Developing Accessible eHealth Portals: A Human-centred Approach

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Abstract: eHealth technology is being developed at a rapid rate in line with advances in Information and Communication Technology (ICT). As eHealth technology increases, ensuring equitable accessibility and usability for all end-users is becoming a significant challenge. Considering human factors in the design phase of an application will help ensure usability and accessibility gaps are addressed. We conducted a survey with a broad range of users to investigate the relationship between different human factors and design elements that address these human factors. From the survey results, we developed a high-fidelity design prototype which we validated with a usability study to enhance the usability and accessibility for diverse end-users.

1 INTRODUCTION

The rapid changes and advances in Information and Communication Technology (ICT) have had a huge impact on the modern healthcare system (Demiris et al., 2008). eHealth services can improve access to health service providers, thereby improving clinical decision making, diagnostic accuracy and treatment particularly with remote health care (AIHW, 2021). According to the biennial report 2020 by the Australian Institution of Health and Welfare (AIHW) (AIHW, 2021), eHealth services have enabled users to manage their health and well-being through better monitoring and communication with health professionals. Internationally, the World Health Organisation (WHO, 2015) has reported a steady increase throughout a broad cross-section of countries; 64.4% of WHO members are aware of the importance of eHealth services and 58% of members have initiated eHealth systems in their countries (WHO, 2016).

Currently, most mobile and web-based eHealth applications are designed to support people to manage their health when it is not necessary for patients to physically consult with a doctor or visit a hospital, e.g., self-managing weight loss. People can access many health services using various devices, such as mobile phones, tablets, and laptops (Kipping et al., 2016) to receive almost the same level of healthcare for many conditions using evidence-based internet-based healthcare services (Das and Svanæs, 2013). Furthermore, eHealth has been developed to enable people to make medical appointments, obtain health information, or order medications, without directly accessing a health professional, simplifying many of the processes between patients and health professionals (Bąkała and Korczak, 2010; Sarkar et al., 2011). Indeed, guidelines or information given in the eHealth applications are more detailed and provided more frequently (Kipping et al., 2016).

The beneficial aspects of eHealth applications are not universally available to every user (Sarkar et al., 2011). eHealth applications are internet-based technologies, and therefore access to eHealth applications are dependent on a person's ability to use the internet (Zambianchi et al., 2019). This is particularly pertinent for elderly users, who have less exposure to the internet and therefore internet-based eHealth technology (Report, 2021; Anderson and Perrin, 2017). As seen in the statistics released by the United Nations (UN, 2017), there is a steady increase in internet usage by the elderly, but the usability and accessibility of eHealth applications have failed to accommodate the trend. There may be several reasons for this gap. One reason is that application developers' and end-users' expected outcomes for eHealth applications vary (Searl et al., 2010). As shown in studies

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by Das and Svanæs (2013), the age group of the developers is generally young, and they focus more on innovativeness and elegance of the technology contained in the application rather than considering the characteristics of healthcare providers and users.

The gap between developers and users can be remedied by conducting a person-centred process to engage relevant stakeholders in the design and development of the eHealth application (Demiris et al., 2008); guidelines exist that provide methods for developing person-centred applications (Power et al., 2012), such as Web Content Accessibility Guidelines (WCAG) 2.0[1] and WCAG 2.1[2]. However, the factors that determine the usability of an application can vary significantly from user to user (Reiners et al., 2019). Even people with similar accessibility issues may have other human factors that influence the way they use eHealth (Ali et al., 2021). In addition, since eHealth service customers and providers are highly likely to have different preferences on both the design and functional features of an application, the evaluation of usability and user experience of the application can also significantly vary (Tieu et al., 2015).

We aim to identify which human factors to consider in designing an eHealth web portal and to find appropriate methods to apply them to the design of the application. This also includes identifying which patients or user groups are likely to be discriminated against when using eHealth applications. We conducted a preliminary survey with 145 participants from various age and language groups to explore the relationships between human factors and design preferences. We provided participants with qualitative and quantitative questions to collect data regarding preferences on the colour tone of the portal, typography, navigation style, and icon/image style. Based on the results, we developed a high-fidelity design prototype for an eHealth web portal for people needing clinical access to Occupational Therapists (OT). A usability study of the prototype verified the effectiveness of the design factors. Our methods contribute to providing the direction of design in the development of other human-centred eHealth applications.

