Optimizing the Design of the Sphygmomanometer Interface for Older Adults based on Visual Cognition

Miao Lu[1, *], Jun Yao[1], Xuecheng Zhao[2]

[1] School of Architecture and Design, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China

[2] Xuzhou Yongkang Electronic Science Technology Co., Ltd, Xuzhou, Jiangsu 221004, China

*E-mail: ts22190059p31@cumt.edu.cn

Abstract

In light of the aging global population, it is essential to improve the quality of life for older adults and alleviate the pressure on healthcare resources. Home medical equipment offers a safer option amid the risk of cross-infection when visiting the doctor. However, older adults struggle with the sphygmomanometer interface. To address this, a study explored the impact of font sizes, types, backlight colors, and main information spacing on the visual reading efficiency of older adults. The results revealed that a main message spacing of 35px was more effective than other spacing options, and that yellow backlight color required more visual attention than white. This study provides valuable insights for designing sphygmomanometer interfaces.

Keywords

Visual Cognition; Sphygmomanometer; Interface Design; Eye Tracking; Design for Aging.

1. Introduction

Abnormal blood pressure in older adults would bring forth many complications, and failure to monitor it in time may even cause very serious consequences. The home sphygmomanometer is one of the important products for the health examination of older adults, which can conveniently measure the blood pressure of older adults, give early warning to the abnormal value of blood pressure in time, prevent the further development of diseases and reduce the pressure on medical resources [1]. The Sphygmomanometer interface shows the real-time monitoring value of blood pressure heart rate and pulse rate, which is an im- important module for users to understand the blood pressure value [2]. However, if the value reading efficiency is low or the value reading is wrong, it may lead to further deterioration of the patient's condition, related complications, and even acute diseases and death [3]. In addition, the level of visual cognition of older adults declines with age, and problems such as presbyopia and weak perception of color plague the daily life of older adults, which can cause psychological frustration in the use of electronic products [4], thus reducing the frequency of sphygmomanometer use. Therefore, older adults need to read the interface information accurately and efficiently.

2. Related Works

2.1 Visual Cognition in Old Age

Visual cognition in the older adults differs markedly from that of the young. By assessing older adults people in a graphical pairing task for visual information processing, Yoshiyuki Kaneko et al. concluded that age is associated with cognitive decline which in turn is associated with difficulties in visual exploration planning [5]. Anjali Thapar et al. concluded that older subjects (60-75 years old) are generally slower and less accurate at letter discrimination than younger subjects [6]. Through two lexical decision-making experiments with younger and older subjects (60-75 years old), Roger Ratcliff et al. concluded that older subjects had longer reaction times than younger subjects but greater lexical reading accuracy. To be specific, older subjects were 80-100ms slower in the nondecision portion of the reaction time than younger subjects and older subjects were more conservative in their decision criterion settings[7]. Through an analysis of three existing experimental models, Duncan Guest et al. measured the accuracy of target stimulus representations in younger and older adults after exposure to different stimulus amounts. The results showed that age differences in processing speed were small when a single stimulus was present and slowed down concerning age when multiple stimulus targets were present [8]. G Bre´bion conducted experiments on the speed and accuracy of verbal processing by young and older adults and showed that older adults consistently responded much slower and with slightly higher accuracy than younger adults, regardless of the type of instruction used. In other words, older adults need to take a more cautious approach to mitigate the detrimental effects of a slower processing system [9]. As a result, the efficiency of visual cognition of external information, especially complex information, is significantly reduced in older adults compared with younger adults. Older people are more conservative in their approach to information processing.

2.2 Eye Movement Experiment

A large number of experiments have shown that eye movement data can be used to monitor the user's visual movement and assess the user's attention level, cognitive load, and interface recognition efficiency through indicators such as average fixation time pupil diameter, eye movement trajectory, and eye movement heat map. For example, Jiang MY et al. investigated the usability of critical care ventilator interfaces through eye-tracking signals and assessed the usability of different critical care ventilator user interfaces through metrics such as task completion time, pupil diameter, and the average slope of pupil diameter change [10]. Wang, JX et al. measured the effect of age on the readability of reading through the measurements of eye movement data. The results showed that older Chinese readers seemed to compensate for age-related reading difficulties by adopting more careful reading strategies [11]. Ming, Y et al. studied monitor color legibility by eye-tracking and revealed that the average gaze duration decreased with legibility in the order of text color black, blue, red, and yellow, with a subsequent decrease in legibility [12]. Li, S et al. measured the effect of age on reading legibility by examining the performance of older adults when they read sentences with normal interletter and word spacing, condensed (10% and 20% narrower than normal), or expanded (10% or 20% wider) sentences. The results showed that visual lexical processing was more disruptive to older readers when text spacing was condensed [13]. Slattery, TJ et al. investigated the effects of interword spacing (spacing between letters within a word) and word spacing (spacing between words) on eye movements during reading through eye movement experiments. The results showed that the interaction between interword spacing and interword spacing affected the readability of fonts [14]. Minakata, K et al. measured the effect of letter style and function on eye movements and found that ultraminimalist fonts produced less gaze and scanning, and that gaze duration on them was longer than that on Roman and extended fonts, which leads to the conclusion that ultra-minimalist fonts are more legible than Roman and extended fonts [15]. Wang, JX et al. found that contrary to the findings in alphabetic languages, older Chinese readers appeared to compensate for age-related reading difficulties by employing more careful reading strategies by monitoring the eye movements of younger and older readers [16]. Therefore, eye movement data measured with eye-tracking devices are very reliable and objective assessment indicators in interface design optimization studies.

