Aging effects on the visibility of graphic text on mobile phones

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S.*Hasegawa, S.Matsunuma, M.Omori, M.Miyao. Aging effects on the visibility of graphic text on mobile phones. Gerontechnology 2006;4(4):200-208.* Text including characters unsupported by built-in fonts of ordinary mobile phones can be displayed on the liquid crystal displays of these phones with the use of graphic text. Disaster information with maps or other important information that can be sent by using graphic text is necessary for persons of all age groups, including elderly people. However, the small characters on the displays in mobile phones are hard for elderly people to read. We studied the visibility of characters by measuring reading speed, rate of misreadings, and viewing distance while 41 young, 14 middle aged, and 33 elderly subjects read graphic Japanese text on mobile phones aloud. We also recorded subjects' subjective evaluations after every trial. The subjects' visual functions of cataract cloudiness and near visual acuity were also measured. We found that reading performance deteriorated as the size of the characters became smaller, and as subjects became older. Cloudiness and near visual acuity were strongly correlated with age, and they also affected reading performance. However, neither of the two had higher correlations with reading speed or viewing distance, than with age. Moreover, viewing distance increased as the subjects became older, but became shorter as the character size became smaller. The effects in terms of visibility are not simple, and the results suggest that aging includes more factors that need to be considered.

Keywords: LCD, legibility, small displays, mobile phones, aging

In the current aging society, there is an increasing need for elderly people to use information devices such as mobile phones (MPs). However, characters on liquid crystal displays (LCDs) in MPs are small because of the restricted size of the LCDs. Few studies have subjectively measured the visibility of characters on LCDs in MPs[1-3], although the recommended character size on video display terminals (VDTs) of personal computers has been standardized,[4,5] even for older office workers,[6] based on the results of many studies[7-16]. In this study we used graphic text to examine the relationship between visibility of characters on LCDs in MPs and subjects' visual functions of cataract cloudiness (CC) and near vision acuity (NVA), as well as their age.

'Graphic text' here means characters represented in a digital image format such as JPEG. Graphic text makes it easy to send text within graphics such as on maps or in comics by e-mail. MPs with built-in camera are useful in sending and receiving graphic data by e-mail. Multilingual information can also be sent with the use of graphic text even if the mobile phone that is receiving the information does not support multilingual character fonts[17]. Disaster maps, typhoon information with weather charts, and other such information can be sent by using graphic text[18]. Needless to say, such important information as disaster prevention information is necessary for persons of all age groups, including the elderly.

In this study we examined the visibility of graphic text on LCDs in MPs with three different sizes of Japanese characters.

METHODOLOGY

Subjects

The subjects were 88 Japanese males and females 20-79 years of age (46.3±17.9 years) including 33 elderly people 60-79 years old (*Table 1*).

Visual functions

Visual function of a single eye with cataract cloudiness (CC) of the lens[19-21] was estimated with the use of an anterior ocular segment measuring instrument, EAS-1000TM (NIDEK Inc.). Binocular near vision acuity (NVA)[21] for a 30cm distant target was also measured for each subject. Subjects with corrected vision wore the eyeglasses they normally use. CC was indicated in 256 levels (0: no cloudiness - 255: maximum cloudiness)[1,22]. NVA was expressed in steps as 0.1, 0.3, 0.5, 0.7, 1.0 or 1.2.

Reading performance

Reading performance of graphic text on LCDs in MPs was measured (*Figure 1*). Samples of graphic text with the same number of Japanese characters were prepared in three different character sizes (*Figure 2*).