[1] http://www.w3.org/TR/WCAG20/
[2] http://www.w3.org/TR/WCAG21/

2 BACKGROUND

2.1 eHealth Portal and Human-centred Design

For any eHealth application development, identifying the characteristics and requirements of the potential users or patient groups should be prioritised (Tieu et al., 2015). In the case of an eHealth portal, it is vital to use effective and familiar design features for targeted user groups (Kildea et al., 2019). This is because the portal is in general used by non-health professionals, such as patients or their guardians in conjunction with their healthcare providers to acquire relevant and accurate health information while building and maintaining a relationship between clinician and patient (Bąkała and Korczak, 2010). Well-designed eHealth services not only facilitate patient-carer interactions but also enable to ease the digital divide and to equalise the knowledge balance between them so that patients can manage their health more effectively (Kildea et al., 2019).
According to ISO 9241-210 (2019) (ISO 9241-210:2019, 2019), human-centric design is defined as:

> *“Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques.”*

The four design phases for a human-centric design plan, according to (ISO 9241-210:2019, 2019), are:

- Phase 1: Understanding and specifying the context of use;
- Phase 2: Specifying the user requirements;
- Phase 3: Producing design solutions;
- Phase 4: Evaluating the design

Capturing considerable human factors during the requirements phase (Phase 2) for an eHealth portal might include basic demographic information as well as computer competency, internet accessibility, physical attributes, preferences, and/or habits (Rot et al., 2017). Not all factors are easy to understand as they are different depending on individuals’ characteristics (Castilla et al., 2016). It is important to consider that even if the functional requirements are fully captured fulfilled, the design elements may adversely affect the evaluation of usability and accessibility of the application (Boulos, 2003; Holzinger, 2002). Therefore, the design plan for a human-centred eHealth portal should be organised according to the correlation between key human factors and design elements (Kalimullah and Sushmitha, 2017).

2.2 Human Factors

The absence of consideration of human factors, which may include Age, Gender, Race/Ethnicity, Education attainment, Disability, Culture/Language, and Emotional state, can have a profound impact on the accessibility and usability of a web application (Reiners et al., 2019). however, it is difficult to correctly define and standardise which human factors should be prioritised given the diversity of human factors in each individual (Tieu et al., 2015). Human factors that should be mainly considered for web application development may change depending on the purpose of the application and target user group (Das et al., 2015). In the case of eHealth applications, different researchers (Goel et al., 2011; Sarkar et al., 2011; Ali et al., 2021; Reiners et al., 2019; Tieu et al., 2015; Ancker et al., 2011; Kahn et al., 2009; Shamsujjoha et al., 2021; Yong et al., 2012) cited human factors as age, gender, race/ethnicity, education attainment, disability, culture, language, and emotional state as important human factors to consider; age and language being two of the main ones.

Age, as a human factor, has the greatest influence on physical capability changes and older age is the biggest risk factor for chronic diseases or disabilities, and therefore has a significant impact on eHealth services (LaMonica et al., 2017). According to a fact sheet released by Report (2021), more than half of the elderly (defined as 65 years or older) responded that they are not able to use new electronic devices or applications without assistance from others. In Australia, 87% of the elderly with disabilities use the Internet, but only 9% of them use eHealth services as they encounter barriers (Ali et al., 2021). This intergenerational adoption gap is in part because physical characteristics of the elderly are not properly or sufficiently reflected in the development stage, but also because their non-physical characteristics, such as preferences, habits, and emotions, are not considered (Castilla et al., 2016). In the same vein, considering human factors in design phases of an application for people with disability, including for those with visual impairment, hearing impairment, and cognitive impairment including dementia, may also positively influence the usability of eHealth application (Das et al., 2015).

Language is another major factor that adversely impacts the usability and accessibility of eHealth applications. People often experience difficulty using web applications in languages other than their usual language, or people if they have low health literacy or low language proficiency. People with language barriers find sourcing information online difficult and may be forced to find information only through direct access with face-to-face health services, limiting their access to online eHealth options.

2.3 Vulnerable Groups

Vulnerable groups include the elderly, people living with disabilities and recent immigrants who are likely to have cognitive, physical, language and cultural barriers, or poor health literacy (LaMonica et al., 2017; Power et al., 2012; Ferati et al., 2012; Yong et al., 2012). Although there are guidelines, such as WCAG 2.0 and WCAG 2.1, to improve usability for people with physical disabilities, developers are often reluctant to comply with them for reasons such as difficulties in identifying human factors precisely, the cost of implementation, and implementing the corresponding functionalities practically. Power et al. (2012) demonstrated that following those guidelines does not always mean the absolute improvement of usability, but that websites complying with the guidelines outperform in certain areas, such as contents recognition and contents navigation, for people with disabilities.

3 APPROACH

Our method consists of 5 main stages: (1) Preliminary survey; (2) Analysis of the participants' responses; (3) Development of a high-fidelity design prototype; (4) User study with a group of participants; (5) Analysis of user study results. In this section, we discuss our survey and prototype design.

3.1 Preliminary Survey

The preliminary survey was conducted anonymously and distributed using Google Form. The participants we recruited for this survey were from various age groups (from 18 to 65 and over). As the authors were fluent in multiple languages, the survey was translated and distributed in Korean and Chinese as well as English. The survey included general descriptive characteristics, such as *Gender*, *Age*, *Current residence*, *Nationality and Language*, *Internet access and usage*, *Education attainment*, *Occupation*, and *Income* and also questions to capture the perception and usage of eHealth services. In addition, questions were included to explore the design elements may be influenced by the individual's human factors to investigate

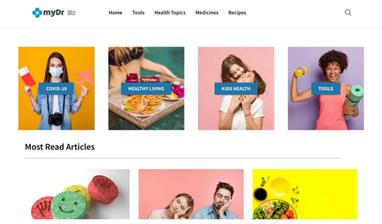

Figure 1: eHealth web application sample 1 *(https://www.mydr.com.au/)*.

