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How much Screen Information can you handle? Making a Subway Ticket Machine more Accessible to the Elderly

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Abstract

We explored the appropriate amount of screen information in the case of a subway ticket machine, for making smart public devices more accessible to older people. We determined interface barriers in using (1) a subway map and (2) a station overview matrix through two paper prototypes, in order to find the appropriate amount of information for each application, as well as to understand the relationship between information quantity and completion time efficiency. To ensure validity, data from older people was compared to that of a control group of young users. As a result, we identified how much screen information the elderly can handle when using digital maps and matrices. We defined an appropriate zooming range and an optimal matrix size to be shown on the screen. This study contributes to designing barrier-free public smart devices.

Screen interface; Elderly users; Paper prototype; Map; Matrix

The world population aged 65 years and older is expected to triple from 1999 to 2050, (U.S. Bureau of the Census, 1996). Responding to this rapid aging, there are several studies about interfaces for the elderly. Oya (2004) argues that the use of interface design components such as icons, colors, structures and texts should be barrier-free, and previous research already identifies the need of appropriate interface designs for the elderly. For example, elderly users require different interfaces, because compared to young users, they have different purposes and use situations (Virpi, 2006). Chaewoo (2014) argues that designs for the elderly should originate from user-centered thinking putting the needs of older people at the core of design. Moreover there is a study about elderly usage of smart home systems that is going to be commercialized in a few years showing that digital technology is pervading the elderly's living spaces and thus making confrontations with digital interfaces inevitable.

(Portet, Vacher, Golanski, Roux, & Meillon, 2013). Finally, Arthur (2009) provides design guidelines for text, icon and sound for the elderly. In summary, these works uncover the need of appropriate designs for the elderly from different perspectives.

Concerning how much visual information an older person can handle, the ability of the human eyesight dramatically drops after age 60, culminating in losing half of the eyesight in their 70s (Hyerim, 2003). In addition, the ability of recognizing icons, menus and words, which are an essential part of graphic interfaces, decreases equally (J. Kim, E. Cho, Y. Cho & S. Kim, 2007). Both physical and cognitive decline limit the amount of information that an older person can handle at once. Thus, we have to understand how information presented through public devices should be designed to meet this need.

The reason why the quantity of information with public devices is important becomes apparent when comparing current public devices with previous ones. In the past, subway ticket machines had a physical button for each station making the ticketing process direct, yet more burdensome in regard to search-and-point (See Figure 1). With recent machines, however, these physical buttons gave way to a touchscreen with a reduced set of digital buttons and navigational depths, which reduces that burden. The amount of information is controlled by hiding further content in submenus and behind virtual page turns. The depth of digital interfaces is effective for gradually unfolding the appropriate amount of information to the elderly. The quantity of screen information is related to the depth of an interface. An interface is deeper when a device provides less information at once, which means that, for example, we have to move through multiple pages on the screen to select a station.

Figure 1: Seoul metro ticket machine 10 years ago and now

However, regarding the interface depths, many public devices require better designs for universal use, since most of the products only focus on majority users who are familiar navigating through complex digital interfaces. Therefore, this paper focuses on senior users who less familiar with interface depth. Through our user study, we tested the appropriate depth of interface for the elderly.

There already exist numerous personal products especially designed for the elderly, such as smartphones with large buttons. However, there are few studies, which examine smart public devices such as ticket machines in subway stations. In the near future, those public devices have to be accessed by the elderly more frequently, as public life spaces are increasingly digitalized and automated. This is problematic, as those devices are not generally designed for the elderly, thus causing great inconveniences. On this backdrop, we focus on making the interface of public smart devices more accessible by adjusting the amount of screen information to the needs of the elderly.

