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DIGITAL LITERACY OF ELDERLY TOURISTS IN THE ALGARVE DESTINATION

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Abstract: This paper studies the digital literacy of elderly tourists who have chosen the Algarve as their destination. Quantitative methods were applied to analyze part of the data collected within the project ACCES4ALL - Accessibility for All in Tourism (2017-2019). In this project, questionnaire surveys were answered by 851 senior tourists aged 60+ at the International Airport of Faro. The present research has the specific goal of identifying and analyzing what characteristics influence the use of the Internet, QR code and NFC technology. Descriptive and inferential statistics were performed. The results show that as the age of the surveyed elderly tourists increases, their Internet use decreases. The higher the respondent's level of education, the higher their internet use. Elderly tourists without disabilities use the Internet more than those with disabilities. Few surveyed elderly tourists are familiar with the use of QR codes and NFC technology. In general, it was possible to observe that the elderly tourists surveyed have a high digital literacy concerning the use of the Internet. Further research will analyse if these senior tourists use digital tools for travel planning.

Keywords: Elderly Tourists; Digital Literacy; Smart Cities; Inclusive Cities; Accessible Tourism

Introduction

Approaches associated with sustainable development, social inclusion and active ageing are driving changes in the current role of seniors in a global society where digitalization is increasingly in the spotlight. The social dimension of sustainability considers social inclusion and social equity, i. e. equal opportunities in the access to goods, services and information, encouraging active participation of citizens and accepting the right to this participation. Inclusiveness is related to equal opportunities, public participation, citizen engagement, co-design, universal design, accessibility, and affordability, and it is considered one of the values of the New European Bauhaus.

In the context of developing tourism activities, social sustainability has implications for the access of all tourists to infrastructure, equipment and services, and therefore access to the city and the rural environment, using public transportation, enabling new experiences in destinations.

These attributes are also associated with the ageing process, which must be considered in the whole tourism value chain. These approaches are being taken institutionally in the United Nations, the European Union and Portugal, which have triggered actions under the New Urban Agendas.

The “Convention on the Rights of People with Disabilities” (United Nations, 2007) helped to dictate the need for improvements by promoting and ensuring the rights and dignity of people with disabilities (e.g. physical, mental, intellectual or sensory disabilities). This convention seeks to empower people with disabilities to live autonomously and fully participate in society by guaranteeing, among other things, equal access to information and communications.

Concerning the United Nations’ Sustainable Development Agenda 2030 (United Nations, 2015), the Goal 9 – to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation - refers to the need to increase significantly access to information and communications technology and strive to provide universal and affordable access to the Internet. Goal 11 concerns the systematic implementation of policies to make cities inclusive, safe, resilient and sustainable. It presents a holistic vision of an inclusive society that serves vulnerable communities by integrating people with disabilities and the elderly, among others, and by focusing on accessibility according to the universal design approach.

People of all ages, social statuses and skills are taken into account within the universal design approach, i.e. every citizen enjoys its implementation, and the whole society benefits from solutions accessible to all. This approach depends on processes in which the perceptions and needs of users are considered and co-design processes are valued.

Inclusive cities have been associated with intelligent cities, requiring specific digital knowledge from users who tend to be connectivity-dependent. Information and Communication Technologies (ICT) are fundamental tools for social inclusion, as they promote equity in access to information. These technologies tend to be used by tourists when planning their trips.

Current transport interfaces, as well as the urban infrastructure around them, must be rehabilitated in order to be accessible for all and connected, as these are attributes of the quality of transport services. Moreover, in the context of smart tourism and social inclusion, interfaces, e. g. bus stops, need to be connected with the digital world.

This is the context of the project ACCES4ALL - Accessibility for All in Tourism (2017-2019), an innovative Portuguese project developed at the University of Algarve, the promoting entity. Its main objective was to develop a pilot study of an accessible, intelligent and sustainable bus stop, to be located at Faro International Airport, meeting the processes of "Universal Design" and "Age Sensitive Design". At this digital bus stop, the availability of Wi-Fi and interactive information regarding the public transportation network was met through Quick Response (QR) codes, Near Field Communication (NFC) technology and an interactive panel that can provide service information on real-time schedules, transportation lines, location maps, daily news and weather conditions, among others.

Seamless travelling allows individual tourists to extend their mobility radius and search for different modes of transport to use their time more efficiently (Döge & Abraham, 2020).

The universal accessibility of information considers all users and should be addressed in this innovative urban furniture. The question was whether older tourists have sufficient digital literacy to use these cutting-edge technologies and to take advantage of these inclusion opportunities.

Thus, as part of the ACCES4ALL Project, surveys were conducted on elderly tourists (aged 60 and over) as users of Faro International Airport. The questionnaires contained questions about their use of information, communication systems, and technologies, among others.

The main goal of this article is to present the digital literacy of elderly tourists who have chosen the Algarve as their destination. In addition, it has the specific objective of identifying and analyzing what characteristics influence the (non-)use of the Internet, QR code and NFC technology.

Smart and Inclusive Cities and Tourism

Smart Cities

Smart cities are often defined as urban areas that use divergent types of electronic Internet of Things (IoT) sensors to collect data and then use the data to manage assets and resources efficiently (Baltac, 2019). However, they should be defined less based on the IoT solutions implemented and the number of digital devices used and more on the optimization of its functions. Along the same line of thought, Nesmachnow & Hernández-Callejo (2020) argue that smart cities rely on adapting smart devices to traditional physical systems to optimise their functions. Therefore, the technology in smart cities can assist in reducing social problems.

Combining smart cities and digital technologies can provide a multidimensional solution to support elderly people and people with disabilities. For example, ICT technologies empower the widespread diffusion of monitoring and sensor technologies to aid transport delivery, mobility and efficiency in urban services (Li & Woolrych, 2021). In the tourism context, the situation is no different, as numerous digital technologies can support seniors and people with disabilities in their tourist destination.