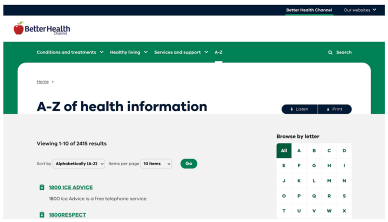

Figure 2: eHealth web application sample 2 *(https://www.betterhealth.vic.gov.au/a-z)*.

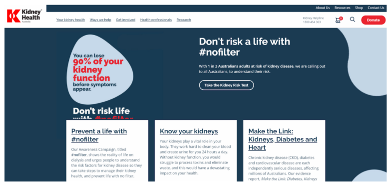

Figure 3: eHealth web application sample 3 *(https://kidney.org.au/)*.

the design preferences of eHealth applications. For these design-related questions, sample images were provided to support uniformity in the interpretation of questions and the accuracy of the responses. In case any of the participants with less experience in the use of eHealth services, we also provided three sample eHealth websites as shown in Fig. 1-3. Fig. 1 is a sample representing a web application consisting of warm colours and images, Fig. 2 cool colours and text-only icons, and Fig. 3 dark colours and texts.
All the websites had different styles, such as overall colour tones, functionalities, icon styles, structures, etc., so that we could identify greater discrimination between participants' responses. Using the same examples, participants were also asked to select specific design elements that they felt would be suitable for eHealth applications. The survey questions in Korean and Chinese and distributed to participants who use these languages in order to obtain more diverse and accurate responses.

3.2 High-fidelity Design Prototype

Based on the analysis of the survey data, a high-fidelity design prototype was created using Figma[3]. Adee[4] and Able[5] plugins were installed and used to check the WCAG 2.1 compliance. Interactions were also created for all the page elements and functionalities for the user study. All images used in this prototype, including icons and photographs, were either self-created, free or open source images from online image archives[6] and were cross-checked with both plugins to satisfy AAA grade for the success criteria stated in WCAG 2.1. As shown in the study conducted by Castilla et al. (2016), the preferences on the navigation styles by age groups are distinctly different. To maximise the usability of the prototype, we strived to provide as diverse but intuitive and concise navigation as possible. For instance, when required to show the additional contents that are related to the current page, pop-up windows or notifications were used to avoid loading a new page. This can mitigate the of users experiencing confusion or failing to continue their task due to too frequent navigations from page to page. One key functionality of this prototype is that the page is customisable using an Accessibility Helper. The Accessibility Helper button is presented at the fixed position, bottom left of all pages so that the user can access it from anywhere in the prototype. The available options for this functionality are depicted in Fig. 4.The functions included in the Accessibility Helper were designed based on the preliminary survey and reviews of other studies regarding the relationship between design features and usability/accessibility for elderly/disabled people. The design of this function also follows WCAG 2.1.

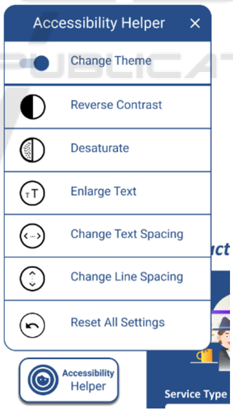

Figure 4: Options included in the Accessibility Helper.

3.2.1 Accessibility Helper

Options contained in the Accessibility Helper are:

1. *Options for colour.*

[3]https://www.figma.com

[4]https://www.adeeapp.com

[5]https://www.figma.com/community/plugin/734693888346260052/Able-

[6]Images are taken from (https://icons8.com/illustrations), (https://www.freepik.com/), and (https://icons8.com/)

[6]The prototype is accessible via https://bit.ly/2THOQ8K, and details of pages, design elements, funcitonalities, and interactions via https://bit.ly/2W4kJcO

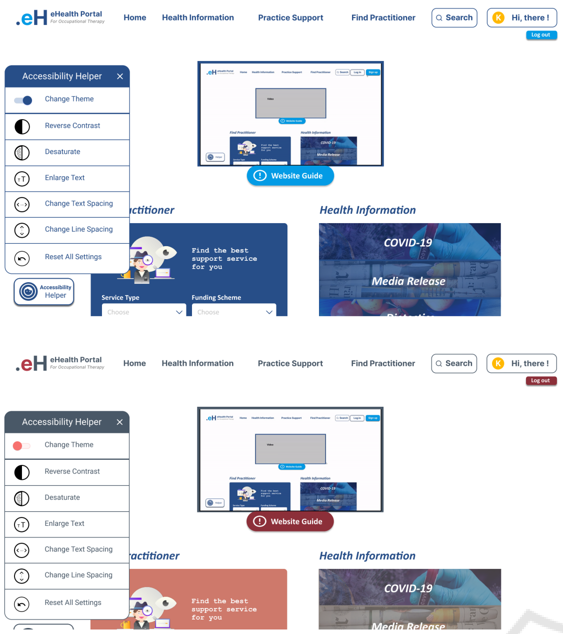

Figure 5: Main page with cool tone (top) and warm tone (bottom).