2.3 Brain-computer Interface Technology in Cognitive Load Research

Currently, several scholars have applied brain-computer interface technology to the study of cognitive load testing[17][18]. Initially developed for biomedical applications to allow physically disabled users to move around, replace vanishing motor functions, and develop assistive devices for medical purposes, it is now widely used in various non-medical fields[19][20][21][22][23][24]. Scholars such as Xinping, Liu, and others have emphasized the importance of EEG-based BCIs for the first time in capturing and identifying event-related potentials and spectral perturbations through the use of channel and independent component analyses, emphasizing the EEG BCI applications in reading tasks to improve cognitive attention and comprehension in users' reading and learning experiences [25]. Using the multiscale parallel convolutional model to extract local features with different sensory fields and introducing Swin Transformer's attentional mechanism to obtain feature correlations between multiscale local features can well characterize different cognitive loads [26]. Deepak D. Kapgate and other scholars conducted brain-computer interface stimulation experiments by using different faces, and the results showed that happy facial stimuli elicit stronger VEP than sad facial stimuli, resulting in more accurate BCI [27]. However, there are still many misconceptions about BCI technology, such as "mind control", "brain control", "mind reading", and the use of BCI to "download" or "read" from the brain. There are still many misconceptions about BCI technology, such as "mind control", "brain control", "mind reading", and the ability to "download" or "upload" information from the brain using BCI [28]. At the same time, the wearing of a convenient BCI device can cause stress and psychological burden to the user, especially older adults, and cannot fully simulate the daily life scenario of using a sphygmomanometer, and noise, fatigue, inattention, motion artifacts, and blinking can also cause nonsmooth signal [29]. Based on such misconceptions, Cretot Richert, Gabrielle and others investigated the potential of EEG devices to become wearable and unobtrusive by investigating the potential of EEG recorded in and around the human ear to determine attention and concentration levels [30]. Zeng, Hong et al. optimize a hand controller as a hybrid gaze-BCI device, revealing the potential of hands-free hybrid gaze-BCI to extend traditional manual MRS input devices in challenging dual-tasking scenarios where both hands are occupied, to create a more operator-friendly interface [31]. Vorreuther et al. Providing a motion-independent communication channel for patients with severe movement disorders by combining functional near-infrared spectroscopy (fNIRS) short-term encoding with BCI communication [32]. Van de Wauw et al. present a differential fMRI activation pattern induced by selective somatosensory attention to tactile stimulation of the right hand or left foot and propose a simple paradigm that is eye-independent and requires limited cognitive functioning, with high potential for clinical application [33]. Yang, Jingcheng, et al. objectively evaluated the effects of virtual reality visual cues (VRVCs) and traditional planar visual cues (TPVCs) on the performance of motor imagery (MI) subjects and brain-computer interfaces (BCIs) when categorizing models of MI-BCIs, and noted that head-mounted VRVCs increased cognitive loads and fatigue levels in subjects [34]. The above studies show that unnatural brain-computer (BC) interactions in current brain-computer interfaces hinder the practicality of BCIs and that BCI research can almost be said to be based on paradigms invented about 30 years ago, such as motor imagery, P300 speller, etc [35][36] Moreover, after experimental testing, most older adults have a greater fear of brain-computer interface devices; therefore, this experiment does not use BCI technology to study cognitive load in older adults for the time being.

2.4 Research on Interface Design for the Older Adults

Research on interface recognition efficiency of older adults focuses on the layout of interface elements, icon design, and interface colors. Martina Ziefle verified the efficiency of information presentation on small screen devices and found that the combination of font size and visual preview affects the recognition efficiency of older adults on mobile devices [37]. Yong ku Kong et al. studied the factors related to Korean character legibility in different age groups of subjects [38]. Ohyama J et al. investigated how letter readability changes with letter design features and age and revealed that visual aging and letter size did affect letter readability [39]. Nelson, MR et al. conducted a study on two factors, namely, color contrast and font style in advertisement design. By comparing the test results of three age groups, they found that most people, especially older adults, rated sans-serif font advertisements with high color contrast the highest in terms of readability [41]. Hou GH et al. explored the influence of larger Chinese character spacing and size on the experience of older adult users and discovered that with the increase of font size, word spacing, and line spacing, the readability experience of older adult users can be improved but their reading speed would decline accordingly.

Their study provides a basis for the improvement of smartphone reading [42]. Yoon, Jong Chan, et al. conducted a study on the effects of smartphone font size, font type, and line spacing on readability in different age groups, and the results showed that font size and line spacing can significantly affect the cell phone text readability of people aged 50-60 years old [43]. Seongwon et al. found that smartphone font size of 13 pt and font type of Serif font were more readable for older people by studying Korean font type, font size, letter spacing, and line spacing [44].

Numerous studies have revealed significant differences in the visual cognitive function of older adults compared to younger individuals. The design of product interfaces can profoundly impact recognition efficiency, particularly for older adults. Despite this, the focus on designing home medical products primarily for middle-aged individuals has led to a lack of research on optimizing interface recognition for older adults, especially those with presbyopia. Therefore, it is imperative to investigate how older adults with presbyopia recognize and interact with sphygmomanometer interfaces.

2.5 Technological Route

This study followed a defined methodology as depicted in Figure 1. It involved analyzing the design of existing sphygmomanometer interfaces, identifying and categorizing variable factors, and establishing logical parameters. Additionally, we conducted an in-depth analysis of the visual cognitive characteristics, living habits, and behavioral habits of older adults to inform the design of the experiment steps. Furthermore, we examined the usage patterns of sphygmomanometers by older adults with presbyopia to enhance their interface recognition efficiency. The primary objective of this study is to alleviate the psychological burden experienced by older adults with presbyopia when using new home medical products such as sphygmomanometers and to facilitate the timely management of their medical conditions. Ultimately, this study aims to alleviate pressure on medical resources and enhance the overall quality of life for older adults.

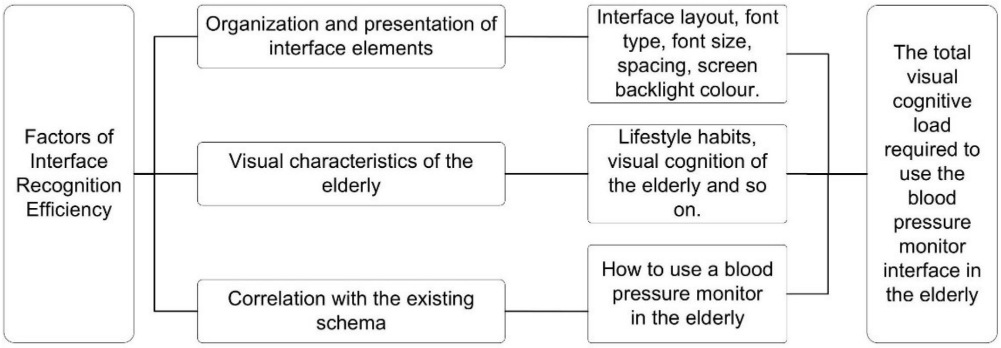

Figure 1. The total visual cognitive load required to use the blood pressure monitor interface in the elderly

3. Material and Methods

3.1 Participants

The study included 30 older adult participants from three nursing homes in Xuzhou. All participants were screened for color blindness, color weakness, and eye diseases. They all had varying degrees of presbyopia but no excessive senile blepharoptosis. The group comprised eight males (average age = 67.75 ± 3.56 years) and seven females (average age = 64.43 ± 5.55 years), with an age range of 55 to 73 years (average age = 66.20 ± 4.89 years). Table 1 shows the basic demographic information for all participants. Before the start of the experiment, the participants were briefed on the experimental procedures and the sphygmomanometer interface. The study was approved by the Ethics Committee of the China University of Mining and Technology, and all participants provided written consent before taking part in the study. All procedures were performed following the relevant guidelines and regulations.