Regarding people with disabilities, it is possible to state that ICT technologies make it possible to improve the infrastructure of public spaces in order to increase autonomy and facilitate the daily life of people with disabilities (Lopes et al., 2018).

According to Skouby et al. (2014), the artificial intelligence implemented in cities can also help to “overcome” many age-related disabilities, such as mobility, visual and cognitive problems. Nowadays, there are audible and vibrotactile signals for pedestrians augmented with systems that can tell older people where they are, systems that translate voice to text or convert and reproduce sign language. These devices can guide seniors through their tasks, among many other digital technologies that can help them on trips and in their daily lives.

In contemporary society, many projects are being developed involving digital technologies that aim to improve senior citizens' and tourists' quality of life. Skouby et al. (2014) refer to the STIMULATE project that uses ICT technology to offer its users centric services such as specific assistance needs, planning a trip, optimizing transport means and itineraries, security advice, local shopping recommendations and assistance.

In the ACCES4ALL Project, Rodrigues et al. (2018) presented the proposal to create a smart bus stop, which would integrate all the features from the existing bus stops, as well as intelligent features to allow its adaptation to different users’ needs through QR code, NFC technology and an interactive panel where the communication adjusts to the profile of the user.

QR code is a type of barcode that can be read easily by a digital device and stores information as a series of pixels in a square-shaped grid. It allows the user to access information instantly. At bus stops, the information is usually about real-time schedules and transportation lines.

NFC is a set of short-range wireless technologies, usually requiring a distance of 4cm or less to initiate a connection. For example, a contactless payment where a customer holding or tapping a mobile device establishes contact with the payments terminal. The NFC-enabled reader and the smartphone pass encrypted information back and forth to each other to complete the payment.

On public transport, people can pay for the trip or use a subway pass by waving the phone to pass through the gates. Tapping the phone at a kiosk gives up-to-date information about schedules, delays, and a lot of other information. NFC technology is designed to increase convenience when learning, shopping, and sharing data.

Emphasis on "Seamless Mobility" is given to promote interventions in the improvement of coordination of the various available mobility services, namely to facilitate transfers between the different means of transport and to make information available about supply transports and digital tools for supporting travel planning, among others.

The use of digital technologies can contribute to the inclusion of seniors in contemporary societies (Dias, 2012). Digital systems and visual communications have been created for all people (Pohlmeyer, 2017). It is assumed that the Internet holds much potential for enhancing opportunities for people with disabilities (Dobransky & Hargittai, 2006).

Inclusive cities have been associated with intelligent cities, holders of innovative technology and digital connectivity, which require specific digital knowledge from users. With the global COVID-19 pandemic having accelerated digitalization, the urgency for universal digital inclusion has hastened (Ng et al., 2022).

Accessible and Inclusive Tourism

Universal Design is a key attribute of accessible and inclusive tourism. The concept of universal design was developed in The Center for Universal Design at North Carolina State University and defined as “the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” (Connell et al., 1997).

In this context, accessibility in accordance with the universal design approach is considered an important attribute of the quality of infrastructure, facilities, services and information associated with mobility and tourism. According to the European Concept of Accessibility, "accessibility is the characteristic of an environment or object which enables everybody to enter into a relationship with, and make use of, that object or environment in a friendly, respectful and safe way" (Aragall et al., 2003, p. 3). Groups often underrepresented such as older adults, children, and people with disabilities, must be integrated (Tauke et al., 2016).

These approaches must be considered in the tourism chain, where online travel planning can influence the choice of destinations. One requirement that allows people with disabilities to travel is accessible online information (Buhalis & Michopoulou, 2011). However, accessibility seems not to be a determinant in tourist sites' performance (Rucci & Porto, 2022).

For the effective implementation of accessibility for all, seven principles associated with the universal design must be considered: 1) equitable use; 2) flexibility of use; 3) simple and intuitive use; 4) perceptible information; 5) tolerance for error; 6) low physical effort; 7) size and space for approach and use (Connell et al., 1997). These principles must always be incorporated in the conception of products, environment, services and information, to create a fair society, where all people have the right to use them, independently and naturally.

This is a great challenge because the World Wide Web and electronic devices (e. g. desktop computers, laptops, tablets, smartphones) have to be designed considering all users, which is not always the case. For example, QR codes and NFC technology are very dependent upon contactless, which is impossible or difficult for people with visual disabilities. These technologies cannot be used or understood by some specific users. On the other hand, the accessed websites have to be designed and developed so that people with disabilities can use them, i.e. *Web accessibility*.

As Richards et al. (2010) write, the tourism sector should be accessible and inclusive for all. Darcy and Dickson (2009) present the concept of Accessible Tourism as a practice that allows all individuals, including the ones who travel with disabilities (such as the elderly), to move independently and with equity through the provision of tourist services and products designed universally to reach the largest number of people. However, according to Burns et al. (2009), tourism is not always accessible and inclusive, since there are tourists with special needs who are excluded from various leisure activities due to their physical and social limitations. When approaching Accessible Tourism, it is unavoidable to not refer to the elderly population since disability and old age are often related (Alén et al., 2012). Ageing is usually associated with dependency, loss of functionality, and cognitive impairment. Associated with ageing are limitations of mobility, visual and hearing impairments and high disease susceptibility, especially chronic diseases (Skouby et al., 2014).

In the ACCES4ALL Project, it was observed that the nature of the disability of elderly tourists was mainly related to motor problems (61.6%), hearing problems (15.2%), visual problems (14.8%) and orientation problems (1.7%). It was also evidenced that disability affected more women (26.8%) than men (23.8%).