– Change Theme (Fig. 5): This enables users to change colour from a cool tone to a warm tone or vice versa.

– Reverse Contrast (Fig. 6) & Desaturate (Fig. 7): These options enable users to change the contrast and saturation of the page.

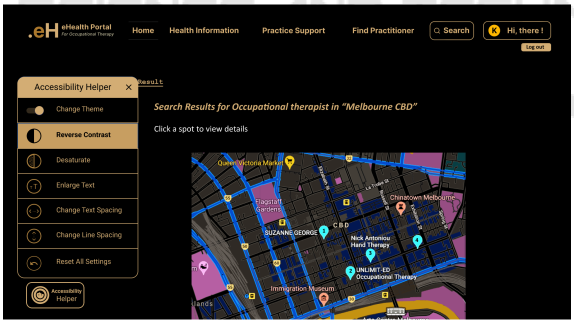

Figure 6: Option: Reverse Contrast.

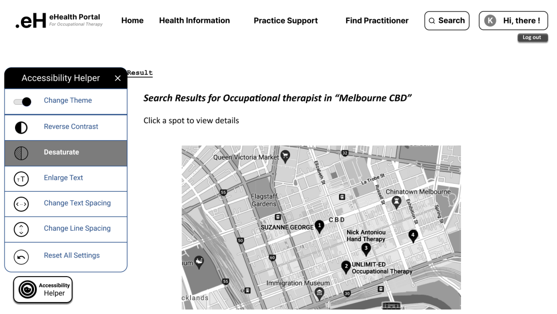

Figure 7: Option: Desaturate.

2. *Options for text.*

– Enlarge Text (Fig. 8): This increases the size of all texts.

– Change Text Spacing & Line Spacing (Fig. 9): This resizes spaces between characters.

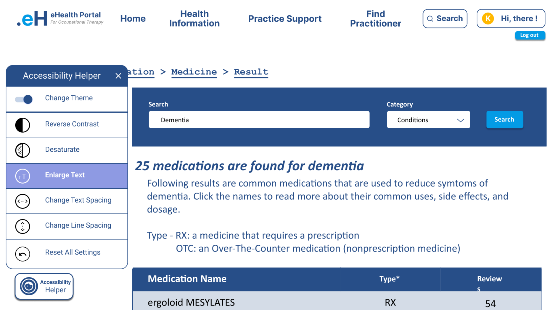

Figure 8: Option: Enlarge Text.

Figure 9: Option: Change Text Space & Line Space.

3.2.2 Navigation Types

Fig. 10 shows different navigation types used in the prototype.

1. Primary navigation (top menu) – this is fixed at the top of the page and enables users to access all available contents,
2. Side navigation: this enables users to access different pages within the same level,
3. Sub-navigation (Hierarchical navigation): this enables a user to see the paths and to navigate back to previous paths,
4. Sub-navigation: this enables users to navigate within a section, and
5. Footer navigation: this presents all accessibility menus as well as important information.

4 RESULT

This section presents the preliminary survey results.

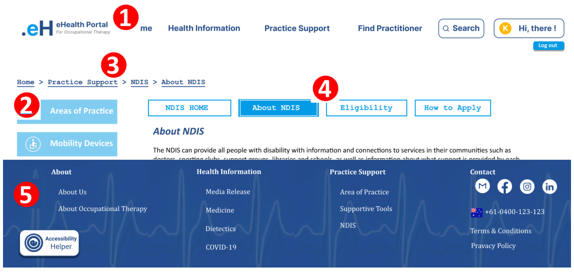

Figure 10: Navigation types used in the prototype.

4.1 Demographics

A total of 145 participants participated in this survey; 89 (61%) were female, 55 (38%) were male and 2 (1%) did not disclose their gender. All participants were categorised into five different age groups. The distributions of each age group are shown in Fig. 11.

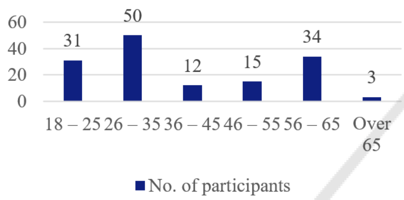

Figure 11: Distribution of age groups.

Among all participants, 32 (21.9%) responded that they currently suffer from at least one chronic disease, and 9 (6.2%) participants were unsure about their chronic conditions. According to the responses, participants' education attainment was high with 77 (53%) participants having completed at least a Bachelor's degrees, but only 12 (8.2%) participants did not have a high school diploma. Only 11 (4.8%) participants responded that they spoke English as their main language and the majority of the participants 133 (91.7%) identified as Asian and spoke Korean, Chinese, Thai, etc., as their main language. All participants except one had access to the Internet, and 131 (89.7%) of people self-evaluated their computer skills as more than moderate.