Currently, Seoul Metro ticket machines do not support an enlarging function for maps, so that it is difficult to use for selecting stations. The map shows 929 stations and even young people can hardly identify a station without zooming in (Figure 2). If we imagine that there was a zoom function, we assume that it could be useful for searching stations more conveniently. In this hypothetical case, what would the appropriate zoom rate for the elderly be? As the map is enlarged, texts become more legible, with the downside of increasing the usage time due to dragging and browsing interactions. Since there is a trade-off between depth and width in navigation, there is a research need for finding the threshold value for the elderly in enlarging a map for best legibility in the least amount of time.

Furthermore, Seoul Metro ticket machines do not provide optimized matrices that balance the amount of information with the information depths, resulting in many page turns. Current matrices consist of five columns by four rows, in the following referred to as '5x4' (Figure 2). These matrices help users find a final destination station and buy a ticket. The name of a station is written in each cell of the matrix. The names are organized according to the order of the Korean consonants. When the number of stations exceeds 20, the remaining stations are shown on a subsequent page, requiring additional work to find a station. In this case, there is a research need for finding the right balance between more pages with a smaller matrix and fewer pages with a larger matrix.

Figure 2: Screens of the Seoul metro ticket machine showing a map and a button matrix

Research design

The study goal was to define the appropriate amount of screen information that older people can handle at once. For this, we made paper prototypes of the Seoul Metro ticket machine, which elders use frequently. As the most common task is searching for stations, our two user scenarios reflected two types of station searches. Accordingly, the two paper prototypes simulated searching for a station on (1) a digital subway map and (2) a matrix of digital buttons. We conducted a map-zoom experiment to find the appropriate zoom rate, and a matrix-search experiment to find the appropriate amount of buttons per screen. To ensure validity, we administered the same set of paper prototypes to two different groups, one with older users and another with younger participants.

Participants

According to the World Health Organization (WHO), the UN generally considers older population as people who are more than 60 years old (personal correspondence, 2001). We decided to follow this criterion for recruiting elderly participants. One group of 10 elderly participants (average age: 67.6, SD=6.38) and another control group of 10 young participants (average age: 23.1, SD=1.20) were recruited. The number of male and female was same in each group. We found a gap between participants who had frequently used the Seoul Metro and those who did not, showing that background knowledge in finding stations on the map has a crucial impact on the result. Therefore, we focused on users without background knowledge. Regarding the strong focus on elderly participants, we adopted a method that considered the participants' limited capabilities. This was necessary as about half way through the experiment, the concentration level of the elder participants dropped significantly, and as the time for finding stations increased 10 times. Since finding stations on maps or matrices requires a high level of concentration, and since too many repeated tasks can be overwhelming, we realized that working with sensitive user groups posed a significant challenge to the research design.

Procedure

We wanted to know how the elderly distinguish different zoom rates. For this, we created a first paper prototype with an existing subway map. Since the ticket machine is closer to a web interface, we followed the standard of the Google Chrome web browser. It provides a 25% zooming increment starting from 100% to 200%, and a 50% increment above 200%. Enlarging the map from 100% to 300%, we raised the zoom rate by 25% per page and thus got nine different map views. We let participants pick a station with their finger, and we measured the completion time to find each station. The goal of the first experiment was finding the threshold, so we printed various map paper prototype with different zoom rates.

In a second paper prototype, we wanted to know how the elderly distinguish different matrix sizes. A pilot test helped adjusting the variance of matrices and the work load to older participants. We offered nine kinds of matrices (5x4, 5x5, 5x6, 5x7, 6x5, 6x6, 6x7, 6x8, 6x9). Three pages for each matrix comprise a set, and nine sets (27pages) were given to the participants. Again, we measured the completion time to find each station. The goal of the first experiment was finding the difference of completion time when using different types of matrices.

In summary, we inquired 20 participants to find specific subway stations. A printed set of maps of seven variances from 100% to 400% with increments of 50% and a set of matrices of four types, 5x4, 5x6, 6x7, and 6x9 were given to the participants. Because existing knowledge could affect the result of the experiment, unfamiliar stations were chosen and limited testers were recruited who are residents outside of Seoul. To reduce an ordering effect for the matrix, a random order of tasks for finding a station is used. To compensate the elders' vulnerability such as declining concentration, we let the participants take a 30 second break between the questions.