One of the MPs used in the experiment was an SA51 (Sanyo) with a 2.1-inch

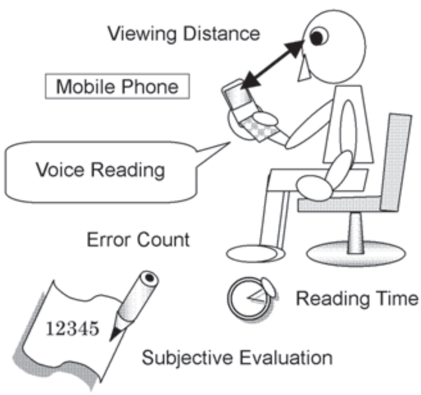

Figure 1. Overview of experiment and measurements

Table 1. Description of subjects

Characteristic	Grouping			
	All subjects	Young	Middle aged	Elderly
Age range	20-79	20-39	40-59	60-79
Mean age ± SD	46.3 ± 17.9	29.3 ± 6.2	47.6 ± 6.8	66.4 ± 4.7
Number	88	41	14	33

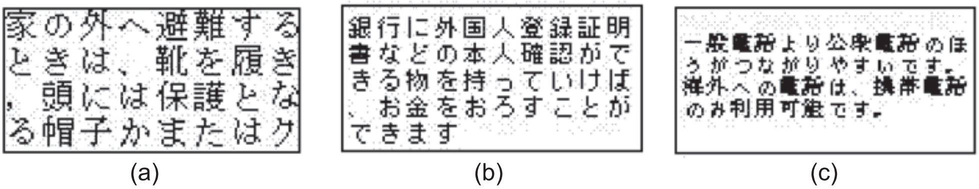

Figure 2. Examples of graphic text prepared for the experiment; (a) Large characters = 8 characters / line; (b) Medium sized = 10 characters / line; (c) Small = 12 characters / line

LCD of 260 K color TFT and 132×176 dots. The contrast ratio (light/dark) was estimated from mean luminance (cd/m^2) in dark and light areas in the LCD measured with a luminance meter LS-100 (Minolta). A sufficient number of graphic text samples with different contents were prepared so that they could be displayed in changing order to avoid any statistical effect of the order of presentation, and no subject read the same phrases. All text samples were parts of sentences relating disaster information which Japanese subjects could easily understand, although the phrases were not common ones, so that every subject could read them with no difficulty. The subjects used eyeglasses as usual, sat in a chair and adopted a position holding the MP in one hand so it was easy to read. They then read aloud the phrase displayed on the LCD (*Figure 1*).

Reading time (RT), number of misreadings (ER) and viewing distance (VD) were measured while the subject read aloud. Subjective evaluations (SE) on a 5-point scale (5: very easy to read, 4: easy to read, 3: moderate, 2: difficult to read, 1: very difficult to read) were also recorded after each reading task. Every subject also responded to a questionnaire asking how they usually use MPs.

Results

Usability of mobile phone e-mail

The results of a questionnaire investigating the way subjects normally use MPs are shown by age group (*Figure 3*). All of the younger subjects with the exception of one who did not own an MP, used MP e-mail. The rate of e-mail use decreased with the age of the group. In the elderly group half of all subjects used MPs, and half of these MP users used e-mail.

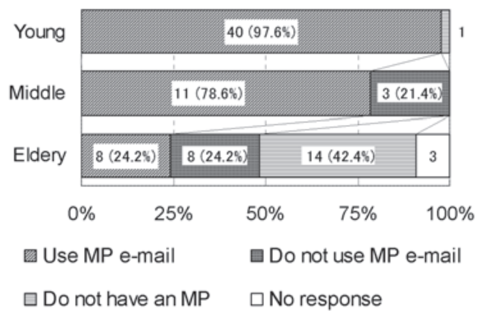

Figure 3. Mobile phone (MP) use in percentages and age of subjects; Young = 20-39 years old; Middle = 40-59 years; Elderly = 60-79 years

Reading performance

Reading speed (RS) was calculated from measured RT, as RS (characters/sec) = N / RT, where N is the number of characters. Error rate (ER) was calculated from the number of errors (Error) as, ER (%) = (Error / N) ×100. The age distributions for SE, RS, VD, and ER are shown in Figure 4a, 4b, 4c, and 4d, respectively. The statistical values of these parameters are shown in Table 2 for each character size, age group, CC group, and NVA group.