Senior Tourism has been a field of special interest for researchers and the academic community, having emerged in various studies in the area of gerontology, travel and leisure time. The elderly are one of the most prominent market segments in the tourism sector (Patterson, 2012; Alén et al., 2016).

Travel tourism can be considered one of the sectors that most contributes to global mobility and the quality of life of seniors (Ovsenik, 2015). But seniors have some special needs and requirements that must be considered, such as "nearby health services, adapted transportation, and so on" (UNWTO, 2016, p. 32), to promote accessibility, inclusion, and equity for this age group.

Digital Literacy

Digital literacy skills are fundamental for social inclusion since they promote equity in access to information. According to Loureiro and Barbas (2014, p. 451), digital literacy is "a person's ability to effectively perform tasks in digital environments”. Thus, to be considered digitally literate, the social agent must know how to access information; collect, handle and organize it in order to use it, as well as evaluate, integrate, interpret and compare information through various sources/sites; create and generate knowledge and finally, communicate and relate information according to the context in which it is found (Loureiro & Barbas, 2014).

The debate about the digital literacy of the elderly has been increasing since they currently have a higher level of use of technologies and the Internet compared to previous generations (Martin et al., 2017).

In April 2012, the Pew Research Center showed that 53% of older adults (aged 65+) in the United States enjoyed the Internet (Zickuhr & Madden, 2012). According to Smith (2014), this number increased to 59% in just one year. The results of a study by Ramos Soler et al. (2019) show that seniors currently play an active role in tourism travel planning through Relational, Information and Communication Technologies. Many seniors choose their travel destination according to their experiences, as well as the recommendations of friends, and in some cases, contrast this information with ideas found on the Internet. In addition, the Internet, considered as the most used information search tool, is often mobilized to book accommodation and transportation.

However, some academic studies show that older adults are still lagging in their digital development (Hargittai & Hinnant, 2008; Song et al., 2021).

Methodology

As part of the co-design process developed in the ACCES4ALL Project, the research team developed a questionnaire survey to understand the profile and perceptions of elderly tourists in the Algarve destination. It considers four sets of questions: (1) information about the respondent; (2) characterization of their mobility; (3) information about the universal accessibility of a bus stop; (4) use of information and communication systems and technologies. The characterization of elderly tourists was made considering gender, age, level of education, professional occupation, country of residence, city or town where they reside, disabilities affecting mobility and the need for technical aids to get around the town.

The survey was developed for foreign elderly tourists aged 60 or over, mainly in August and September 2018. Inquiries were conducted in such a way that involved equal opportunities for different profiles of people (randomly) by professional inquirers (experts on Marketing) at Faro International Airport, mainly in waiting areas before departure. During the survey, the interviewers used photographs to explain technical aspects to elderly tourists. Inquiries, totalling 851, produced considerable data that was introduced into an electronic file, using the advanced statistical analysis capabilities of Statistical Product and Service Solutions (IBM SPSS, v.26). Because of the low frequency of participants who were 90+ years old, 85+ years old participants were grouped.

This article only focuses on the use of information and communication technologies, referring to the fourth part of the applied questionnaire surveys. It should be noted that in this part, only three questions regarding the use of the Internet, QR, and NFC, were selected for further analysis since they are the ones that most represent the sample's digital literacy.

Descriptive statistics of the frequency of each answer were created, characterizing elderly tourists by gender, age, level of education, disability and type of geographical residence area (city and countryside). Bar graphs representing the frequency of Internet, QR code and NFC technology use by age, level of education, gender, disability and type of geographical residence area were created with error bars representing a 95% confidence interval. Inferential statistics were performed to determine if there was a statistically significant difference between the several groups for each characteristic regarding the use of the Internet, QR code and NFC technology. The chi-square test of independence was performed to assess the statistical significance of these relationships. The level of statistical significance was set at 5%; thus, whenever results provided $p < 0.05$, $\mathrm{p} < 0.05$it was assumed that there is statistical evidence to consider that the study variables are dependent and that the differences tested are statistically significant. To perform the chi-square test, in the case of the analysis by age, only three groups were considered, namely 60-69, 70-79 and 80+, and regarding the level of education, again three groups were considered, namely basic+secondary, vocational and higher education. The error bars in the bar graphs complement chi-square test results indicating the groups (by age, gender, level of education, the condition of having or not having a disability and by type of geographical residence area) with significant differences regarding the study variable (frequency of Internet, QR code and NFC technology use) by looking for the overlap of the correspondent error bars.

Results

Considering valid answers, 60.7% of the respondents are men and 39.3% are women. The age group of 60-69 is the group with higher frequency, namely, 44.8%, the age group 70-79 amounts to 39.8 % and only 15.4% aged 80 or over. Concerning the different levels of education, 2.5% have a basic level, 23.2% secondary level, 54.0% vocational/technical training, and 20.3% have a higher level. As ageing is usually associated with dependency, loss of functionality, and cognitive impairment, older people were asked if they had disabilities that affected their mobility, and 25.3% answered positively. In terms of geographical residence area of the respondents, 24.7% live in the countryside and 75.3% live in the city.