Table 1. Add caption

	Participants	
	Male	**Female**
Number	8	7
Mean±SD	67.75±3.56	64.43±5.55

3.2 Experimental Parameters

In the experiment, we used a total of 24 interface experimental materials, displayed on a home blood pressure monitor. These materials included pressure, pressure standard, pulse, user information, and time. The selected pressure parameters were high pressure and low pressure, shown in both English letters and Arabic numerals. To ensure readability, we used black font color and avoided the use of other colors. Before the experiment, the subjects had an opportunity to familiarize themselves with the interface parameters and were also introduced to the experimental procedure and informed of the necessary precautions to take while participating in the experiment.

3.3 Experimental Equipment and Environment

The experiment utilized the Tobii Pro X3-120 eye-tracking device. The Tobii Pro X3-120 eye-tracking device is a portable tool from Tobii that comes with dual eye-tracking sensors and offers both bright pupil and dark pupil tracking modes. It boasts a 97% tracking capability and an accuracy of 0.4°, with a sampling rate of 120 Hz. The screen resolution is 1980 x 1080 pixels, and the recommended distance between the subject and the center of the screen is 550-600mm. The device has an accuracy of 0.24° for the viewpoint position, and the overall latency is less than 11ms.

The experiment took place in the Intelligent Interaction Laborator. A sign was posted outside the door to prevent interference from others during the experiment. Before the experiment, the subjects were asked if they were comfortable, and adjustments were made to their seating to ensure their comfort. Their blood pressure was measured before the experiment to familiarize the subjects with the interface parameters, the experimental process, and the precautions to be taken.

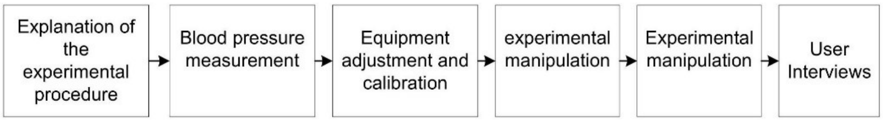

Figure 2. Experimental procedure

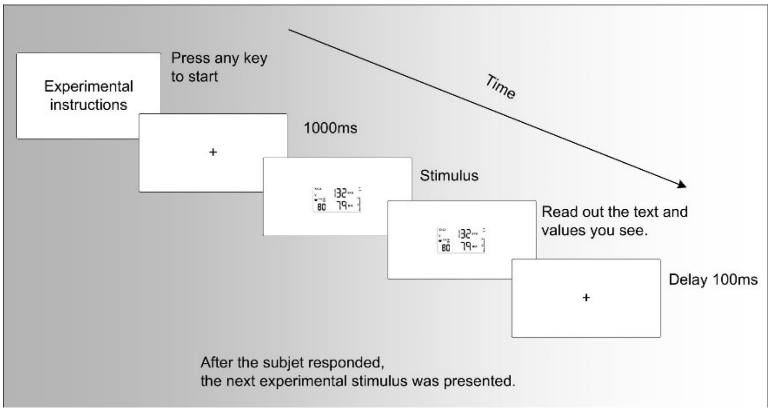

Figure 3. Mission Flow

3.4 Experiment Design

In the experiment, we utilized eye movements to gauge the participants' cognitive load. Before the experiment, participants familiarized themselves with the process by testing and perusing data from the sphygmomanometer product. They were instructed to read the guidelines and then click the start button (as shown in Figure 2) to commence the experiment. The experiment entailed displaying a gaze point (+) in the center of the screen for 500ms, followed by the presentation of the target interface. After vocalizing the value and observing the stimulus, participants clicked the left mouse button, and the stimulus vanished with a 100ms delay. The experimenter recorded the percentage of accurate readings. Once a participant finished reading the stimulus, the interface automatically provided the next set of tests. Each participant was randomly assigned to a total of 24 experiments, with 20 minutes provided to complete all tests.

3.5 Stimulus

The objective of this study is to evaluate the ability of older adults with varying degrees of presbyopia to interpret blood pressure measurements on sphygmomanometer interfaces. The experiment utilized the Yong Kang YK-BPA7 arm sphygmomanometer as the standard reference object, and the interface layout was displayed on a screen at a 1:1 size ratio, as outlined in Table 2. The interface was segmented based on its functions, and the primary factors influencing the interface were identified and categorized as experimental stimuli.

Table 2. Experimental stimuli

Variable	Level of variable
Font Type	82pt, 92pt
Font size	digital display, digital display tfd
Main Message spacing	35px, 25px, 45px
Screen backlight color	Yellow screen backlight (R255, G255, B221) White screen backlight (R255, G255, B255)

The experimental stimuli in this study consist of font type, font size, interface backlight color, and spacing of the main parameterized information. Two experimental fonts were used: digital display and digital display tfb, commonly found on general sphygmomanometer screens (refer to Figure 3). The font size was chosen from the existing sphygmomanometer Yongkang YK-BPA7 font, with sizes of 82 pt and 92 pt (82 pt on the left side, 92 pt on the right side) (refer to Figure 4). The spacing between the blood pressure function area and the heart rate and basic information area on the left side was initially set at 35px but would vary as a parameter to 25px and 45px. On the right side, the corresponding spacing between the blood pressure standard area and the heart rate and basic information area was 17px, 27px, and 7px, as shown in Figure 5. The existing sphygmomanometer backlight colors were low light (white) and warm light (yellow), as shown in Figure 6.