Result of Study 1: Zooming Rate of Map in a Screen for Elderly

Data Collection

The goal of the first experiment is figuring out the zooming rate that should be provided with maps in smart public devices for elderly users. We printed out seven maps as a paper prototype set and named them alphabetically as A (100%), B (150%), C (200%), D (250%), E (300%), F (350%), and G (400%) page. From the 100% view, the following maps were enlarged by 50% from the center of previous version.

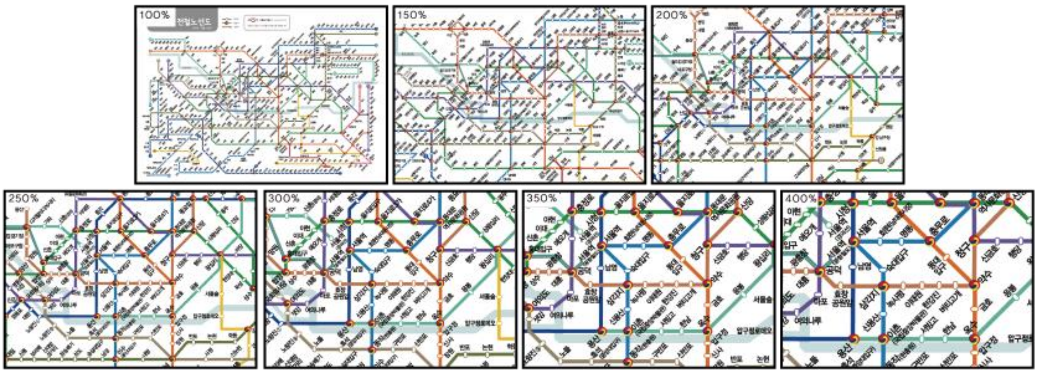

Figure 3: Paper prototype with maps; the names of pages are A to G, from top left side to bottom right side

Data Analysis

We compared the completion time for map A (100%) to map G (400%) between the two participant groups. For the comparison of each page, we conducted independent samples t-test. (See Table 1) In seven times of analysis from map A to map G, the completion time of the two groups showed significant differences. This means that the elderly people spend more time to find information in maps than younger people. According to the result, this study clearly emphasizes the need of designing a map interface that is tailored to the needs of the elderly.

Table 1: Comparison of completion time between young and elderly participants using maps

Independent variables	Young Participants		Elderly participants		t-value (18)	p
	Average time	SD	Average time	SD		
Map A (100%)	24.99	16.63	74.30	22.68	5.54	p < 0.05
Map B (150%)	22.40	17.80	57.68	18.89	4.31	p < 0.05
Map C (200%)	14.66	8.58	33.43	12.80	3.85	p < 0.05
Map D (250%)	8.84	5.27	27.43	7.54	6.39	p < 0.05
Map E (300%)	7.49	7.73	21.93	6.85	4.42	p < 0.05
Map F (350%)	4.27	2.94	14.74	5.79	5.09	p < 0.05
Map G (400%)	3.01	2.35	12.95	3.62	7.28	p < 0.05

In a second step, we analyzed how the elderly's completion time decreased with different zoom rates. Data from seven different enlarged maps ranging from 100% to 400% were compared. Six times of paired samples t-tests were conducted to compare data from one page with the data with the previous page. The result (Table 2) showed significant differences in completion time between maps A and B, and maps B and C, which means that there is a decreased amount of time spent on finding a station as the map is zoomed in. No meaningful difference in completion time was found between maps C and D, and maps D and E. However, there was a significant decrease in time between map E and F. This shows that it took more time to find stations in map C, D and E, whereas it took less time in map F. Finally, there were no significant differences between maps F and G, and differences of average time decreased as shown in Figure 4. This means F is a threshold page for the appropriate completion time, after which there will be no significant improvements through further zooming. There were no meaningful differences between map C, D and E, as those were no threshold pages and just required more zooming.