Character size

The p-values shown in Table 2a are the results of ANOVA by character size. A significant decrease in visibility was seen as the size of characters became smaller. With smaller character size, the

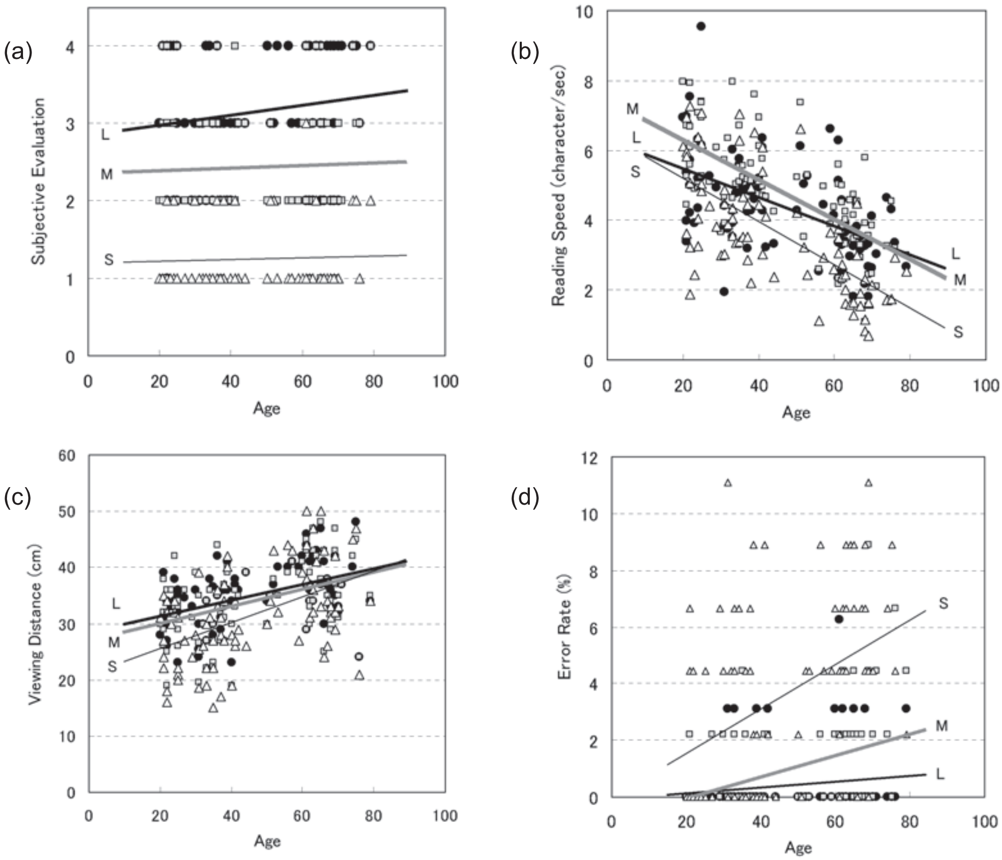

Figure 4. Age dependency of reading performance measures for 3 different character sizes; dot = large, square = middle, triangle = small; (a) Subjective evaluation; (b) Reading speed; (c) Viewing distance; (d) Error rate

points for SE decreased, VD became shorter, and ER became larger (*Table 2a*). There were significant differences in RS, VD, and ER between character sizes of M and S, but there was not a significant difference between L and M. RS tended to be faster with M than with L. Five of the 88 subjects (5.7%) gave up reading the S size characters before finishing, so they were excluded from the measurements.