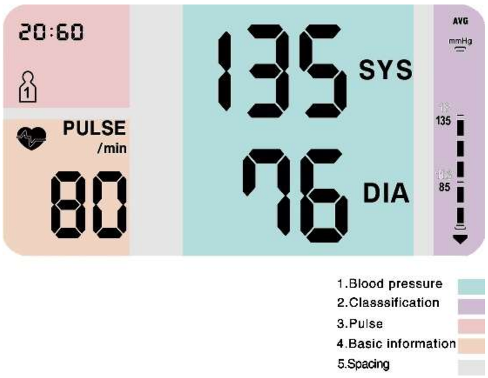

Figure 4. Interface and information partition diagram of sphygmomanometer

Figure 5. Font type selection

Figure 6. Font size selection (left is 82pt, right is 92pt)

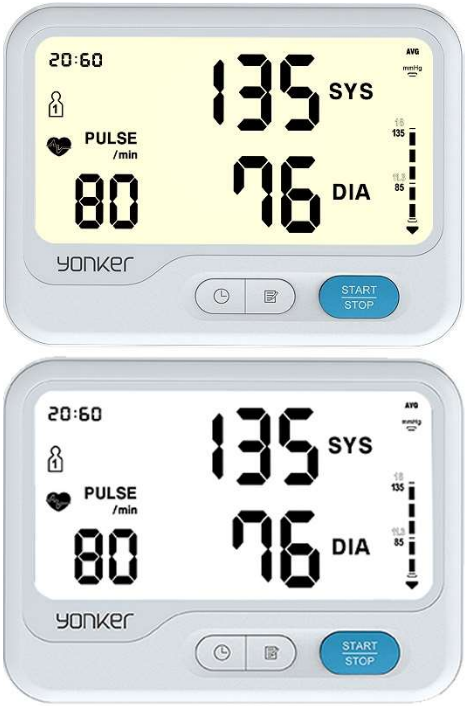

Figure 7. Color of screen backlighting

3.6 Equipment and Procedure

In our research, we employed a single visual change detection task. Participants were tasked with vocalizing the presented stimuli while their accuracy was assessed by the experimenter. The visual search experiments entailed integrating parameterized information from various stimulus elements without repetition. Each experiment's interface displayed a layout resembling a blood pressure monitor, and participants were instructed to carefully review all presented information. The study was designed using a 2 × 2 × 2 × 3 full factorial experimental design, encompassing 24 sets of stimulus element permutations. We meticulously considered combinations of font type, size, background color, and spacing to optimize efficient searches within a brief timeframe.

Ahead of the actual experiment, a group of participants was selected to conduct a pre-experiment to assess the scientific validity and feasibility of the experimental process. Ten subjects were chosen to take part in the pre-experiment. It was noted that older adult subjects encountered difficulty in understanding the instructions, and an excessive number of experimental combinations affected their motivation to continue. Furthermore, subjects who lacked proficiency in using computers faced challenges with mouse clicks that could compromise the accuracy of the experiment. Towards the conclusion of the experiment, the older adult subjects, due to waning enthusiasm, became perfunctory with the experiment. To address these issues, the following improvements were implemented:

1) The order of experimental combinations was randomized.

2) Subjects were required to verbalize the data they saw before proceeding to click the mouse.

3) Pre-experimental blood pressure measurements and familiarization with the experimental stimuli on the interface were made mandatory.

4. Results

Eye-tracking devices capture data on eye movements, allowing us to explore the correlation between eye movements and human visual cognitive efficiency. The hotspot map illustrates the distribution of the user's points of interest while navigating the sphygmomanometer interface, providing insights into their browsing habits. Additionally, the eye-track map indicates the initial focal point when the user sees the sphygmomanometer. Furthermore, the average fixation time serves as a measure of how long it takes to process information within the interface, offering insights into the clarity of information layout. Lastly, the mean pupil diameter can be utilized to gauge the cognitive load experienced by the subjects. In this study, hotspot maps and eye-track maps were instrumental in identifying the key areas of interest within the user interface.

4.1 Average Fixation Time

Table 3. Mean and standard deviation of average fixation time and mean pupil diameter for blood pressure values in various conditions

Font Type	Font size of Blood Pressure Numbers	Main message spacing	Color of screen backlighting	Average fixation time	Mean Pupil Diameter
				Mean	Mean
digital display	82pt	35px	Yellow	0.14	2.31
	92pt			0.14	2.56
	82pt	25px		0.13	2.55
	92pt			0.11	2.57
	82pt	45px		0.13	2.56
	92pt			0.15	2.48
digital display tfb	82pt	35px		0.09	2.47
	92pt			0.11	2.50
	82pt	25px		0.15	2.44
	92pt			0.11	2.43
	82pt	45px		0.10	2.48
	92pt		White	0.13	2.42
	82pt	45px		0.09	2.42
	92pt			0.11	2.41
	82pt	25px		0.12	2.47
	92pt			0.11	2.47
	82pt	35px		0.11	2.45
	92pt			0.11	2.42
digital display	82pt	35px		0.13	2.43
	92pt			0.14	2.40
	82pt	25px		0.14	2.40
	92pt			0.11	2.42
	82pt	45px		0.07	2.36
	92pt			0.12	1.97

The average fixation time refers to the duration it takes for a user to process information within a specific area. A cluttered interface can prolong the user's fixation time, thus reducing the efficiency of information processing. Table 3 presents data on the average fixation time of 30 older adults using 24 different sphygmomanometer interfaces. The findings demonstrate that the combinations of elements in these interfaces significantly influence the average fixation time of older adults. Notably, the combination of a digital display, 92pt font size, 45px resolution, and yellow backlight resulted in the longest average fixation time, while the combination of a digital display, 92pt font size, 45px resolution, and white backlight yielded the shortest average fixation time.

In our study, we utilized Statistical Products and Services Solutions (SPSS version 27.0.1) to conduct a statistical univariate repeated measures ANOVA. The results are detailed in Table 4.