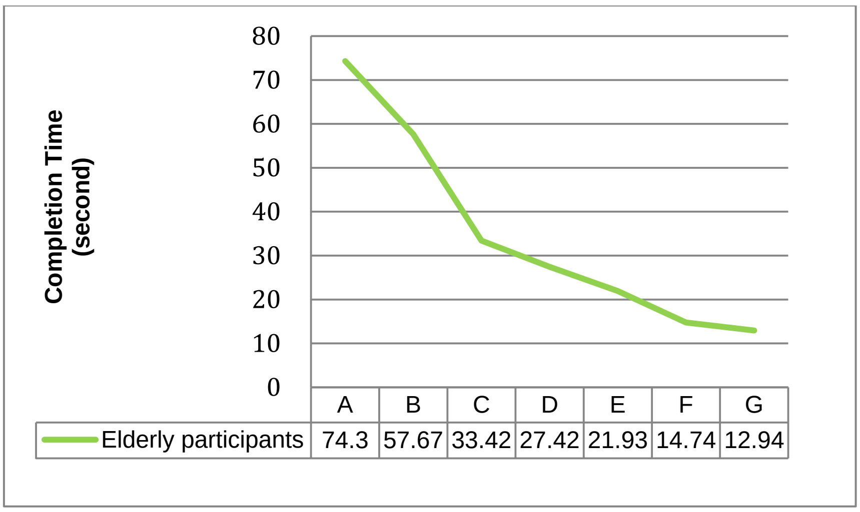

Figure 4: Completion time to find a station in each page by the elderly

Table 2: Results of Multiple Regression Analyses

Elderly participants			
Between	**t-value (9)**	**p**	**Significant difference**
A and B	1.78	p < 0.05	Yes
B and C	3.37	p < 0.05	Yes
C and D	1.28	p = 0.11	No
D and E	1.71	p = 0.05	No
E and F	2.54	p < 0.05	Yes
F and G	0.82	p = 0.21	No

The graph in Figure 4 shows that map F is a threshold page. We can expect that elderly users will perform faster after the map is zoomed beyond 350%. In the real world, it could take more time to find a station in zoomed maps, because users have to drag and search on the screen. To standardize the result from this experiment, we counted the number of stations in the threshold page, which stood at 350%. There were 57 stations in the map. This result suggests that the map should only be enlarged to a maximum zoom rate that accommodates around 57 stations.

Result of Study 2: Size of matrix in a screen for elderly

Data Collection

The second experiment was conducted to identify the appropriate quantity of information in the form of a matrix. We used a total of 12 paper prototype sets. For each matrix (5x4, 5x6, 6x7, 6x9) we made three pages which consisted of different station names. The name of the station was arranged in consonant sequence from the top to bottom and left to right. We only used the Korean language, as all the participants were Korean. The name of alphabet was assigned to the matrices according to the size of matrix H (5x4), I (5x6), J (6x7), and K (6x9). Each page was named with a number. For example, matrix H3 meant the third page of a 5x4 matrix. We recruited the participants as shown above. We also used the same method and process as the first experiment. We reduced the ordering effect by randomized the orders of the page. For example, we asked the participants to search for a station from the third page of the 5x4 matrix and then another station from the second page of the 6x7 matrix. Overall, the test was completed when the participants found 12 stations.

