes were not concrete-simple. Exceptions from this rule were the real phone icons for “net availability” and “mailbox”. In spite of their high degree of abstractness they were correctly assigned to their reference function, showing that the superiority of concrete over abstract icons disappears with increasing familiarity.

3.3 Effects of Familiarity (Repeated Measurements)

Analyzing the effect of measurement repetitions it turned out that significantly shorter RTs ($F(3,162)=49.4$, $p<0.001$) and higher CRs ($F(3,162)=5.4$, $p<0.01$) occurred with increasing numbers of repeated measurements irrespective, whether icons were abstract or concrete. No significant interaction between icon concreteness and measurement repetition were observed. Concrete icons were significantly more often judged as appropriate than abstract ones even for the last repetition implying that -contrary to previous findings- the benefiting effects of icon concreteness on semantic transparency did not disappear with increased user experience (Figure 2a-b).

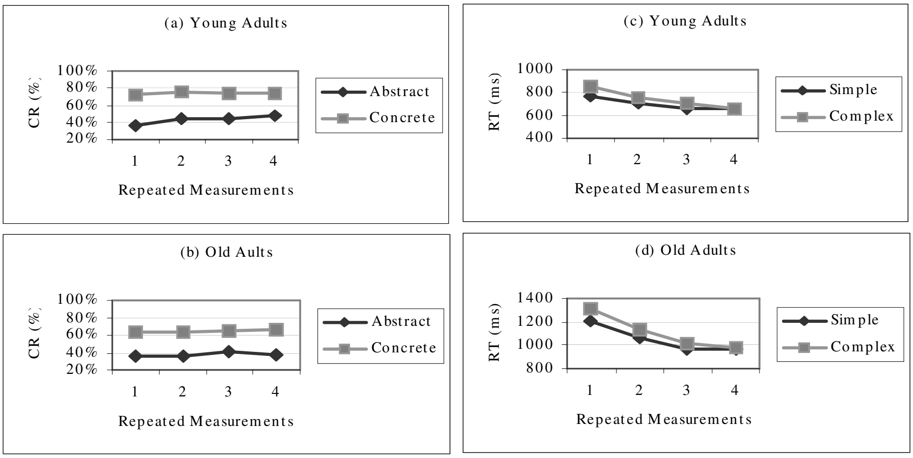


Fig. 2. Time on Task Effects for both age groups and icon characteristics

Similar to the findings regarding icon concreteness, significantly shorter RTs ($F(3,162)=47.9$, $p<0.001$) and higher CRs ($F(3,162)=4.6$, $p<0.05$) occurred for both steps of icon complexity over time. In addition considerably larger RT gains could be realized for visually complex than for visually simple icons ($F(3,162)=5.8$, $p<0.01$). The difference vanished, however, across repetitions (Figure 2c-d).

4 Discussion

The present research was guided by two major goals. One goal was to determine characteristics of icons in the mobile sector that ensure high semantic transparency. To this end, icons' visual complexity and concreteness were scrutinized. Overall, the results showed both of them to be important determinants of the semantic transparency of mobile phone icons. Whereas visually complex icons require longer RT than visually simple ones, concreteness significantly affects the fraction of CR: Whereas concrete icons were confirmed in more than 70%, abstract icons in contrast were confirmed in only 40% of all cases. Contrary to previous findings [2,3], this strong benefiting effect of icon concreteness did not vanish with familiarity: Even in the last of four repetitions concrete icons were significantly more often judged as appropriate than abstract ones. Overall, the findings here show icon concreteness rather than complexity to be the crucial element that determines user performance.

Yet icon complexity is not irrelevant. Beyond its direct effect upon RT complexity mediates the effect of familiarity on RT: RT gains coming along with increasing familiarity due to measurement repetition are much higher for complex than for simple icons resulting in virtually identical RTs in the long run. The time consuming process to encode visually complex icons obviously decreased with measurement repetition, and visual inspection in the end was mainly confined to the encoding of indispensably pictorial elements for object recognition.

With respect to the second goal to determine whether icon design has to meet age specific design requirements our results favor the idea of a uniform approach to information design in mobile devices: no major age-related differences were uncovered beyond older adults` generally slower processing times, which is well known [6, 7]. This means that identical design features allow a good comprehension of icons for different age groups. According to our findings icons should represent concrete information from familiar context and should be designed visually simple to be easily understood by both younger and older users. The importance of these design requirements will grow whenever icons are not – as in the present study – scaled up but represented in the original small scale format; and elder people (> 65 years) likely to suffer from age-related visual and cognitive deficits and to be less experienced in using technical devices are included in the sample.

Based on our findings it can be concluded that the specifics of icon design strongly impact upon the ease with which icon functions in mobile devices are comprehended. The observance of this relationship is requisite for a flawless device use which is of utmost importance in some applications, e.g. in medical context.

References

1. Pappachan, P., Ziefle, M.: Cross-Cultural Comprehensibility of Icons in Mobile-Computer-Interaction. Behaviour and Information Technology (in press)
2. McDougall, S.J.P., Curry, M.B., De Bruijn, O.: Exploring the Effects of Icon Characteristics on User Performance: The Role of Icon Concreteness, Complexity, and Distinctiveness. Journal of Experimental Psychology 6(4), 291–306 (2000)
3. Rogers, Y.: Icon Design for the user interface. International Reviews of Ergonomics 3, 129–154 (1989)
4. Isherwood, S.J., McDougall, S.J.P., Curry, M.B.: Icon Identification in Context: The Changing Role of Icon Characteristics With User Experience. Human Factors 49(3), 465–476 (2007)
5. Arend, U., Muthig, K.P., Wandmacher, J.: Evidence for global superiority in menu selection by icons. Behaviour and Information Technology 6, 411–426 (1987)
6. Fisk, A.D., Rogers, W.A. (eds.): Handbook of human factors and the older adult. Academic Press, San Diego (1997)
7. Park, D., Schwarz, N.: Cognitive Aging. Buchanan, Philadelphia (1999)
8. Ziefle, M., Schroeder, U., Strenk, J., Michel, T.: How young and older users master the use of hyperlinks in small screen devices. In: Proc. SIGCHI 2007, pp. 307–316. ACM Press, New York (2007)
9. Park, D.C., Puglisi, T., Smith, A.D., Dudley, N.: Cue Utilization and Encoding Specifity in Picture Recognition by Older Adults. Journal of Gerontology 42, 421–425 (1987)
10. Smith, A.D., Park, D.C., Cherry, K., Berkovsky, K.: Age differences in memory for concrete and abstract pictures. Journal of Gerontology: Psychological Sciences 45, 205–209 (1990)
11. Howell, W.C., Fuchs, A.H.: Population stereotypy in code design. Organisational Behavior in Human Performance 3, 310–339 (1968)