Age

Figure 4 shows the age distributions for the parameters of reading performance. SE showed no strong relation with age (*Figure 4a*). With each character size, RS decreased (*Figure 4b*) and VD tended to be longer as subjects became older. VD became shorter as the characters became smaller, especially among the younger subjects. Among the elderly, in whom VD was longer, little difference was seen with character size (*Figure 4c*). When character size was S, ER rose markedly with age (*Figure 4d*). A two-way ANOVA with factors of age groups and character size was conducted for each parameter. The statistical significance of the differences between age groups is shown in Table 2b. For SE, only the effect of character size was significant, and there were no significant differences between ages. For RS, VD, and ER, both character size and age group were seen to be significant main effects (*Table 2b*). All 5 of the subjects who gave up reading with the S charac-

Table 2. Reading performance in relation to character size (as characters / line), age of the subject, cataract cloudiness and near-vision acuity; Subjective evaluation on a 5 point scale; Reading speed in Japanese characters/s; Viewing distance in cm; Error rate in % of misreadings

Measurement	Mean ± standard deviation of reading performance at 3 different values of an influential factor			Significance p-value		
(a)	***Characters / line***			***L - S***	***L - M***	***M - S***
	8 (L)	***10 (M)***	***12 (S)***			
Subjective evaluation	3.15 ±0.87	2.44 ± 0.83	1.25 ± 0.60	<0.0001	<0.0001	<0.0001
Reading speed	4.38 ± 1.38	4.81 ± 1.52	3.64 ± 1.67	0.0079	-	<0.0001
Viewing distance	35.1 ± 5.4	34.1 ± 6.6	31.4 ± 8.2	0.0019	-	0.0305
Error rate	0.39 ± 1.14	0.96 ± 1.71	3.51 ± 3.31	<0.0001	-	<0.0001
(b)	***Age in years***			***A - C***	***A - B***	***B - C***
	20-39 (A)	***40-59 (B)***	***60-79 (C)***			
Subjective evaluation	2.23 ± 1.11	2.26 ± 0.94	2.41 ± 1.15	-	-	-
Reading speed	5.09 ± 1.40	4.59 ± 1.42	3.13 ± 1.16	<0.0001	-	<0.0001
Viewing distance	30.5 ± 6.2	34.2 ± 6.2	37.2 ± 6.4	<0.0001	0.0037	0.0405
Error rate	1.03 ± 2.19	1.19 ± 2.28	2.46 ± 3.00	<0.0001	-	0.0022
(c)	***Cataract cloudiness***			***A - C***	***A - B***	***B - C***
	20-79 (A)	***80-139 (B)***	***140-199 (C)***			
Reading speed	5.08 ± 1.39	3.72 ± 1.47	3.04 ± 1.08	<0.0001	<0.0001	<0.0001
Viewing distance	30.2 ± 6.0	36.9 ± 6.7	36.1 ± 6.2	<0.0001	<0.0001	-
Error rate	0.97 ± 2.13	1.97 ± 2.90	2.73 ± 2.90	<0.0001	0.0021	0.1097
(d)	***Near-vision acuity***			***A - C***	***A - B***	***B - C***
	1.2-1.0 (A)	***0.7-0.5 (B)***	***0.3-0.1 (C)***			
Reading speed	5.13 ± 1.36	3.34 ± 1.16	3.60 ± 1.38	<0.0001	<0.0001	-
Viewing distance	30.7 ± 6.2	35.6 ± 5.1	36.3 ± 7.0	<0.0001	0.0004	-
Error rate	0.94 ± 2.10	2.15 ± 2.70	1.98 ± 2.68	0.0006	0.0059	-

ter size belonged to the elderly group, and corresponded to 15.2% of the 33 elderly subjects.

Visual functions.
The measured visual functions of CC and NVA were strongly correlated with subjects' age (Figure 5). CC had a strong positive correlation (r=0.91) and NVA a negative one (r=-0.86), with age. CC is almost linear with age, however it varied considerably in the elderly group. The NVA value showed more variation in each age group.

