

# Time Reduction Design Method for Cognitive Assist Technology

Junji Ohyama<sup>(✉)</sup>, Nana Itoh, Kenji Kurakata, and Ken Sagawa

National Institute of Advanced Industrial Science and Technology,  
1-1-1, Higashi, Tsukuba City, Ibaraki 305-8566, Japan  
{j.ohyama, nana.itoh, k-kurakata, ken.sagawa}@aist.go.jp

**Abstract.** Given the importance and abundance of current visual information, visual display designs should consider their accessibility to elderly people. However, adapting designs not only to young users but also to older users is difficult because the difference in perception and cognition between these age groups remains unclear. In order to solve this accessible design issue, we introduce three studies: a study on the effect of aging on visibility, the construction of a database containing the sensory characteristics of older persons and persons with disabilities, and experimental and conceptual studies of our proposed design method, the time reduction design. The time reduction design method can solve the cognitive problems of aging societies by improving both spatial visibility and recognition speed.

**Keywords:** Vision · Time design · Cognitive technology · Experimental psychology

## 1 Introduction

Important signs, user interfaces, and other visual information should be designed in a way that can be read and understood by all users. Designers can create user-friendly visual designs by drawing upon their experience and existing design methods. However, a substantial number of these designs are adapted only to young users. The United Nations reported that the percentage of elderly people in most industrialized countries will be 30 % or greater by the year 2050 [1]. Therefore, designers should consider the ways in which their designs will be read and understood by elderly people. However, adapting designs not only to young users but also to older users is difficult because the difference in perception and understanding between the young and old remains unclear. The goal of our study is to complete this data in order to obtain accessible designs.

Three studies are presented as solutions to the issue of accessible design. Part 1 discusses experimentation that was performed in order to study the effect of aging on visibility. Part 2 constructs a database that contains the sensory characteristics of older persons and persons with disabilities. Lastly, Part 3 analyzes the experimental and conceptual studies of our proposed design method: the time reduction design (TRD).

## 2 Part 1: The Effect of Aging on Visibility

In the introduction, we discussed the experimental studies conducted on the effect of aging on visibility. The elements of visual signs that enhance visibility are size, shape, color, and contrast. Therefore, we examined the effect these visibility factors have on both the young and elderly.

### 2.1 How to Examine the Effect of Aging on Visibility

In order to examine visual perception data, we primarily used general psychophysics and experimental psychology methods. However, some considerations are necessary in the study of aging, especially as they concern the measurement and analysis of aging data.

One of the elements that must be examined when studying the effects of aging is the age of the participants. The experiment must be designed in a way that examines the differences between age groups. The most conscientious way to do this includes recruiting participants from each decade, i.e., participant ages should range between 10 and 70. We used this method to study the effects of aging on basic visual functions, such as visual acuity and spectral sensitivity. The results showed two types of aging change, the linear and sigmoidal types, which had previously been observed in the aging change of other visual functions. Therefore, if the purpose of studying aging is to create accessible, user-friendly visual designs, only two age groups must be studied: the younger and the older. If the proposed design system applies to both younger and older users, the system's visual design will also apply to users between these two age groups. In our other studies, we compared two age groups (20s and 60s) and estimated each aging trend by complementing data between the two groups.

Another element that can be explored is the medical history of ophthalmological surgeries. In order to calculate the effect of aging on visibility, we can separate participants according to eye surgery experience, such as surgery for cataracts. In our studies, we recruited people who had not received eye surgery.

To calculate the effect of visual design features on visibility, the difference in individual basic visual acuity must be addressed. We measured the visual accommodative power of each participant using an auto refract meter and corrected individual vision to the topmost visual acuity for given test distances using an optometry lens.

When applying the results of vision studies to display design, we regarded not only the participants' average but also their distributions are meaningful. For example, in some cases, the acceptable visibility level of the 80 % of the 60s population was more practically meaningful than the average level (i.e., 50 % of the population). In order to enable this analysis, data must be collected from a substantial number of participants. In our research, we enlisted approximately 100 participants for each study. Table 1 lists our investigations concerning the effects of aging on visibility.