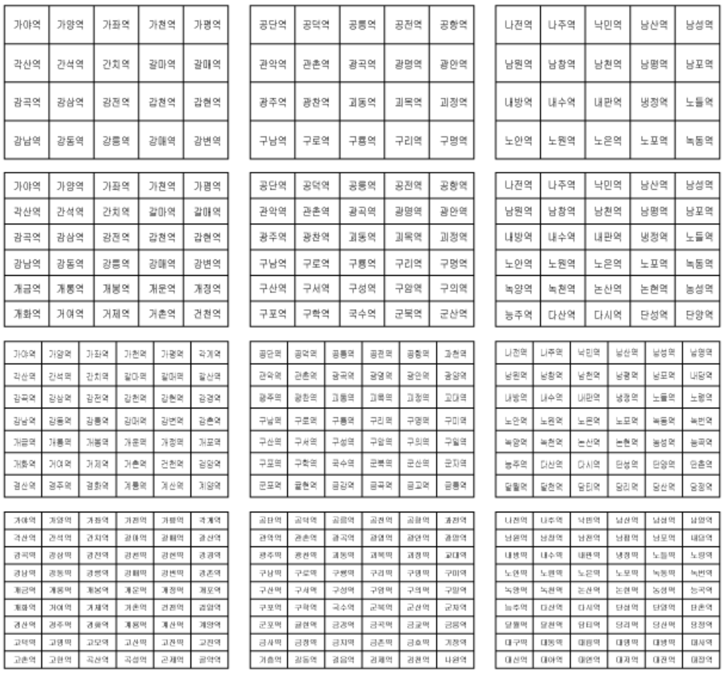

Figure 5: Paper prototype with matrices; the names of pages are matrix H, I, J and K, from top to bottom

Data Analysis

An independent samples t-test was performed to distinguish the difference between the data of the elderly and the young participants in set H (5x4), showing statistically significant differences. This analysis was also conducted for the matrix I (5x6), J (6x7), and K (6x9), and all results showed significant differences (Table 3). This meant that elderly people spent more time to find information in matrices than younger people. This result also emphasized the need for designing matrices that suit the needs of the elderly.

Table 3: Comparison of the completion time between young and elderly participants with matrices

Independent variables	**Young Participants**		**Elderly participants**		**t-value (58)**	**p**
	Average time	SD	Average time	SD		
H (5x4)	4.91	2.60	16.00	5.90	9.43	$p < 0.05$
I (5x6)	5.02	2.26	17.39	9.03	7.28	$p < 0.05$
J (6x7)	6.78	3.36	18.42	10.08	5.99	$p < 0.05$
K (6x9)	7.40	3.37	25.14	13.88	6.80	$p < 0.05$

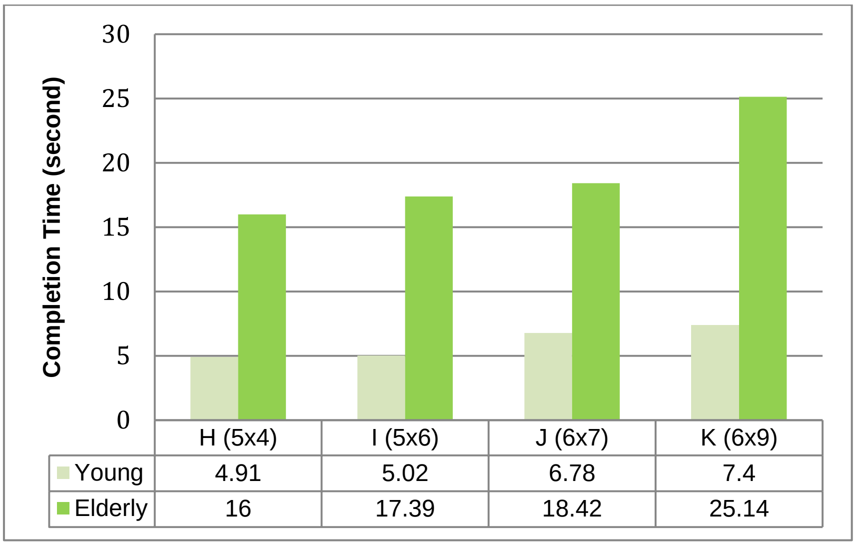

Figure 6: Completion time according to the increasing size of matrices

The elderly's performance data was analyzed in more detail, as we divided it into a comparison between matrices and a comparison between pages. In the comparison between matrices, there were no differences among matrix H, I, and J, but there were significant differences between matrices J and K (Table 4). This meant that the elderly spent much more time to find stations with matrix K than with other matrices. To compare the data of each page, we first analyzed matrix H. The result of a paired samples t-test showed that the completion time in each matrix H1 and matrix H2 was statistically different. This statistical result was the same between matrix H2 and matrix H3. For the cases of matrix I, J and K, paired samples t-tests were performed repeatedly and all the results showed significant differences. It signified that additional pages of matrices require users to spend more time finding a station.