Table 4. Mean and standard deviation of average fixation time for blood pressure values in various conditions

Tests of Between-Subjects Effects						
Dependent Variable: average fixation time						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.005^a	11	.000	8.636	.000	.888
Intercept	.393	1	.393	7249.923	.000	.998
Font Type	.000004	1	.000004	.077	.786	.006
Font size	.000004	1	.000004	.077	.786	.006
Main message spacing	.005	2	.002	45.308	.000	.883
Font Type * Font Size	.000	1	.000	1.923	.191	.138
Font type * Main message spacing	.000008	2	.000004	.077	.926	.013
Font Size * Main Message Spacing	.000058	2	.000029	.538	.597	.082
Font Type * Font Size * Master Message Spacing	.000058	2	.000029	.538	.597	.082
inaccuracies	.001	12	.000054			
(grand) total	.399	24				
Amended total	.006	23				
a. R-square = .888 (adjusted R-square = .785)						

We discovered that the main effect of main message spacing is statistically significant at the 0.05 level ($F = 45.308$, $p < 0.05$, and $\eta 2= 0.883$), as well as the main effect of the case ($F = 798$, $p < 0.001$). Additionally, the main effects of font type ($F = 18$, $p<0.05$) and font size ($F =32$, $p<0.05$) are also statistically significant. Furthermore, the interaction between font size and main message spacing is significant ($p<0.05$).

These findings suggest that main message spacing has the most significant impact on average fixation time, which is related to the main message position and screen center offset. This is consistent with the law of human visual cognition, indicating that human eyes first start recognizing information from the screen center.

We also observed that font size and font type affect mean gaze time. Specifically, the font type "digital display" has a shorter average fixation time than "digital display tf". Furthermore, we found that a font size of 82pt requires less average gaze time to recognize information than a font size of 92pt. This contradicts the common belief that older adults prefer larger fonts due to cognitive decline. This unexpected result may be attributed to the fact that both font sizes are large enough, but 82pt provides greater spacing between information, making it easier to distinguish between different pieces of information.

The LSD method was utilized to compare the average fixation time for different main message spacings, and the results are presented in Table 5. According to the table, there are significant differences in average fixation time for main message spacings of 25px, 35px, and 45px. Figure 7 illustrates the average fixation time required for different main message spacings. A main message spacing of 35px requires less cognitive load, indicating that the interface layout at this spacing is relatively user-friendly, especially for older users.Furthermore, in Figure 8, the interaction response between font size and main message spacing was analyzed. It was found that a font size of 82px required less gaze time than a font size of 92px at a main message spacing of 35px.

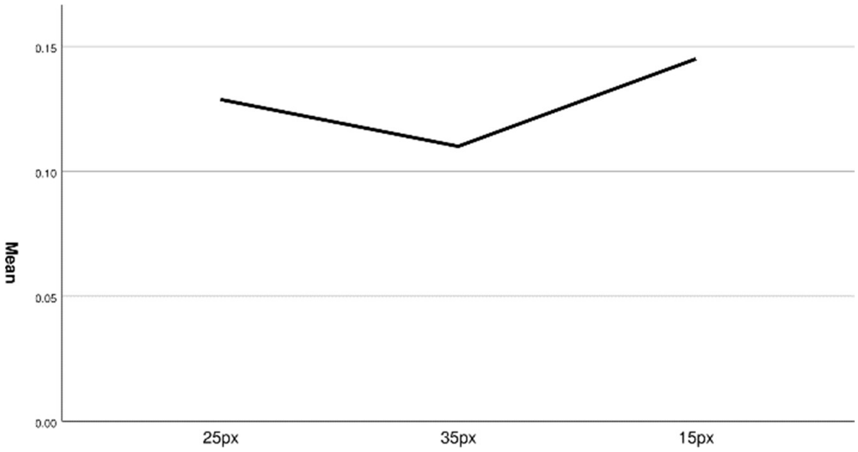

Figure 8. Average fixation time required for different main message spacing

Table 5. Multiple comparisons by using least difference method on response time to different main message spacing

(I) Main Message Spacing	(J) Main Message Spacing	Difference in mean values (I-J)	standard error	significance	95% confidence interval	
					lower limit	limit
25px	35px	.0188*	.00368	.000	.0107	.0268
	45px	-.0163*	.00368	.001	-.0243	-.0082
35px	25px	-.0188*	.00368	.000	-.0268	-.0107
	45px	-.0350*	.00368	.000	-.0430	-.0270
45px	25px	.0163*	.00368	.001	.0082	.0243
	35px	.0350*	.00368	.000	.0270	.0430

4.2 Mean Pupil Diameter

The mean pupil diameter serves as an indicator of unconscious reflexive cognitive load, assessing the influence of interface information arrangement on cognitive load. Pupil dilation, a change in the size of the pupil diameter, occurs in response to intense emotions such as fear or pain. According to studies by Paas et al., pupillary response is highly sensitive to fluctuations in cognitive load levels [45]. Similarly, research by Jackson and others has demonstrated that individuals dealing with working memory, focused attention, sensory discrimination, or other cognitive loads evoke pupillary responses [46]. Moreover, pupil dilation was found to be more pronounced when conditions required greater mental effort, confirming that changes in pupil dilation are indicative of cognitive load. In a digit breadth memory task, researchers noted that pupil size tended to increase with each additional digit appearance, returning to baseline levels after the digit was recalled [47]. Therefore, pupil dilation has been proven to be one of the most accurate physiological indicators of cognitive load.

In Table 6, the ANOVA results reveal that different combinations of interface elements significantly impact the pupil diameter of elderly subjects. Specifically, the screen backlight color stimulus has the most significant effect on mean pupil diameter, suggesting that visual discrimination efficiency in elderly adults is influenced by screen backlight color.

Table 6. One-way ANOVA main effects results for mean pupil diameter of blood pressure value areas

Tests of Between-Subjects Effects						
Dependent Variable: average pupil diameter						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.230^a	11	.021	3.019	.035	.735
Intercept	143.228	1	143.228	20720.174	.000	.999
Font Type	.001	1	.001	.102	.755	.008
Main message spacing	.037	2	.018	2.670	.110	.308
Screen backlight color	.081	1	.081	11.646	.005	.493
Font type * Main message spacing	.019	2	.009	1.364	.293	.185
Font Type * Main message spacing	.059	1	.059	8.536	.013	.416
Main message spacing * Screen backlight color	.020	2	.010	1.462	.270	.196
Font Type * Main message spacing * Screen backlight color	.013	2	.007	.966	.408	.139
Error	.083	12	.007			
Total	143.541	24				
Corrected Total	.312	23				

The Statistical Products and Services Solutions (SPSS, version 27.0.1) was used to perform Statistical univariate repeated measures ANOVA. The results of the statistical analysis are pre- sented in Table 4. The results indicate that the main effect of backlight color is statistically significant at the 0.05 level (F =11.646, p <0.05, and 2 = 0.493). Similarly, the main effect of the case is found to be statistically significant (F = 3.019, p<0.05, and 2 = 0.735). However, the main effects of font type (F = 0.102, p >0.05, and 2 = 0.008) or main message spacing(F = 2.670, p >0.05, and 2 = 0.308) are not significant. The main effect between font type and backlight color is found to be significant (F = 8.536, P <0.05, and 2 = 0.416).