4.2 Analysis Methods

Descriptive statistics were used to analyse the data collected from the survey. A Chi-square test was conducted to investigate the association between key sociodemographic factors and design elements. Age was considered the major sociodemographic factor of interest, and thus the statistical significances between age and design elements were mainly investigated. For the group of participants who had never used an eHealth application (100 of 145, 68.5%), emotional states or the first impressions from the given sample eHealth applications were also investigated using the Chi-square test. This was conducted to clarify the significance of design elements for eHealth applications from potential users as well as relationships between users' emotions and design elements. To determine the association between more than three variables, the Multinomial Logistic Regression model was used. Two sociodemographic factors were selected as independent variables to determine the relationships with design elements and the usage of eHealth applications. Using the model, we identified the relationships of design choice with age and gender, the relationship of colour choice with age and chronic disease, the relationship of eHealth usage with age and gender, and the relationship of eHealth usage with age and computer skill. The alpha levels for both methods were set to 0.05. Microsoft 365 Excel was used for all analysis and Real Statistics Add-in (Zaiontz, 2021) was installed to calculate the Multinomial Logistic Regression.

4.3 Association between Human Factors and Design Elements

We determined "Age" as the key human factor as it is highly related to other factors, such as the likelihood of having a chronic disease, computer skills, preferences, etc., and thus it was mainly used to investigate the association with design elements (Ali et al., 2021; Reiners et al., 2019; Kalimullah and Sushmitha, 2017; LaMonica et al., 2017; Schaller et al., 2016).

4.3.1 Design Type vs. Age (+ Gender)

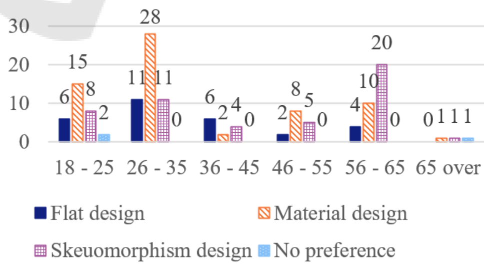

Figure 12: Design types selected by participants by age groups.

The preference on the design type is clearly distinguishable between generations. Younger people were more likely to choose Material over Flat and Skeuomorphism designs while older people were more likely to prefer Skeuomorphism to other designs as seen in Fig. 12. According to the Chi-square test, the associations between Age and design types were statistically significant with χ^2 of 22.1710 and p-value of 0.0143 at $\alpha = 0.05$.

We also tested how participants' design selections were associated with age and gender through a Multinomial Logistic Regression model as gender is another human factor that often determines preferences (Goel et al., 2011; Reiners et al., 2019; Ancker et al., 2011). The model showed that gender was not a statistically significant factor that determined a design type as seen in Table. 1. For any given gender, the tendency to select the design type was highly dependent on a participant's age. The model forecasts that the likelihood of choosing Material design decreases as age increases: the 45 years and over participants were 42.43% more likely to choose the Skeuomorphism design rather than Material design. However, the older generations did not show clear design preferences over the younger generation. Less than 23% of younger people would be more likely to choose Skeuomorphism design while over 34% of older people would be expected to choose Material design.

Table 1: Summary of Associations between design elements and human factors.

	Chi-square	p-value	Alpha	Significance
Design type vs. Age	22.1710	0.0143	0.05	Yes
+ Gender	10.6338	0.1004	0.05	No
Icon types vs. Age	18.9094	0.0414	0.05	Yes
Font size vs. Age	64.4726	5.11E-10	0.05	Yes
Colour vs. Age	10.2934	0.4151	0.05	No
+ Gender	2.9792	0.5613	0.05	No
+ Chronic disease	0.8354	0.9337	0.05	No
Emotional state vs. Age				
Sample 1	25.0458	0.0493	0.05	Yes
Sample 2	22.5657	0.0938	0.05	Yes
Sample 3	11.5834	0.7103	0.05	No

4.3.2 Icon Types vs. Age

Participants' preferences for icon types were highly tilted towards "Both icon and text". It was observed that 80.82% of participants chose icons with both image and text across all age groups. As shown in Table. 1, the result of the Chi-square test showed that age and icon types were not independent of each other and the relationship between them was statistically significant with χ^2 of 18.9094 and a p-value of 0.0414 at $\alpha = 0.05$.

4.3.3 Font Size vs. Age

The relationship between age and font size was also statistically significant with χ^2 of 64.4726 and a very low p-value of 5.11E-10 at $\alpha = 0.05$ as shown in Table. 1. However, this result may not be accurate because the image we provided in the Google form automatically responded to the screen size it was displayed on. This might imply that the font sizes shown in mobile phones and computer monitors would be different. Therefore, we used this result to investigate participants' general preferences for font size rather than finding out the exact font sizes they preferred.