Subjects were classified by CC of 20-79, 80-139 and 140-199, indicating low to high cloudiness (*Table 2c*), and by NVA of 1.2 or 1.0, 0.7 or 0.5, and 0.3 or 0.1, indicating high to low vision (*Table 2d*). Two-way ANOVAs with the character size were performed for each parameter. For SE, only the effect of character size was significant. RS, VD and ER showed significant differences depending on the CC and NVA classification (*Table 2c-d*). Significant differences were seen, especially between class A (20-79) and B (80-139) of CC (*Table 2c*), and between class A (1.2 or 1.0) and B (0.7 or 0.5) of NVA (*Table 2d*). The influence of CC and NVA on SE, RS, VD, and ER

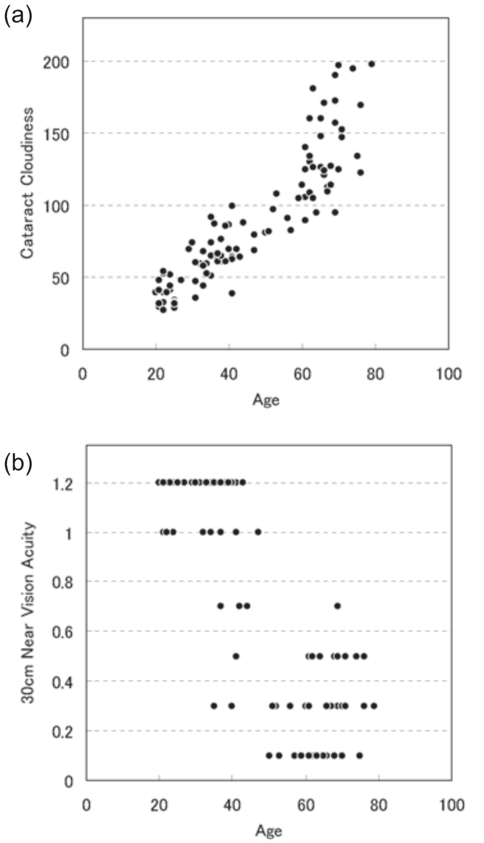

Figure 5. Age dependency of visual functions; (a) Correlation of cataract cloudiness and age; (b) Correlation of near-vision acuity and age

showed similar trends to the influence of age.

Table 3 shows correlation coefficients between visual functions (age, CC, NVA) and reading performance (RS, VD, ER). With the exception of some ER, age showed the strongest correlation in most cases. For RS, CC showed the next highest correlation following age. Age also showed the strongest correlation for VD, followed by NVA. For ER, CC tended to have a high correlation.

Discussion

Character e-mail with graphic text is useful in sending information to MPs. However, it is necessary to consider the visual characteristics of the elderly and others in order to make information available to all people.

Nearly all the younger subjects regularly used character e-mail on MPs, but as subjects' age increased there was a decrease in the rate of people who used character e-mail or even MPs themselves (*Figure 3*). This could be either because older people find it difficult to use character e-mail on MPs or because they simply did not feel the need. If it is because of the former, it is a real problem. The reasons for the difficulty felt by older people may be related to both usability of e-mail system and visibility of characters on LCDs in MPs.

Visibility decreases as character size becomes smaller, and lower SE, lower RS, shorter VD, and higher ER are seen (*Figure 4*). However, the horizontal width of mobile phone LCDs is short, and as character size increases the number of characters that can be displayed on one line decreases. It is not necessarily the case, then, that larger character size makes reading easier. In terms of readability, Figure 4b suggests that the optimum character size (number of characters per

Table 3. Correlation coefficients of performance measures and influential factors

Subject characteristic	**Performance measure at different numbers of characters / line**								
	Reading speed			**Viewing distance**			**Error rate**		
	8	10	12	8	10	12	8	10	12
Age	-0.54	-0.69	-0.66	0.47	0.42	0.50	0.18	0.40	0.42
Cataract cloudiness	-0.53	-0.65	-0.62	0.38	0.38	0.41	0.18	0.48	0.38
Near-vision acuity	0.4	0.54	0.56	-0.40	-0.34	-0.46	-0.16	-0.21	-0.37

line) is about 10 characters per line for Japanese (equivalent to 20 characters in the Roman alphabet). In any case, if the characters are too small, reading performance declines. With graphic text in particular the display resolution of small letters can be lost because of nonconformity (*Figure 2c*). This can be a cause of marked decreases in visibility.