Digital Literacy of the senior tourists

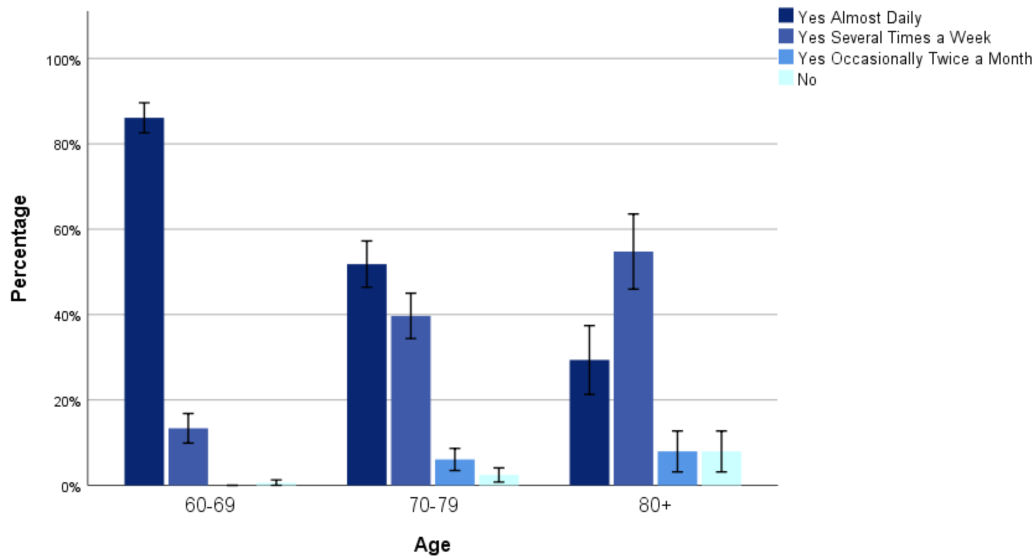
The total percentage of elderly tourists surveyed that use the Internet is 97.5%, which means that the vast majority of respondents use the Internet. As for the total percentage of elderly tourists that use QR code and NFC technology, this corresponds to only 18.2% and 11.5%, respectively, thus allowing us to consider that most respondents do not use these technologies.

Frequency of internet use

Analyzing the frequency of internet use by age, it is possible to verify that 86.1% of the respondents aged between 60-69 use the internet “almost daily”, 13.4% use the internet “several times a week” and 0.5% do not use it at all; 51.8% of the respondents aged between 70-79 use the internet “almost daily”, 39.7% use the internet “several times a week”, 6.1% use it “occasionally twice a month” and 2.4% do not use it at all; 29.4% of the respondents aged over 80 use the internet "almost daily", 54.8% use the internet "several times a week", 7.9% use it "occasionally twice a month" and 7.9% do not use it at all.

The results show that the frequency of internet use is not the same between the three age groups considered, $[\chi^2(6\,;n = 830) = 117.15, p = 0.000][\chi^2(6; \mathrm{n} = 830) = 117.15,\ \mathrm{p} < 0.001]$. Moreover, senior tourists that most use the internet "almost daily" are aged between 60-69 and the "almost daily" internet use decreases with the age of the senior tourists. On the other hand, the "several times a week" internet use increases with age and senior tourists that mostly use the Internet "several times a week" are 80 years old or more. Regarding "occasionally twice a month" usage, there is no difference between the groups 70-79 and 80+ groups, but the group 60-69 differentiates from these two and is the group that least uses "occasionally twice a month". Regarding no internet use, there is no difference between the 60-69 and 70-79 groups, but the group 80+ differentiates from these two and is the group that most does not use the Internet (Figure 1).

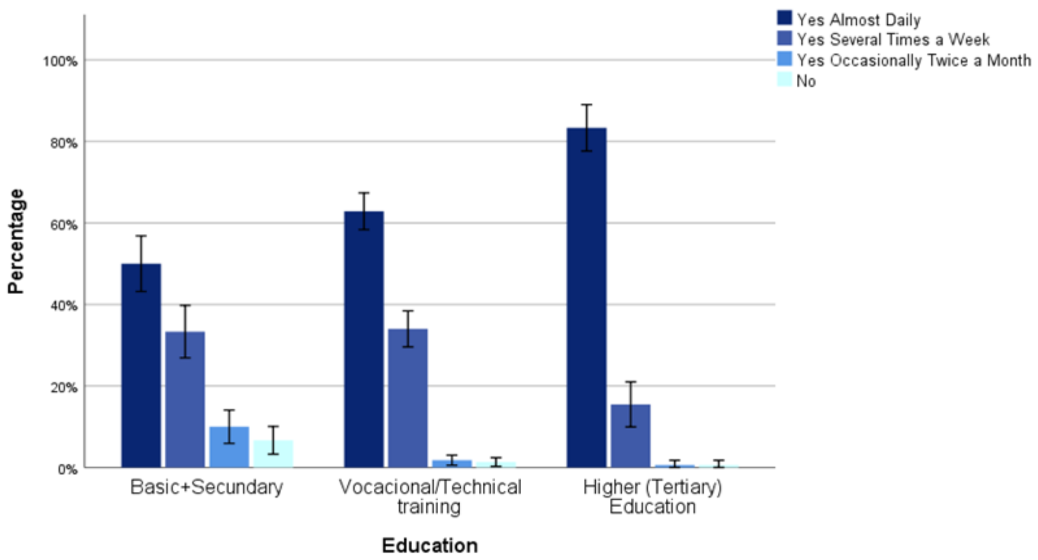
Figure 1. Percentage of elderly tourist participants by age and frequency of internet use (Source: Authors´elaboration)



Looking at the frequency of internet use by level of education, it can be observed that 50.0% of the respondents with basic or secondary education use the internet "almost daily", 33.3% use it "several times a week", 10.0% use it "occasionally twice a month" and 6.7% do not use it al all; 62.9% of the respondents with vocational/technical training education use the internet "almost daily", 34.0% use it "several times a week", 1.8% use it "occasionally twice a month" and 1.3% do not use it at all; 83.3% of the respondents with higher (tertiary) education use the internet "almost daily", 15.5% use it "several times a week", 0.6% use it "occasionally twice a month" and 0.6% do not use it at all.