Table 4: Comparison between matrices and between pages used by the elderly participants

Between	**t-value**	**p**
Between matrices (d.f.=29)		
H and I	0.70	p = 0.24
I and J	0.41	p = 0.39
J and K	2.15	p < 0.05
Between pages (d. f.=9)		
H1 and H2	2.38	p < 0.05
H2 and H3	4.04	p < 0.05
I1 and I2	2.72	p < 0.05
I2 and I3	3.01	p < 0.05
J1 and J2	2.29	p < 0.05
J2 and J3	2.20	p < 0.05
K1 and K2	3.51	p < 0.05
K2 and K3	2.11	p < 0.05

In consequence, we can adjust the matrix based on the amount of information if the number of cells in a matrix is less than 42 as it is the case of matrix H, I, and J. Here, showing more than 54 matrix cells at once, as it is done in matrix K, is not desirable. Also, we can conclude that it is better to minimize the number of pages. For instance, if we provide 40 stations, it is recommended to show them via matrix J. If there are 60 stations, the I matrix is preferable to three pages of matrix H. With less than 20 stations, it is better to use matrix H that shows information with bigger text. If the number of information exceeds 100, which is over the coverage of this study, it is suggested to use some ways other than matrix search, such as consonant search. Thus, these results imply a potential of further studies to find differences among matrix search and other search types for cases with more than 100 items of information.

Discussion and Design implication

As the smart device market rapidly expands into the public domain, it becomes more important how to make smart public devices accessible to all users, especially to vulnerable groups such as older people. Moreover, Usability and User Experience (UX) have to become fundamental elements in smart devices and should not differ from company to company due to a lack of common guidelines. Older users in particular get confused by the same information delivered in different ways. Therefore, common design guidelines for designers and developers are needed to design better public devices for elders. Different types of information representations other than matrices and maps also need to be tested to identify the appropriate amount of information and ways of representation. As we focused our study on maps and matrices only, we encountered shortcomings that might have been solved by other representation forms, as there are numerous other ways to deliver information in smart public devices besides maps and matrices. Future research on other forms will enable are more comprehensive design guideline for the ideal quantity of screen information in smart public devices. Our study also relied on a small sample size with 10 elderly participants. By conducting a broader study the result can be more representative. However, in our case we focused on narrowing down specific usability issues with well-defined information representations that, according to Nielsen (2000), do not require more than five users. Overall, if we complement the findings of more comprehensive future studies with our research results, much needed design guidelines for smart public device interfaces can be developed, which will help designers create appropriate interfaces for the elders, and which will contribute to tackling the challenges of the aging society.

Conclusion

We researched about how much screen information is appropriate with maps and matrices in smart public devices. From two experiment using paper prototypes, we could obtain two results for optimal ways of presenting information. First, finding a threshold value from the map-enlargement experiment, we gained knowledge about how much maps should be enlarged and about how much information is appropriate. This finding can be applied to guidelines for other types of map interfaces. Secondly, from the matrix-finding experiment, we learned that the depth or the number of pages should be minimized and that the completion time to search information increases rapidly when there are more than 54 information items shown on a page. This can be used to develop a guideline for the number of rows and columns of a matrix according to the amount of information. The result of this study suggests guidelines for designing smart public devices for elderly and implies possible further researches. Comparing matrix search and Korean consonant search can identify differences in the cognition level, based on the way of providing information. Design guidelines for the elderly have not yet been established properly for smart public devices. We hope that this study will contribute to interface design for smart public devices and that it will facilitate related studies. Eventually, we expect barrier-free smart public devices for elders to become common place.

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