4.3.4 Colour vs. Age (+ Gender, + Chronic Disease)

The 'cool' tone was preferred over the 'warm' tone (54.8% compared to 37.7% respectively) for eHealth applications, however, there was no statistically significant relationship between colour tone and Age (χ^2 = 10.2934 and p-value = 0.4151 at $\alpha = 0.05$). These results were not changed by applying gender and chronic disease along with age to the Multinomial Logistic Regression model. The model shows that the relationship of Colour with Age and Gender is not statistically significant (χ^2 is 2.9792 and p-value is 0.5613 at $\alpha = 0.05$). With Age and Chronic disease, there was no statistical significance between those variables with colours (χ^2 is 0.8354 and p-value is 0.9337 at $\alpha = 0.05$).

4.3.5 Emotional State (Sample 1, 2, and 3) vs Age

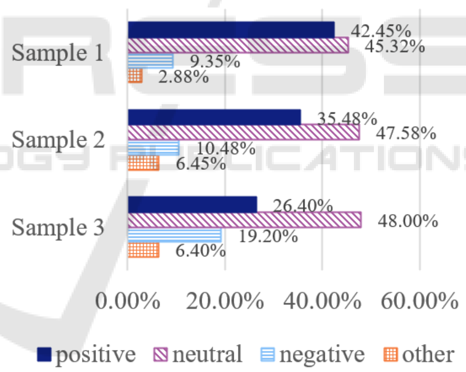

Figure 13: Summary of participants' emotional states.

Participants were asked to choose up to 3 different options for the first impression on each sample website. Options given to the participants were joy, trust, surprise, neutral, anticipation, disgust, fear, and sadness. We recategorised the selections into Positive, Neutral, with Negative: Positive included joy, trust, and surprise[7]; Neutral included neutral and anticipation[8]; Negative included disgust, fear, and sadness. The summary of participants' emotional states is shown in Fig. 13. The chart illustrates the summary of participants' first impressions and emotions for each sample website shown in Fig. 1, Fig. 2, and Fig. 3. After categorising all data, we conducted a Chi-squared test to find if there was a relationship between age and emotions for each sample website design. As shown in

Table. 1, the associations between Age and Sample 2 and 3 were not statistically significant. However, our results showed that the proportion of positive emotions that responded to sample 3 (26.4%) were significantly lower than those of sample 1 (42.45%) and 2 (35.48%). These results are in line with the participants' comments about each sample website. Participants mentioned that they feel comfortable with the bright tone, regardless of colour, and they preferred a website with sufficient white spaces, to help them to distinguish contents and functionality more easily. Participants who left comments on sample 3 said that they feel uncomfortable because the page was constructed with too much text and small font sizes, making it stressful to read the content.

5 EVALUATION

We designed the prototype presented in Section 3.2, according to the survey results. To ensure the usability of the prototype, we conducted a user study with nine participants. We recruited the participants among those who answered positively to the survey question that asks the intention of participating in the user study. The age distribution of participants included four people in their 20s, two in their 30s, and three people in their 60s. Among younger participants, no one had chronic diseases or disabilities, however, two out of three participants aged over 60 reported that they cannot properly read contents in normal text size, which is generally 16 ft, without magnifying reading glasses due to eyesight impairment.

The first author conducted the user studies as a mediator. During the user study, the mediator provided participants with the necessary information and observed participants' behaviours. The behaviours and time spent on each task were recorded as well. The user study began by providing a brief explanation about the project and provided instructions to install and execute the prototype. Each participant was then given some basic tasks and corresponding questionnaires. Tasks were categorised into two parts. In the first part, participants were asked to navigate page to page so that they can understand the structure of the prototype as well as the design elements used in the prototype. The second part of the tasks asked participants to use the functionalities contained in the prototypes, which included personalising features of "Accessibility Helper". After finishing each section, participants also completed the corresponding questionnaires[9]. Many participants shared their thoughts regarding the prototype with us and provided invaluable feedback as well.

This user study was conducted using Zoom and held for 30 to 35 minutes on average, including time for providing instruction and explanation about the project. All participants were asked to join the user study using either desktop or laptop. To complete all the tasks, participants spent approximately 13 to 15 minutes. Overall, participants' responses to the prototype were significantly positive. Participants scored 4.625 out of 5 for satisfaction on the user interface (design components), 4.875 for the overall functionality, and 4.875 for the overall satisfaction.

We could not observe any significant problem in using navigation features, however, we were able to identify how participants varied in the way their navigation between generations. A participant in his 20s, performed almost all navigation-related tasks using footer navigation, while another participant in her 20s, used side and sub-navigation actively. According to this participant's comment on the navigation functionalities, she found that the structure of the prototype was very intuitive as it was comfortable to navigate between pages and contents using different navigation options. In contrast to the use of various navigation by young participants, it was observed that participants over 60 tried to perform most of the tasks using only primary navigation. Even when completing tasks using side navigation, they first looked at the primary navigation to find the corresponding functionality. For example, although the functionality for converting displayed information from Map view to List view was distinctly presented on the side menu, all participants in their 60s tried to find the relevant feature from the top menu. A 62-year-old female participant commented that she looks habitually at the top menu first, regardless of tasks. Details of each navigation type are shown in Fig 10.