The results show that the frequency of internet use is also different between the three levels of education groups, $[\chi^2(6\,; n = 825) = 82.25, p = 0.000][\chi^2(6; \mathrm{n} = 825) = 82.25,\ \mathrm{p} < 0.001]$. Senior tourists with higher education are the ones that mostly use the internet "almost daily". In addition, the "almost daily" internet use increases with the level of education. Regarding "several times a week" usage, there are no differences between basic or secondary education and vocational/technical training education. However, the group with higher education differentiates from these two groups and is the group that least uses the internet "several times a week". However, in the case of the "occasionally twice a month" usage and no usage at all, there are no differences between vocational/technical training education and higher education but the group with basic or secondary education differentiates from these two groups and is the group that most uses the internet "occasionally twice a month" or that do not use it at all (Figure 2).

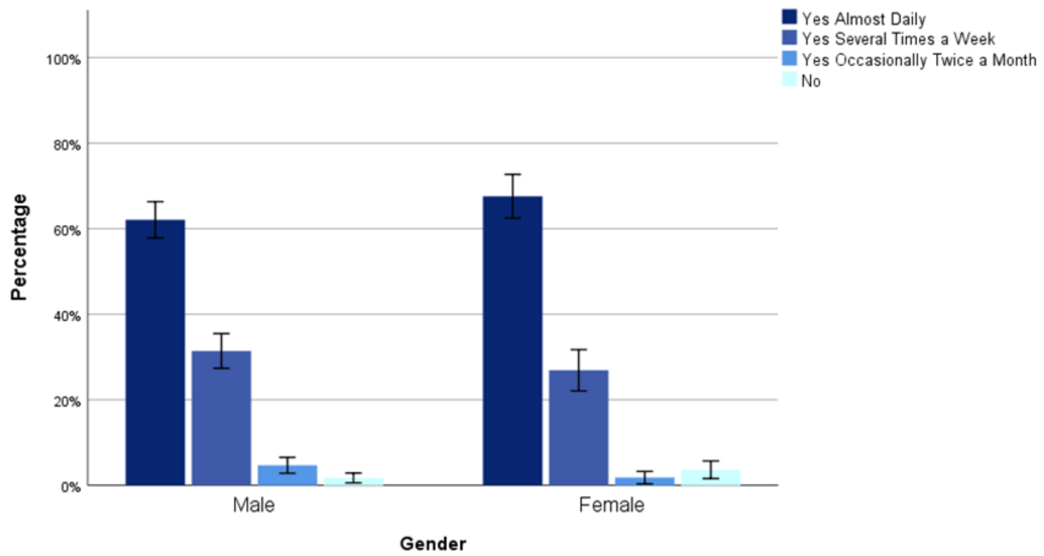
Figure 2. Percentage of elderly tourist participants by level of education and frequency of internet use (Source: Authors´elaboration)



Concerning the frequency of internet use by gender, it can be observed that 62.1% of the elderly male respondents use the internet “almost daily”, 31.4% use it “several times a week”, 4.7% use it “occasionally twice a month” and 1.8% do not use it at all; 67.6% of the elderly female respondents use it “almost daily”, 26.9% use the internet “several times a week”, 1.8% use it “occasionally twice a month”, and 3.7% do not use it at all.

The results show that there are differences between men and women regarding the frequency of internet use, $[\chi^2(3\,; n = 836) = 9.78, p = 0.021]$, $[\chi^2(3; \mathrm{n} = 836) = 9.78,\ \mathrm{p} = 0.021]$, but only in the case of “occasionally twice a month”, men being the ones that most use the internet “occasionally twice a month” (Figure 3).

Figure 3. Percentage of elderly tourist participants by gender and frequency of internet use (Source: Authors´elaboration)

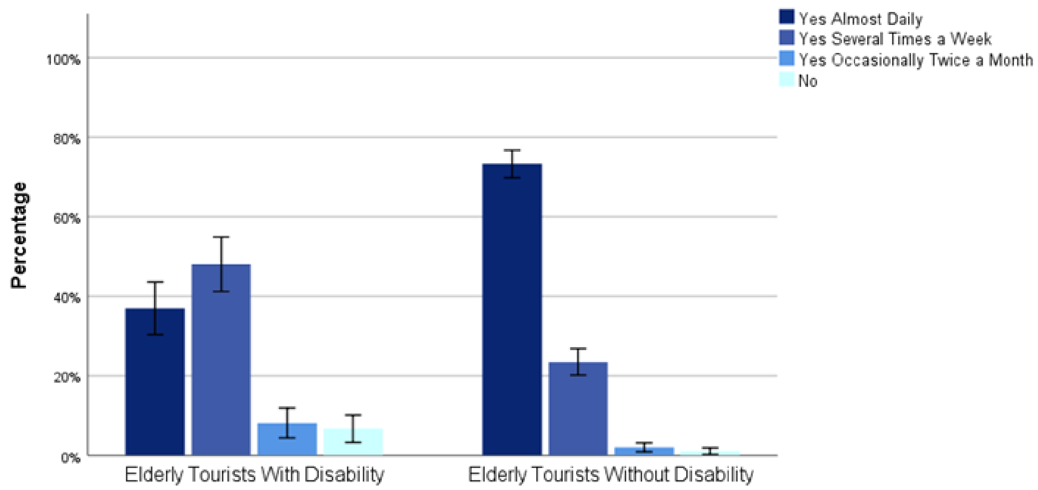


Considering the groups of senior tourist respondents with or without disability, it can be observed that 37.0% of the elderly with disability use the internet “almost daily”, 48.1% use it “several times a week”, 8.2% use it “occasionally twice a month” and 6.7% do not use it at all; 73.3% of the elderly without disability use the internet “almost daily”, 23.5% use it “several times a week”, 2.1% use it “occasionally twice a month” and 1.1% do not use it at all.