Using these results, we developed methods for evaluating and improving accessible visual design not only for the young users but also for older users. For example, we calculated the minimum legible font size and proposed a legibility estimation formula that depends on age. In order to obtain an elder-friendly accessible design, the visual

**Table 1.** Examples of the effect of aging on visual perception

Studied aging effects on visual characteristics	Participant age groups (Number of participants)	Relative examined conditions in addition to age
Legibility of font size	20–29, 60–79 (90)	Viewing distance, Environmental illumination, Font type, Letter complexity
Legibility of letter contrast	18–29, 60–83 (108)	Size, Viewing distance, Environmental illumination, Contrast polarity, Font type, Letter complexity
Spectral sensitivity	10s, 20s, 30s, 40s, 50s, 60s, 70s (91)	Target color, Background color, Luminance contrast
Useful field of view	20–29, 60–79 (98)	Target size, Target color, Target luminance, Target, direction, Background color, Environmental illumination
Contrast sensitivity	10s, 20s, 30s, 40s, 50s, 60s, 70s (110)	Environmental illumination, Duration of target presentation
Readability of text	20–29, 60–79 (36)	Kerning, Leading, Viewing distance, Font type, Font size
Ability of categorization of colors	20–29, 60–79 (89)	Target color, Environmental illumination

functions of older people must be considered when selecting color, contrast, and size. The data for these visual characteristics have been used to establish the international and Japanese standards [2, 3]. We are also preparing another proposal of the related guidelines to present to the international standards.

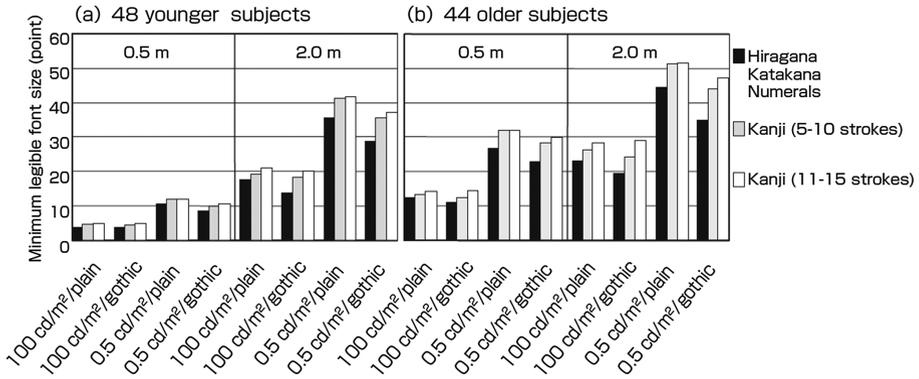
## 2.2 Legibility Data

A typical study on aging includes its effect on the minimum legible font size. We measured the effects of aging on the minimum legible font size under multiple conditions, including distance, luminance, font type, and characters, assuming that the characters were written in black on a white background. The results for one of these experiments are shown in Fig. 1.

Additionally, we used these results to estimate the minimum legible font size of one character for a person of a given age with a given viewing distance, luminance, font type, and characters. This estimation equation can be written as

$$P = a(D/V) + b \quad (1)$$

Here,  $D$  represents the viewing distance in meters,  $V$  is the visual acuity,  $P$  is the estimated minimum legible font size, and  $a$  and  $b$  are coefficients decided by the font type and letter complexity. For example, in order to estimate the minimum legible font size of Gothic font numerals, we have  $a = 6.4$  and  $b = 3.0$  (see [4, 5] for other conditions). Visual acuity is related to environmental illumination and age. Therefore,  $V$  is estimated using the target user's age and environmental luminance, and we can estimate the minimum legible font size and preferred legible font size using this formula or gathered data in order to improve legibility.