By observing participants' performances for completing given tasks, we could identify barriers they encountered. The most crucial factor that adversely affects the usability and accessibility of the prototype was linguistic differences. Due to the limitations of the design prototype, we were not able to provide an option to change to different languages. The design prototype that we provided was all in English, thus participants with low English proficiency had difficulty completing the tasks. This was especially evident when accessing specific information that con-

[8] The surprise emotion is in general considered as a positive emotion and anticipation emotion as a neutral emotion in Korean and Chinese. As the majority of our participants are originally from those countries, we classified surprise as a positive and anticipation as neutral emotion.

[9] The details of tasks and questionnaires provided to the participants can be found at https://bit.ly/36SoQdW.

tained unfamiliar words, such as medical terms as highlighted by one participant.

> *"It was difficult for me to access certain information as I have never heard of such terms, like dementia and dietetics. But, for me, even with the same medical terminology, the one with the picture was easier to find." [P5/Female/20s]*

One of the participants, who was originally Korean, in his 60s and was not well versed in English, could not perform the task properly without support due to the language barrier. The mediator translated both tasks and contents in the prototype into Korean to help him process the user study. This barrier was observed not only in non-English speakers but also in participants who use English as their second language. When carrying out the task of finding specific information containing medical terms, three participants had to spend more time compared to other participants who speak English as their main language. The time spent on each task for all participants is shown in Table 2.

Table 2: User study participants and time spent on each task.

	Gender	Age	Main Language	Eng. Prof.[a]	T1[b]	T2[c]
P1	Male	60s	Korean	VL	4'5"	8'48"
P2	Male	30s	Korean	H	3'00"	4'3"
P3	Female	30s	English	VH	3'25"	4'27"
P4	Male	20s	Chinese	M	4'15"	4'15"
P5	Female	20s	Japanese	H	4'15"	4'59"
P6	Female	20s	English	VH	2'35"	3'30"
P7	Female	60s	Korean	L	7'3"	4'1"
P8	Male	60s	Korean	M	4'4"	5'36"
P9	Female	20s	English, Cantonese	VH	3'16"	3'36"

[a] Eng. Prof. stands for English proficiency. VH, H, M, L, and VL stand for Very High, High, Moderate, Low, and Very Low, respectively.
[b] T1: Time spent on completing task 1
[c] T2: Time spent on completing task 2

Similarly, we could find evidence of how the use of certain images enhanced accessibility. Another participant was not able to understand the purpose of icons yet he could infer the functions through the icon's shape, location, and image. This was consistent with the result of the preliminary survey that we conducted. According to the survey results, more than 80% of participants responded that they preferred icons with both text and image as those icons are more intuitive and effective to convey meanings.

In this user study, we also received various feedback related to the Accessibility Helper. In general, young participants responded that it was interesting and new to them, while older participants emphasised the need for this functionality. A male participant in his 60s revealed considerable satisfaction in changing theme colour function. As per his comment:

> *"If a health-related web application is comprised of too many different colours, I feel rejected because its atmosphere is too hectic. Also, in the case that the colour used in such a web application is too dark, I hesitated to use it as it gives me some negative feelings. I think the Accessibility Helper will contribute to utilising this application more precisely and frequently because users can choose the colour to suit their personal taste." [P1/Male/60s]*

His comment was also consistent with participants' responses regarding the colour of the eHealth application as a number of participants also pointed out that the factor that causes the bad first impression is the colour used in the application. They felt discomfort if a health application is too colourful or too dark. In addition, a participant with poor eyesight mentioned that the function that enabled her to change the font size and text space was very impressive and helped her to read and understand contents. She also provided feedback that such functionalities are essential for older populations like herself as vision impairment is one of the most common problems that the elderly have. A male participant in his 60s emphasised that the guidelines for the functionalities should be provided to maximise the usability:

> *"I have never seen this function, called Accessibility Helper, before. I think this function will be very useful for the elderly, those with disabilities, and even ordinary users. It can be especially helpful for people with vision impairment, old people like me. But for the elderly, it is hard to even know if there is such function or not unless a clear explanation is given." [P8/Male/60s]*

One common feedback received from elderly participants was that personalisation features should be saved individually without having to change them every time they access the application. This was an important point to consider for future work.

6 DISCUSSION

For healthcare-related web applications, it is important to precisely consider human factors that have a significant impact on the usability and accessibility to design elements because the main stakeholders, such as the elderly, disabled people, and other patients, are highly likely to have a different physical or psychological characteristics. As shown in the results of our survey responses from 145 diverse participants, the preferences for design elements, such as font sizes and icon types, are distinguishable by age groups. Although the relationship between age and colour of the web application was not statistically significant, most participants responded that their impressions and emotions towards an application were determined by the colour and therefore it should be considered as one of the main design elements.