The line graph in Figure 9 shows that changing the font type of the sphygmomanometer display to digital display tfb results in a relatively smooth change in the average fixation time. How- ever, changing the font type to digital display leads to a drastic change in the average fixation time. Additionally, the figure il- lustrates that with yellow screen backlighting, the average pupil diameter is relatively larger, while with white screen backlight- ing, it is the smallest.

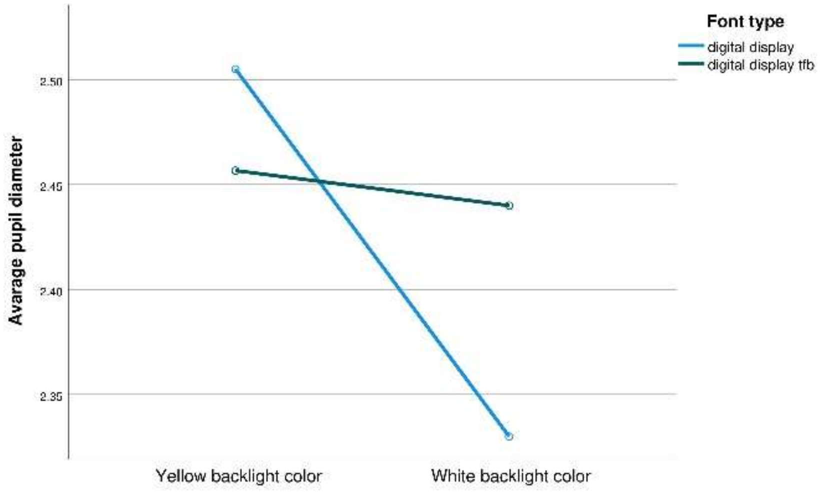

Figure 9. Screen backlight color vs. font type for average pupil diameter

Furthermore, the statistical analysis conducted using Statistical Products and Services Solutions (SPSS, version 27.0.1) and presented in Table 4 indicates that the main effect of backlight color is statistically significant at the 0.05 level ($F = 35.103$, $p < 0.05$).

4.3 Page Heat Map

The hotspot map reflects the distribution of the subject's points of interest when browsing the interface, according to which researchers can judge the location of the subject's focus when browsing the page. The hot spot map can intuitively show the stimulus elements that the subjects pay more attentionto, thus reflecting the more visually attractive elements on the whole interface. As can be seen in Figure 10, the visual hotspots of the subjects mainly focus on the blood pressure value, pulsevalue area and time display area, indicating that the distribution of visual attention is relatively uniform, and the partition is relatively reasonable. This is in line with the subjects' visualcognitive habits. Technically, when observing the interface, thesubjects would concentrate their visual hotspots in the center ofthe interface, bright color blocks and larger value areas.

Figure 10. Eye movement hotspot map of the combination with the shortest aver- age fixation time

4.4 Eye Tracking Diagram

It is observed that elderly users usually read visual message from top to bottom and left to right. Figure 11 shows that el- derly users first focus on the center of vision where high pres- sure value is displayed, and then move downwards to read the low pressure value. However, some elderly users prefer to readfrom left to right in order, which is related to their reading habits and the length of the interface direction.

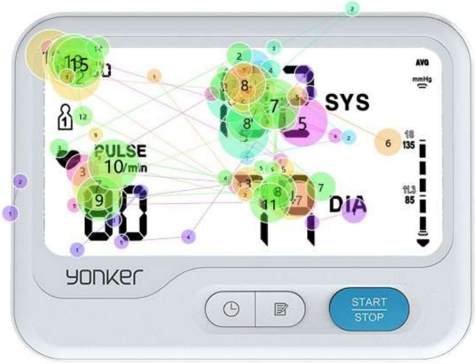

Figure 11. Eye tracking diagram of the combination with the longest average fix- ation time

5. Discussion

This study aimed to examine whether the use of home blood pressure monitors could reduce visual fatigue in older adults, resulting in improved reaction time and visual recognition efficiency. Four variables were investigated: font type, font size, main message spacing, and screen backlight color. Furthermore, the interaction among these variables was also analyzed.

The experimental results revealed that visual recognition was significantly more efficient and response time was the shortest when the main message spacing was set at 35px. This finding is consistent with a study by Feifei Liang et al., which demonstrated that the frequency of Chinese character positions and character spacing affect users' vocabulary acquisition efficiency during reading [48]. According to the law of human visual cognition, the human eye tends to prioritize information from the center of the screen. With the 35px spacing of the main message, the offset from the screen's center is minimized, leading to improved visual cognition efficiency for older adult users.

When the screen backlight is yellow, the pupil diameter is at its smallest. This finding is consistent with the research of S. T. Chung and P. L. Pease, who found that pupil diameters were larger when using yellow lenses than when observing a broad-spectrum white field at the same luminance. This implies that using a yellow filter may lead to subjective luminance enhancement [49]. Additionally, the study showed a significant interaction between font type and screen backlight color. The combination of the digital display tfb font and white backlight color resulted in the smallest mean pupil diameter. Furthermore, the line chart generated by the digital display tfb font type shows a more pronounced trend, whereas the digital display font type displays a relatively mild trend.

The type and size of font have a minimal impact on-screen recognition efficiency, whether individually or combined. This is because the fonts used in this experiment are relatively large, and varying them within a certain range does not have a significant effect. This contradicts a study by Jonathan Dobres and Benjamin Wolfe, which suggests that larger text is more legible than smaller text and that crowded displays require more processing time than single-word displays [50]. However, the two common clock font types used in the experiments had little effect on visual recognition efficiency, contrary to Abdullah Z Alotaibi’s findings that the N12 font in Times New Roman improved the user’s reading ability [51]. The recent study by Dobres et al. found a significant interaction between font type and age in conditions with a high legibility threshold [52]. However, the hypothesis requires further experimental verification because the font types and sizes selected for the experiment were not comprehensive enough.