The results reveal that in all categories of frequency of Internet use, there are differences regarding having or not having some disability, $[\chi^2(3\,; n = 838) =$

$100.01, p = 0.000]$, $[\chi^2(3; \mathrm{n} = 836) = 100.01, \mathrm{p} < 0.001]$, and that the senior tourists without disability are the ones that use the internet “almost daily” most, but the senior tourists with disability most use it “several times a week”, “occasionally twice a month”, and are also the ones that most do not use it at all (Figure 4).

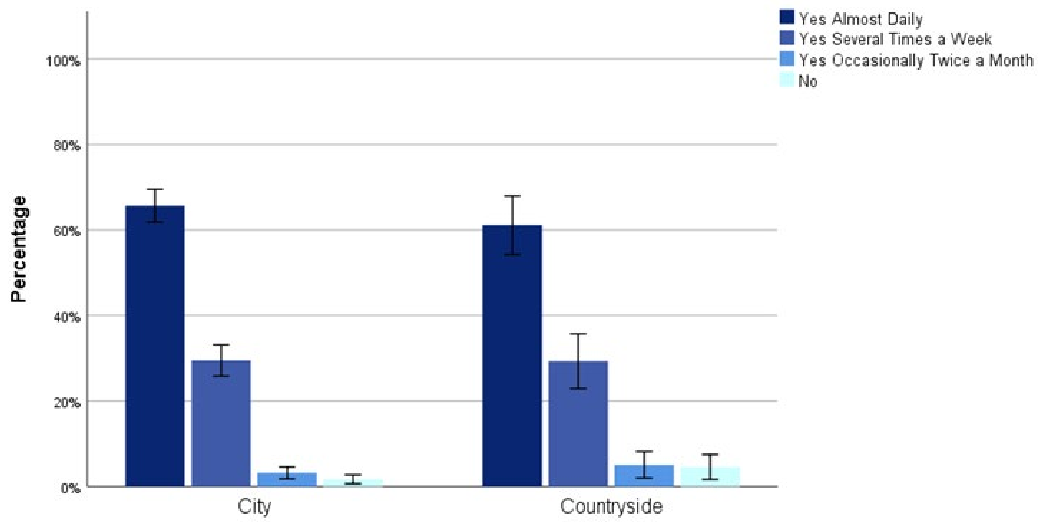
Figure 4. Percentage of elderly tourist participants by disability and frequency of internet use (Source: Authors´elaboration)



In the case of the type of geographical residence area, 65.7% of the respondents that live in a city use the internet “almost daily”, 29.5% use it “several times a week”, 3.2% use it “occasionally twice a month” and 1.7% do not use it at all; 61.1% of the respondents that live in the countryside use the internet “almost daily”, 29.3% use it “several times a week”, 5.1% use it “occasionally twice a month” and 4.5% do not use it at all.

The results indicate that there are no differences regarding the frequency of internet use between the two groups, $[\chi^2(3\,; n = 795) = 7.03, p = 0.071]$ $[\chi^2(3; \mathrm{n} = 836) = 7.03,\ \mathrm{p} = .071]$ (Figure 5).

Figure 5. Percentage of elderly tourist participants by geographical residence area and frequency of internet use (Source: Authors´elaboration)

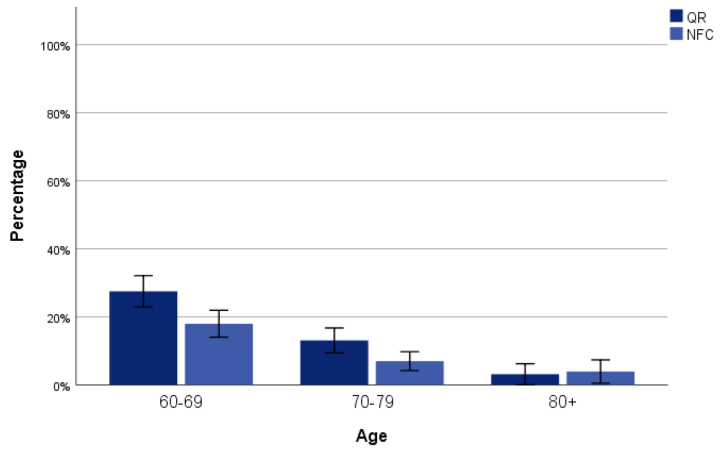


QR code and NFC technology use

Analyzing the QR code use by age, it is observed that it is used by 27.4% of the respondents aged between 60-69, 13.1% of the respondents aged between 70-79 and 3.1% with age over 80. Analyzing the NFC technology use by age, it is observed that it is used by 17.9% of the respondents aged between 60-69, 7.0% of the respondents aged between 70-79 and 3.9% aged over 80 (Figure 6).

The results indicate that the QR code and NFC technology use decreases with the age range $[\chi^2(2\,;n = 825) = 46.47, p = 0.000]$ $[\chi^2(2; \mathrm{n} = 825) = 46.47,\ \mathrm{p} < 0.001]$ and $[\chi^2(2\,;n = 825) = 29.02, p = 0.001]$, $[\chi^2(2; \mathrm{n} = 825) = 29.02,\ \mathrm{p} < 0.001]$, respectively. Note that the results also indicate no differences in NFC technology usage for the age groups 70-79 and over 80 years old, but the group 60-69 differentiates from these two, being the group that uses it the most.