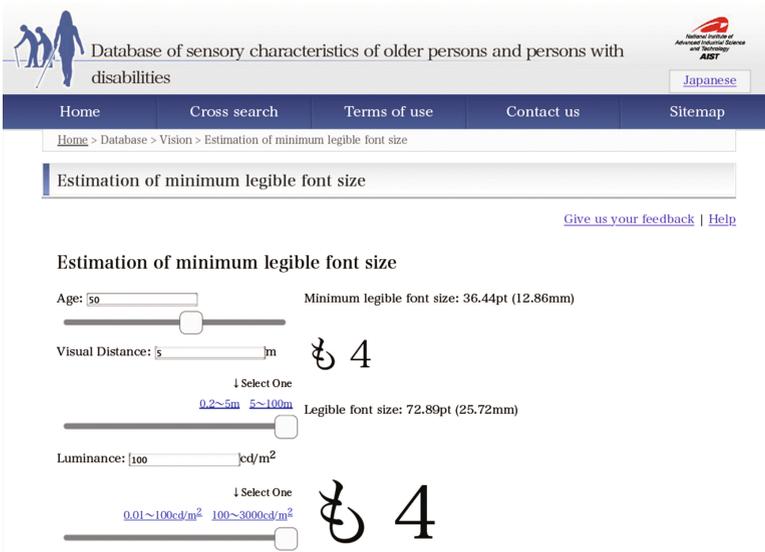
**Fig. 1.** Minimum font size required to read a single Japanese letter (hiragana/katakana/numerals, kanji 5–10 strokes, kanji 11–15 strokes) with viewing distances 0.5 and 2 m and luminance levels 100 and 0.5 cd/m<sup>2</sup>. (a) Results of 48 younger participants. (b) Results of 44 older participants. (Figure provided by [4].)

This estimation formula was used to establish the JIS S 0032: 2003 *Guidelines for the elderly and people with disabilities—Visual signs and displays—Estimation of minimum legible size for a Japanese single character* [3], which has been proposed to the International Standards Organization (ISO).

### 3 Part 2: Development of Interactive Database for Accessible Design Assistance

In Part 1, we suggested some practical considerations when examining aging effects on visual perception. We also explained how to apply the data in order to evaluate and improve design accessibility. These data and evaluation methods are useful to designers who are familiar with their technical terms and academic data; however, they remain difficult for most laypersons to comprehend. In addition, accessing reports and guides is difficult. Therefore, we developed an interactive online database, which has a simple graphical interface, using the visual characteristic data explained in Part 1. The database graphically describes various sensory characteristics using equations and tables, and it also presents preferred designs based on the target users' information and environmental settings, such as age, viewing distance, and luminance. A sample application of this database can be seen in Fig. 2.

Not only is the minimum legible font size calculated but also eight estimations concerning age-related visibility characteristics. Table 2 exhibits these database items and the corresponding effects of aging on vision. We also examined age-related changes in auditory characteristics (see [6, 7]). Moreover, we are cooperating with other researchers and institutes in order to link their reports and studies in our database, compiling a worldwide guide for accessible design. This constructed database has been released charge-free to the public on our institute's website [6].



**Fig. 2.** Example from the database of sensory characteristics of older persons and persons with disabilities: input to the left; calculated results and corresponding examples to the right.

**Table 2.** Database items and supporting experimental data for the effects of aging

Design items	Supporting experimental data
Estimation of minimum legible font size	Legibility of font size
Size and contrast threshold for legibility	Legibility of letter contrast
Age-related relative luminance	Spectral sensitivity
Age-related changes of visual field size for detection: size of visual field & detection rate	Useful field of view
Contrast sensitivity function	Contrast sensitivity
Preferred kerning and leading of text and sentences	Readability of text
Color combinations based on fundamental colors	Ability of categorization of colors

### 4 Part 3: Time Reduction Design for Accessible Design and Future Cognitive Assist Technology

In the final part of this paper, we introduce the conceptual and experimental studies of our proposed design method: the time reduction design.

## 4.1 Time Reduction Design Concept

Previously, we discussed studies concerning the effects of aging on visual characteristics and a method for using this data in order to improve design. For example, the visibility of visual information and signs can be improved using the spatial characteristics of vision that change with age, such as shape and color, found in our database. However, the improvement of spatial visibility is not sufficient for the creation of useful visual signs because most signs dynamically change, and their everyday recognition has time constraints. Designs that enable fast, accurate recognition are necessary in an aging society that is flooded with information. Our time reduction design (TRD) method can solve the cognitive problems of aging societies by improving not only spatial visibility but also recognition speed [8–10].