Based on the hotspot map of the subject’s eye movement on the screen, the main message is currently located in the visual hotspot area, thus making it easier to be recognized. Older adults in this age group tend to regularly measure their blood pressure and are therefore more familiar with the standard values. As a result, they tend to pay less attention to the area displaying the right blood pressure standard values. If the warning area needs to be optimized, appropriate adjustments can be made to the color, shape, and size of the warning message. However, scholars need to further explore this optimization principle in future studies.

5.1 Implications and Contributions

"Table 1The current study only examined two common colors of backlighting available on the market. However, future research should compare a broader range of screen backlighting colors. Additionally, further efforts will be made to explore a wider variety of clock fonts and font sizes. The spacing of the main message on the screen has a significant impact on the average fixation time. Specifically, the average fixation time is minimized when the main message spacing is set to 35px. Furthermore, changing the screen backlight color can also affect the user's pupil diameter. In particular, the average pupil diameter is smallest when the screen backlight color is white, which can also reduce the visual cognitive load of the users. These findings offer valuable principles for designing user-friendly interfaces for home blood pressure monitors. Moreover, the experimental results of this study can guide designing interfaces for other home medical products that are also age-friendly.

5.2 Limitations and Future Research Directions

Please remember the following points from the study. The study has some limitations that should be addressed in future research. Firstly, the participants in the experiment were all between 55 and 73 years old. It is important to consider the real-life usage environment and further divide the age groups in future studies.

Secondly, the study only examined the average fixation time for three main message spacings: 25px, 35px, and 45px. Although the study found that the average fixation time is shortest at a main message spacing of 35px, it did not clarify how the average fixation time changes as the main message spacing progresses from 25px to 45px. Therefore, more research is needed to investigate the effects of changes in the main message spacing within this range and beyond the average fixation time.

Thirdly, the experiment only considered two backlight variables: yellow backlight and white backlight. These backlight colors were chosen because they result in smaller average pupil diameter and require less cognitive load. However, studying only these two common screen backlight colors has limitations. Therefore, future studies should include other backlight colors for a more comprehensive understanding.

6. Conclusion

This study conducted an eye-tracking experiment to analyze the typographic elements of a home blood pressure monitor interface. The experiment simulated the interface and examined font type, font size, main message spacing, and screen backlight color as variables. The findings showed that main message spacing significantly influenced average fixation time, while screen backlight color had a notable effect on mean pupil diameter. The interaction between font type and screen backlight color also had a substantial impact on visual cognitive load. However, the effect of font type and font size on average fixation time and mean pupil diameter was found to be insignificant.

The study also revealed that a main message spacing of 35px led to shorter average fixation times compared to spacing of 15px and 25px, suggesting reduced visual load on the subjects. Additionally, it was observed that when the backlight color was white, the mean pupil diameter was smaller than when using a yellow backlight color, indicating that the white backlight color required less visual attention. These findings offer valuable insights for the optimal design of interfaces for home blood pressure monitors and other aging-friendly home medical devices.

Acknowledgments

Funding: This project is funded by the Graduate Innovation Program of China University of Mining and Technology, project number "2024WLJCRCZL334".

References

[1] Li, Yan, et al. "The Health and Economic Impact of Expanding Home Blood Pressure Monitoring." American journal of preventive medicine 65.5 (2023): 775-782.

[2] Blubaugh, Morgan V., and Mark M. Uslan. "Accessibility attributes of blood glucose meter and home blood pressure monitor displays for visually impaired persons." (2012): 246-251.

[3] Kario, Kazuomi, et al. "Home blood pressure can predict the risk for stroke/bleeding events in older adults patients with nonvalvular atrial fibrillation from the ANAFIE registry." Hypertension 79.12 (2022): 2696-2705.

[4] Polat U, Schor C, Tong J L, et al. Training the brain to overcome the effect of aging on the human eye[J]. Scientific reports, 2012, 2(1): 278.

[5] Kaneko, Yoshiyuki, et al. "Differential effects of aging and cognitive decline on visual exploration behavior in the older adults." Neuroscience Research 171 (2021): 62-66.

[6] Thapar, Anjali, Roger Ratcliff, and Gail McKoon. "A diffusion model analysis of the effects of aging on letter discrimination." Psychology and Aging 18.3 (2003): 415.

[7] Ratcliff, Roger, et al. "A diffusion model analysis of the effects of aging in the lexical-decision task." Psychology and aging 19.2 (2004): 278.

[8] Guest, Duncan, et al. "Aging and the rate of visual information processing." Journal of vision 15.14 (2015): 10-10.

[9] Brébion, Gildas. "Language processing, slowing, and speed/accuracy trade-off in the elderly." Experimental Aging Research 27.2 (2001): 137-150.

[10] Jiang M, Liu S, Feng Q, et al. Usability study of the user- interface of intensive care ventilators based on user test and eye-tracking signals[J]. Medical science monitor: in- ternational medical journal of experimental and clinical re- search, 2018, 24: 6617.

[11] Wang J, Li L, Li S, et al. Adult age differences in eye movements during reading: The evidence from Chinese[J]. The Journals of Gerontology: Series B, 2018, 73(4): 584-593.

[12] Ha-Lim Kim, Su-Hyun Kim, Dong-Min Shin, etc. A study on readability according to monitor text color using an eye tracker [J]. Journal of the Korean Society of Ophthalmol- ogy, 2014, 19(2): 279-284.

[13] Li S. Adult age differences in effects of text spacing on eye movements during reading. Front. Psychol. 9 (2019)[J]. 2018.

[14] Slattery T J, Rayner K. Effects of intraword and interword spacing on eye movements during reading: Exploring the optimal use of space in a line of text [J]. Attention, Per- ception, Psychophysics, 2013, 75: 1275-1292.

[15] Minakata, Katsumi, and Sofie Beier. "The effect of font width on eye movements during reading." Applied ergonomics 97 (2021): 103523.

[16] Kim, K., et al. "EEG microstate features according to performance on a mental arithmetic task. Sci Rep 11: 1–14." (2021).

[17] Yadav, Hitesh, and Surita Maini. "Electroencephalogram based brain-computer interface: Applications, challenges, and opportunities." Multimedia Tools and Applications 82.30 (2023): 47003-47047.

[18] Kerous B, Skola F, Liarokapis F (2018) EEG-based BCI and video games: a progress report. Virtual Real 22(2):119–135.