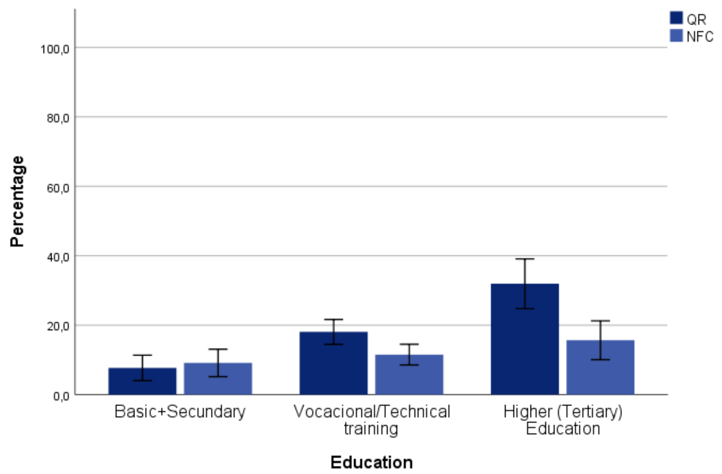
Figure 6. Percentage of elderly tourist participants by age who use QR code and NFC technology (Source: Authors´elaboration)



Considering the level of education, it is observed that the QR code is used by 7.7% of the respondents with basic or secondary education, 18.1% of the respondents with vocational/technical training education and 31.7% of the respondents with higher education. It is also observed that NFC technology is used by 9.0% of the respondents with basic or secondary education, 11.5% of the respondents with vocational/technical training education and 15.7% with higher education (Figure 7).

The results indicate that the QR code use increases with the level of education $[\chi^2(2\,;n = 819) = 36.18, p = 0.000]$ $[\chi^2(3;\mathrm{n} = 819) = 36.24,\ \mathrm{p} < 0.001]$, but the NFC technology use is independent of the level of education $[\chi^2(2\,;n = 819) = 3.96, p < 0.138]$.

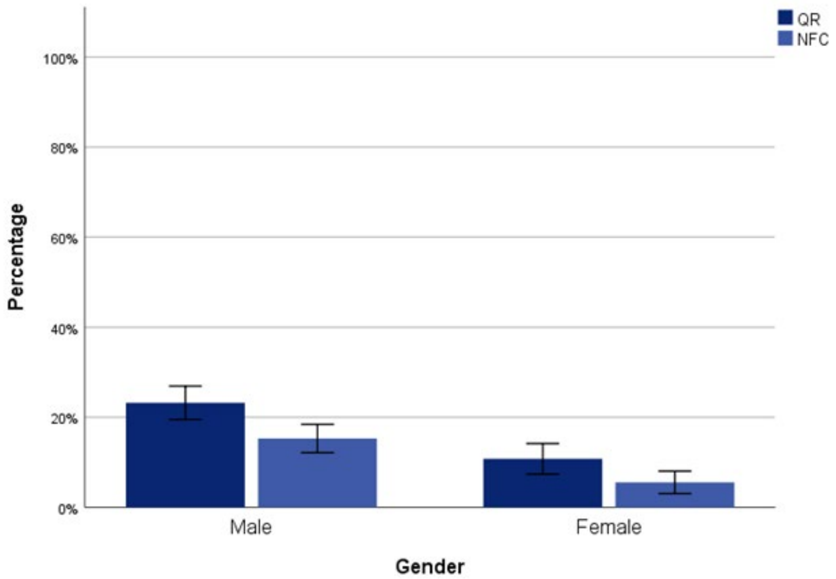
Figure 7. Percentage of elderly tourist participants by education who use QR code and NFC technology (Source: Authors´elaboration)



Analyzing the QR code use by gender, it is observed that it is used by 23.2% of the elderly male respondents and 10.7% of the elderly female respondents. Analyzing the NFC code use by gender, it is observed that it is used by 15.3% of the elderly male respondents and 5.5% of the elderly female respondents.

The results indicate that the QR code and NFC technology use is different between men and women $[\chi^2(1\,;n = 831) = 19.66, p = 0.000]$ $[\chi^2(1;\mathrm{n} = 831) = 19.66,\ \mathrm{p} < 0.001]$ and $[\chi^2(1\,;n = 831) = 17.76, p = 0.000]$, respectively$[\chi^2(1;\mathrm{n} = 831) = 10.38,\ \mathrm{p} < 0.001]$. Moreover, it is possible to verify that more men use the multimedia QR and the NFC than women (Figure 8).

Figure 8. Percentage of elderly tourist participants by gender who use QR code and NFC technology (Source: Authors´elaboration)

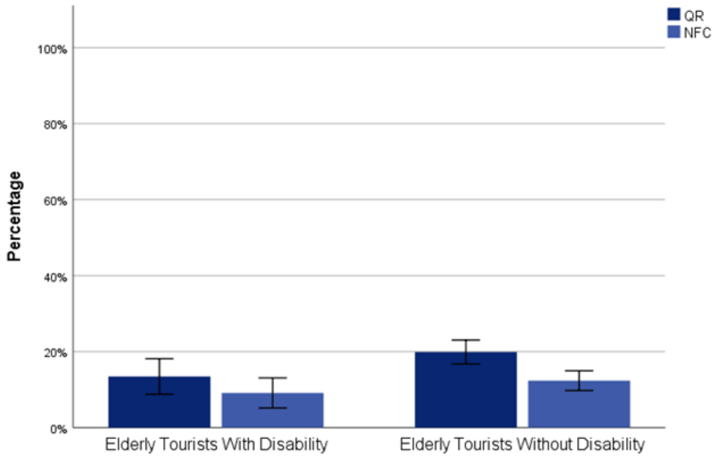


Looking at the QR code use considering the groups of respondents with or without disability, it is observed that it is used by 13.5% of respondents with disability and 19.8% of respondents without disability. Looking at the NFC technology use considering the groups of respondents with or without disability, it is observed that 9.1% of the respondents with disability and 12.3% of the respondents without disability use it.