### **Assisting Recognition Speed for Fast, Adaptive Control Using the TRD.**

Improvements made using the TRD method have the potential to save lives. Elderly people are often the victims or victimizers of accidents caused by a lack of available recognition time. For example, the number of careless car accidents perpetrated by elderly drivers is increasing in Japan [11]. Drivers must quickly and accurately recognize multiple signs while driving. However, the time required for older drivers to recognize visual information is not considered when signs are being designed or arranged. Some of these careless accidents could be related to the decrease in older drivers' recognition speed.

**Assisting Recognition in Time-Pressured Situations Using the TRD.** It has been argued that the evacuation delay of elderly people in Japan was one of the factors that increased the number of flood victims [12]. Emergency signs and evacuation maps do not take into account the recognition speed of elderly people. The TRD can transmit information quickly and accurately to all people—both young and old alike—in time-pressured situations.

**Assisting the Personalization of Individual Cognitive Abilities Using the TRD.** A substantial gap exists between the increase of available information due to technological progress and the decrease of sensory and cognitive ability due to aging. Our information technology society demands that people have access to and understand the dynamic up-to-date contents provided by smartphones, tablets, and digital signage. The TRD can adapt the interfaces of these informational devices to individual users.

In order to do this, we calculated the relation between the display duration and recognition accuracy of signs and letters. We then estimated the time required for visual design recognition. We also introduced some examples of ongoing studies and discussed the proposed method's effectiveness.

## 4.2 Time Reduction Design Experimental Results

As part of our experimental evaluation, we calculated the relation between the display duration and recognition accuracy of signs and letters, and we estimated the time required for visual design recognition. The experimental settings and method were

similar to previous visibility studies. The exception to this concerns the timing control. We constructed a computer program that can precisely fix stimulus display time to 10 ms per frame (100 Hz). This technique for producing stable high-frequency displays was previously used in the fields of computer information and gaming but has rarely been used in experimental psychology and accessibility studies. We applied the time control technique to the TRD experiments in order to calculate the time required for visual design recognition.

**TRD Studies on Visual Elements.** As was previously mentioned, visual signs must be understood within a short time period. We examined the amount of time required to recognize visual signs and the ways in which spatio-temporal abilities change with aging. Table 3 displays the amount of time required to recognize the basic elements of visual signs.

These studies supported multiple observations. First, the required recognition time for a 5.62-degree letter was approximately half of that for a 1.69-degree letter. Letter luminance affected only small letters. Letter color affected letter recognition for letters with an approximate size of 1.69 degrees but did not affect smaller or larger letters. Word recognition speed was strongly influenced by its familiarity value but was not influenced by its ease of utterance. Four-digit numbers required a duration that was about 1.6 times longer than that needed for three-digit numbers. Pictograms were recognized faster than road signs, and the simultaneous recognition of three road signs required 736.2 ms for older persons. If a vehicle were traveling 60 km/h, it would travel 12.2 m in this duration. To recognize three road signs in 50 % of accuracy, older drivers need to pay attention to the sign during 12.2 m travel. Therefore, our results imply that demand for the accurate recognition of triple road signs would be difficult and dangerous for older drivers in most cases.

**TRD Study of Caption and Subtitle Design.** Movie captions and subtitles are examples of displays that require a TRD. These texts must have a duration that considers recognition speed. Moreover, captions are useful alternative methods for communicating auditory information for deaf and hard of hearing people. Although a substantial percentage of hearing-impaired people are elderly, the effect of aging on recognition speed is not addressed during the caption design and creation process.