[19] Huang KC, Huang TY, Chuang CH, King JT, Wang YK, Lin CT, Jung TP (2016) An EEG-based fatigue detection and mitigation system. Int J Neural Syst 26(04):1650018.

[20] Zhang HY, Stevenson CE, Jung TP, Ko LW (2020) Stress-induced effects in resting EEG spectra predict the performance of SSVEP-based BCI. IEEE Trans Neural Syst Rehabil Eng 28(8):1771–1780.

[21] Al-Nafjan A, Hosny M, Al-Ohali Y, Al-Wabil A (2017) Review and classification of emotion recognition based on EEG brain-computer interface system research: a systematic review. Appl Sci 7(12):1239.

[22] Huang H, Xie Q, Pan J, He Y, Wen Z, Yu R, Li Y (2019) An EEG-based brain computer interface for emotion recognition and its application in patients with disorder of consciousness. IEEE Trans Affect Comput 12(4):832–842.

[23] Alariki AA, Ibrahimi AW, Wardak M, Wall J (2018) A review study of brian activity-based biometric authentication. J Comput Sci 14(2):173–181.

[24] Liu, Xinping, and Zehong Cao. "Enhance Reading Comprehension from EEG-Based Brain-Computer Interface." Australasian Joint Conference on Artificial Intelligence. Singapore: Springer Nature Singapore, 2023.

[25] Li, Zhongrui, et al. "MST-net: A multi-scale swin transformer network for EEG-based cognitive load assessment." Brain Research Bulletin 206 (2024): 110834.

[26] Kapgate, Deepak D. "The Use of Happy Faces as Visual Stimuli Improves the Performance of the Hybrid SSVEP+ P300 Brain Computer Interface." Journal of Neuroscience Methods (2024): 110170.

[27] Chen, Yanxiao, et al. "Several inaccurate or erroneous conceptions and misleading propaganda about brain-computer interfaces." Frontiers in Human Neuroscience 18 (2024): 1391550.

[28] Liyanage SR, Guan C, Zhang H, Ang KK, Xu J, Lee TH (2013) Dynamically weighted ensemble classification for non-stationary EEG processing. J Neural Eng 10(3):036007.

[29] Crétot-Richert, Gabrielle, et al. "Assessing focus through ear-EEG: a comparative study between conventional cap EEG and mobile in-and around-the-ear EEG systems." Frontiers in Neuroscience 17 (2023): 895094.

[30] Zeng, Hong, et al. "Extended Control With Hybrid Gaze-BCI for Multi-Robot System Under Hands-Occupied Dual-Tasking." IEEE Transactions on Neural Systems and Rehabilitation Engineering 31 (2023): 829-840.

[31] Vorreuther, Anna, et al. "It takes two (seconds): decreasing encoding time for two-choice functional near-infrared spectroscopy brain–computer interface communication." Neurophotonics 10.4 (2023): 045005-045005.

[32] Van de Wauw, Cynthia, et al. "Talking with hands and feet: Selective somatosensory attention and fMRI enable robust and convenient brain-based communication." NeuroImage 276 (2023): 120172.

[33] Yang, Jingcheng, et al. "The Effects of VR and TP Visual Cues on Motor Imagery Subjects and Performance." Electronics 12.11 (2023): 2381.

[34] Wang, Kun, et al. "Enhance decoding of pre-movement EEG patterns for brain–computer interfaces." Journal of neural engineering 17.1 (2020): 016033.

[35] Xu, Minpeng, et al. "Current challenges for the practical application of electroencephalography-based brain–computer interfaces." Engineering 7.12 (2021): 1710-1712.]

[36] Wang, Jingxin, et al. "Adult age differences in eye movements during reading: The evidence from Chinese." The Journals of Gerontology: Series B 73.4 (2018): 584-593.

[37] Ziefle, Martina. "Information presentation in small screen devices: The trade-off between visual density and menu foresight." Applied ergonomics 41.6 (2010): 719-730.

[38] Kong, Yong-Ku, et al. "The effects of age, viewing distance, display type, font type, colour contrast and number of syllables on the legibility of Korean characters." Ergonomics 54.5 (2011): 453-465.

[39] Ohyama, Junji, and Ken Sagawa. "The effects of letter

[40] design features and aging on legibility." Perception 45.6 (2016): 642-656.

[41] Nelson, Michelle R., and Kirby Cook. "Accessibility and Age: Can Legibility Improve Opportunity to Process Advertising?." Journal of Advertising 53.3 (2024): 307-325.

[42] Hou, Guanhua, et al. "Larger Chinese text spacing and size: effects on older users' experience." Ageing & Society 40.2 (2020): 389-411.

[43] Yoon, Jong-Chan, and Jin-Young Ha. "Influence of Font Size, Font Face and Line Spacing of Smartphones on Legibility of 20~ 30s and 50~ 60s." Journal of the Society for Digital Content (J. DCS) 20.1 (2019): 33-40.

[44] Jeong, Seong-Won. "Impact of smartphone Hangul typography on the legibility of the older adults." The Journal of the Korea Contents Association 16.11 (2016): 661-674.

[45] Paas, Fred GWC, and Jeroen JG Van Merriënboer. "Instructional control of cognitive load in the training of complex cognitive tasks." Educational psychology review 6 (1994): 351-371.

[46] Beatty, Jackson, and Brennis Lucero-Wagoner. "The pupillary system." (2000).

[47] Granholm, Eric Ed, and Stuart R. Steinhauer. "Pupillometric measures of cognitive and emotional processes." International Journal of Psychophysiology (2004).

[48] Liang, Feifei, et al. "The role of character positional frequency on Chinese word learning during natural reading." PloS one 12.11 (2017): e0187656.

[49] Chung, Susana TL, and Paul L. Pease. "Effect of yellow filters on pupil size." Optometry and vision science 76.1 (1999): 59-62.

[50] Dobres, Jonathan, et al. "The effects of visual crowding, text size, and positional uncertainty on text legibility at a glance." Applied ergonomics 70 (2018): 240-246.

[51] Alotaibi, Abdullah Z. "The effect of font size and type on reading performance with Arabic words in normally sighted and simulated cataract subjects." Clinical and Experimental Optometry 90.3 (2007): 203-206.

[52] Dobres, Jonathan, et al. "Utilising psychophysical echniques to investigate the effects of age, typeface design, size and display polarity on glance legibility." Ergonomics 59.10 (2016): 1377-1391.