We developed a Figma-based high-fidelity design prototype for an eHealth web application. This prototype targets those who regularly seek occupational therapists due to their physical or mental impairments, or their guardians. To narrow the gaps resulting from the difference in human factors between our participants, we designed a functionality called Accessibility Helper. This feature accommodates the users' needs by allowing them to change each design element based on their preferences. Participants who used this feature in the user study did not reveal any negative emotions regarding the design elements that they had from the sample web application we provided in the survey. Moreover, in the user study, we found that the usability of web applications for each participant was exacerbated by different design elements. We hypothesised that the enhancement of the usability and accessibility resulting from the modifying design elements is dependent on the distinctive characteristics people have. This finding was consistent with the evidence we explored initially as shown in the results of the preliminary survey.

In particular, we were able to clearly see the correlation between people's characteristics and preferences on the design elements in the responses provided by participants aged less than 35 and participants aged over 55. We found that younger participants focused on the novelty and rarity of the Accessibility Helper rather than considering the effectiveness of this function. In other words, we could observe that they focus heavily on functional factors of the prototype when evaluating the usability rather than considering how the function might be beneficial to them. This is likely because compared to the older participants, younger participants have more opportunities to use a variety of web applications and have less hesitation to adopt new technology [8]. Moreover, another reason why they may prioritise the functional aspects is that they are less likely to have disabilities or other physical impairments that hinder them from accepting design elements consisting of web applications [23]. Based on the observation from the user study, the only factor that impressed them was the "Changing theme" option that affects the overall atmosphere of the prototype; the other design options they stated that it would be useful for those who are visually impaired or disabled.

In the case of older participants, the deterioration of usability due to a decline in physical capability is a factor that should be considered more important than dissatisfaction from the functional aspects (Kalimullah and Sushmitha, 2017). We found this from the feedback provided by elderly participants as well. One common disability or impairment that elderly participants have is the eyesight impairment due to ageing (AIHW, 2000). All three participants in their 60s reported that they are unable to read content with small-sized texts which significantly affects usability and accessibility. In the same vein, they emphasised that the typography-related functions, such as changing font size, text spacing, and line spacing, are essential features for them. In addition, the structure of the application is another significant factor that should be considered. When designing the prototype, we assumed that the elderly would have relatively lower proficiency or frequency of using IT technology compared to younger people. Therefore, in line with the research conducted by Castilla et al. (2016), we designed the structure of the prototype as intuitive and concise as possible by using pop-up windows and notifications and by providing various navigations. What we found from the observation of the user study was consistent with the assumption as older participants who are aged over 60 could not properly perform the tasks that require using different navigations rather than linearly navigating between pages. They completed most of the tasks using only the primary navigation, and in the case of tasks that could not be performed with the primary navigation, they tried to find the way from the menu closest to the contents they have.

Regardless of the age groups, some participants encountered difficulty in using the prototype due to linguistic differences. The usability and accessibility gaps caused by the absence of health literacy or digital literacy are difficult challenges for developers to solve as it is least likely to estimate the universal level of those literacies of their stakeholders (Tieu et al., 2015). As shown in the work of Holzinger (2002), one efficient approach to solve these disparities is to attach appropriate images to the contents that users may not be able to understand easily. In our user study, we found that participants tried to perform the tasks by analogy through images for several tasks containing medical terminologies. They also commented that they were able to complete the tasks by assuming through images shown in the icons and contents even though they had no idea of the meaning of the words. This proves that usability and accessibility can be enhanced by visualising contents appropriately.

7 LIMITATION

An important limitation of our work is that we did not have people with substantially severe disabilities in the participants. Although the Accessibility Helper contains options to change the contrast and saturation of the contents, we could not verify their effectiveness because none of our participants had colour blindness. However, we verified that all contents used in this prototype are visible for those with colour blindness or colour deficiencies by cross-checking with the colour simulator[10] website and Figma plugins.

Secondly, the quantitative results from our work were likely to have confounding bias. We relied mainly on univariate statistics and the largest number of variables included in one relationship was three. Moreover, the fact that the age distributions of participants favoured particular groups is likely to lead to another bias. The third limitation is that the sample population for both the preliminary survey and user study did not include participants aged under 18. According to a report released by AIHW (2020), approximately 9% to 10% of people who are in general classified as children and adolescences have disabilities, which is higher on average than the age group between 20 and 35 who was one of the main participant groups involved in this work.

Finally, since our work is based on the high-fidelity design prototype, the usability and accessibility we investigated may differ from actual applications with practically runnable functionalities. With the design prototype we have, it is difficult to estimate the usability changes resulting from the frequency of the use and the time spent for each functionality.

8 CONCLUSIONS

We identified the correlation between human factors and design elements through a preliminary survey and demonstrated the effectiveness of this correlation through a Figma-based high-fidelity design prototype. In the user study to investigate the effectiveness of the prototype, we found barriers that hinder usability. In addition, by looking at the preference or priority by age groups, we were able to understand which design elements should be primarily considered to enhance the usability for each age group. This study contributes in understanding how human factors can be applied to eHealth applications. In future, we will aim to focus on implementing this prototype on a web application by reflecting on findings from this work to enhance the usability and accessibility of the application. Moreover, the resulting web application will be tested and verified by more diverse user groups.

[10]Colblinder: https://www.color-blindness.com/coblis-color-blindness-simulator/

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