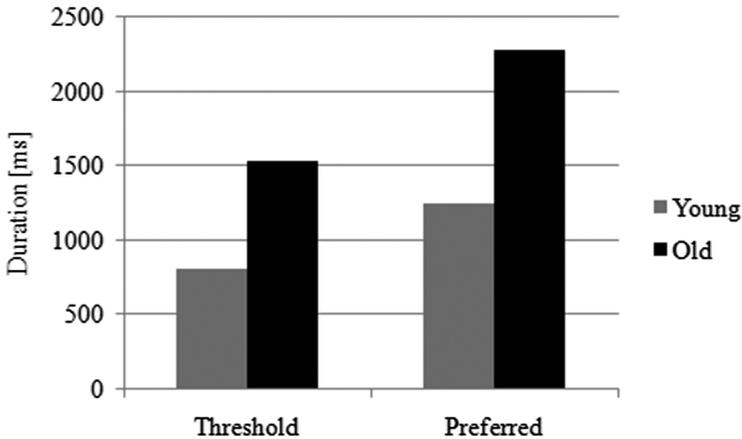
Figure 3 shows one example from our experimental studies concerning the required duration of caption presentation. The graph displays the mean required duration for both young (twenties) and old (60 and older) participants. In the preliminary study, we found that captions containing 25 to 30 letters most frequently appeared in Japanese National Broadcasting news programs. Therefore, we sampled captions having 25 to 30 letters from the news to use in the study. Results suggested that both the threshold and preferred levels of required display time for captions are approximately twice as long for elderly people than for young people. The average number of words in each caption was approximately 18 words. Therefore, the minimum duration required for recognition was approximately 44.9 ms per word for young

**Table 3.** Time required to recognize basic visual elements. Young signifies people in their twenties, and Elder represents people between the ages of 60 and 80. The estimated durations, measured in milliseconds, were 50 % and 80 % of the correct duration.

Design for			Young		Elder	
			50 % correct	80 % correct	50 % correct	80 % correct
A letter	Size: 0.63 degree	Color: White	31.44	39.12	38.40	47.49
		Color: Gray	30.79	38.28	51.47	60.41
		Color: Lime	32.50	38.95		
		Color: Aqua	33.15	41.07		
		Color: Yellow	30.80	38.62		
		Color: Fuchsia	38.05	48.54		
	Size: 1.69 degrees	Color: White	22.76	32.64	27.13	37.00
		Color: Gray	22.17	31.66	34.95	50.01
		Color: Lime	21.89	35.12		
		Color: Aqua	21.02	33.36		
		Color: Yellow	22.46	32.36		
		Color: Fuchsia	24.03	35.35		
	Size: 5.62 degrees	Color: White	5.11	11.14	19.06	30.35
		Color: Gray	6.25	14.20	18.24	33.06
		Color: Lime	5.79	10.73		
		Color: Aqua	4.66	11.06		
		Color: Yellow	6.18	11.25		
		Color: Fuchsia	4.95	10.15		
A word (Size: 1.69 degrees)	3 letters	Familiar	36.97		96.22	
		Unfamiliar	40.83		109.35	
	4 letters	Easy utterance	36.40		97.39	
		Difficult utterance	69.05		238.16	
Number	3 digits (Size: 1.69 degrees)		49.78		105.68	
	4 digits (Size: 1.69 degrees)		75.37		173.83	
Sign	Pictogram		2.82		20.16	
	Road sign	One	9.63		31.48	
		Triplet	35.77		736.2	

people and 85.2 ms per word for elderly people. These results are consistent with the TRD studies of visual elements.

We are preparing to propose our guide for the accessible visual presentation of captions and subtitles to the international standard, ISO/IEC/JTC1.



**Fig. 3.** Age-related difference for caption recognition time requirements. The threshold is the mean minimum duration needed to recognize captions, as determined by the participants. The preferred level is the mean duration in which caption evaluation is considered easy.

## 5 Conclusion

In this paper, we discussed multiple aspects of visibility and its age-related changes, and we demonstrated a method for applying experimental data to the improvement of everyday designs. We also introduced the long-term accessible visual design research performed in our laboratory. An interactive database and standard guidelines were provided as examples. In addition, we introduced the concept of our spatio-temporal design, the time reduction design, and analyzed experimental results concerning the time required for visual element recognition. Moreover, our study on caption recognition speed and its relation to aging was presented as an application of our method. The TRD clarifies the dynamic process of visual recognition for older persons and can be applied to the estimation and evaluation system of visual designs and user interfaces. Furthermore, the TRD calculates and evaluates personal abilities of perception and cognition. Therefore, it can be applied to personalized cognitive assist tools in the near future.

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