Reading performance tended to decrease with the age of subjects (*Figure 4*). This decrease was marked when character size was small. These results agree with those from many studies on visibility on VDTs and other devices[1-3,7-9], but MPs are characterized by small displays and being hand held during use. In the present study an effect from small characters was seen on RS and ER, especially in elderly subjects, and the difference between elderly subjects and both middle aged and young subjects was large, although the difference between middle aged and younger subjects was not significant (*Table 2b*). A large difference in VD was also seen between younger subjects and both middle aged and elderly subjects (*Table 2b*). It is easy to adjust VD when holding an MP in the hand, but it cannot be viewed at distances greater than arm length. It is thought that young and middle aged people can compensate for poor visibility from small characters by decreasing the viewing distance, but older people who are affected by presbyopia increase the viewing distance regardless of character size. The decrease in RS and increase in ER is especially marked with small characters, and in some cases elderly people simply give up trying to read, indicating the difficulty of reading such characters.

The strong correlation between age and visual functions (for example, CC and NVA in Figure 5) also suggests that decreased visual function is a main cause of the decline in reading performance with age. A previous study[1] indicated that there is a relationship between visibility of VDTs and 50 cm NVA, but since the VD was shorter in the present study with MPs (*Figure 4c*), an assessment was made with 30 cm NVA. Both CC and NVA show a strong correlation with age, but the range of values was particularly large among older subjects (*Figure 5*). We were able to conduct a detailed investigation of the condition of elderly subjects, who have large individual differences, as a parameter of visual function. As expected, both CC and NVA exhibited the same age-dependent trend for reading performance (*Table 2*). As for the correlation of visual functions and reading performance (*Table 3*), the results were what may have been reasonably expected, such as relatively strong effects of NVA on VD and CC on ER. Meanwhile, in nearly all cases the parameter of age showed a stronger correlation than either CC or NVA. This suggests that visual functions other than CC and NVA measured in the present study (for example, contrast sensitivity and luminous efficiency)[3,8,9,13,22], as well as psychological and physical factors[23], may have affected the reading performance of MP characters. Differences in the normal state of use of MPs may also have had an effect (*Figure 3*).

There have been reports stating that a contrast ratio of 3 or more is needed for good visibility[9,14,15], and that the decline in contrast sensitivity in elderly people is one factor in decreased visibility. In the environment used in the present study the contrast ratio on the LCD was approximately 3.6. This is thought to be a sufficient contrast for young people, but considering the visual functions of elderly people it seems likely that this contrast is problematic.

Conclusions

Performance in reading graphical text on LCDs in MPs deteriorated as subjects became older, and as the size of the characters became smaller.

Visual functions (CC, NVA) were strongly correlated with age, but this was not a direct linear correlation (*Figure 5*). CC seems to be an effective factor for RS and ER (*Table 2c*) in addition to age (*Figure 4, Table 2b*). NVA also has a strong effect. NVA of lower than 1.0 was uniformly associated with low reading performance (*Table 2d*). However, both objective visual functions of CC and NVA did not have higher correlations with RS or VD than with age (*Table 3*). Moreover, VD increased as the subjects became older, although VD was shortened as the character size became smaller (*Figure 4c*). The effects in terms of visibility are not simple, especially in terms of VD. The results suggest that aging includes more factors that should be considered in association with reading performance, although CC and NVA are important factors.

Visibility of characters on LCDs in MPs deteriorates remarkably as the characters become small, especially when the user is elderly. Although the size of the displays on MPs tends to increase as the technology develops, the trade-off between convenience of compactness and visibility of the display, including its resolution, brightness, contrast and size, should be examined. In order to make mobile information available to all age groups, effects of aging including visual functions must be considered.

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