The results indicate that the use of the QR code and the NFC technology is independent of having or not having some form of disability $[\chi^2(1\,;n = 833) =$

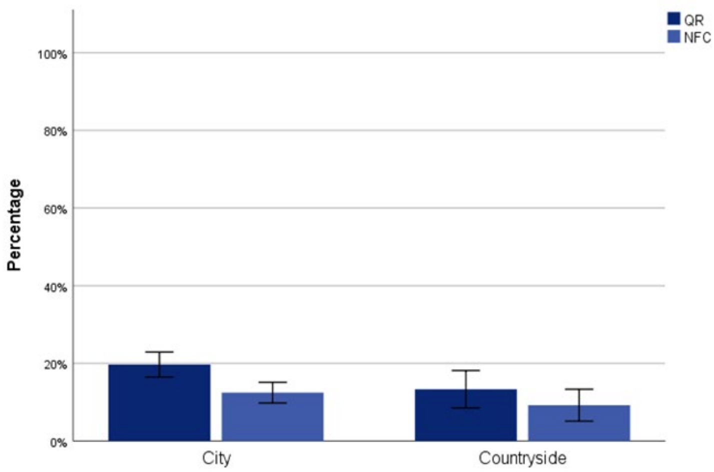
$3.84, p = 0.059]$ $[\chi^2(1; \mathrm{n} = 833) = 3.84,\ \mathrm{p} = .059]$ and $[\chi^2(1\,; n = 833) = 1.32, p = 0.251]$,$[\chi^2(1; \mathrm{n} = 833) = 1.32,\ \mathrm{p} = .251]$, respectively (Figure 9).

Figure 9. Percentage of elderly tourist participants by disability who use QR code and NFC technology (Source: Authors´elaboration)



Now, looking at the QR code use considering the geographical residence area, it is observed that it is used by 19.7% of the respondents that live in a town or in a city and 13.2% of the respondents that do not live in a town or in a city. In the same way, looking at the NFC technology use considering the geographical residence area, it is observed that it is used by 12.4% of the respondents that live in a town or in a city and 9.2% of the respondents that do not live in a town or in a city (Figure 10).

Figure 10. Percentage of elderly tourist participants by geographical residence area who use QR code and NFC technology (Source: Authors´elaboration)



The results indicate that the type of geographical residence area and the QR code or NFC technology use are independent, $[\chi^2(1\,; n = 791) = 3.79, p = 0.052][\chi^2(1; \mathrm{n} = 791) = 3.79,\ \mathrm{p} = .052]$ and $[\chi^2(1\,; n = 791) = 1.16, p = 0.282],[\chi^2(1; \mathrm{n} = 791) = 1.16,\ \mathrm{p} = .282]$, respectively (Figure 10).

Discussion

Digital resources include devices, internet connection and digital literacy which have become basic needs (Ng et al., 2022).

This investigation has helped to understand that the great majority of elderly tourists who have chosen the Algarve as their destination and participated in this study have some digital literacy since 97,5% of them use the Internet. The results indicate that the frequency of internet use by the elderly tourist respondents depends on the age range, level of education and the condition of having or not having a disability of the surveyed elderly tourists. Nevertheless, relative to gender and the geographical residence area, no association with the frequency of internet use was verified.

Regarding the age range, it was observed that as the age of the surveyed elderly tourists increases, their Internet use decreases. This is consensual with previous studies that concluded, in the case of older adults, there is a higher digital illiteracy (König et al., 2018), which can imply that there are not the same opportunities in terms of access to information.

This may be linked to the fact that most older seniors have a lower level of education than most younger seniors, so they have greater difficulty in learning how to use the Internet, or simply in using the proper devices that allow them to have access to it (for example, computer or cell phone). Besides that, the older an individual gets, the more limitations in physical and cognitive mobility arise, which means that age can be a limiting factor in the use of the Internet or other technologies due to cognitive or even visual and/or hearing problems (Skouby et al., 2014). So, this is a disability issue. Eusébio et al. (2020) recommended the promotion of text alternatives for any non-textual content to make the switch to other formats possible according to the needs of people with disabilities, e. g. large print, braille, speech, symbols or simpler language.

Relative to the level of education, the results indicate that the higher the level of education of the respondent, the higher their internet use. Probably because the less information there is, the greater the distrust, insecurity, and less knowledge. If the individual has a low level of education and training, the less familiar they will be with new technologies and their benefits (Martin et al., 2017; Song et al., 2021).

When it comes to the surveyed elderly tourists with or without disabilities, it is possible to observe that the respondents without disabilities are the ones who use the Internet the most. This may be linked to the fact that elderly people with disabilities could have less access to the use of the Internet and that the proper devices are not accessible to them due to their disability. This evidence becomes interesting since it is expected that individuals with disabilities have a greater need to use the Internet as a tool that allows them access in their daily life for planning their activities, planning trips and/or searching for information on the place of destination, without having to go somewhere to obtain this information physically.

Relative to gender and the geographical residence area, no association with the frequency of internet use was verified.

Analysing the inquired elderly tourists who do not use the Internet (Table 1) there are always people who are not integrated into the global group of people that use the Internet, mainly tourists aged over 80, those with less education, women, people with disabilities and those living in the countryside. They are excluded from the digital world which has implications in terms of access to important touristic information.

This is consensual with Dobransky and Hargittai (2006), who assumed that information technology can increase social inequality by leaving behind certain groups of the population, including people with disabilities and older people. In addition, the present study adds people with less education, women, and people who live in the countryside.

Digital societies have excluded many people with cognitive or physical disabilities because access to online information and the ability to navigate website elements such as radio buttons, sliders, navigation bars, and website forms can be barriers to a useful digital experience (Mason, 2020).

A study conducted by Johansson et al. (2021) has demonstrated that most people with disabilities lag behind those without such impairments, i.e. they do not have as much access to devices, they barely use the Internet to pay bills compared to those without disabilities, they use the Internet to shop online less, they use mobile bank ID for identification less, and they feel less included in the digital world. According to these authors, the type of disability/diagnosis, gender and socio-economic factors, especially education and accommodation, have an influence on disabled people's digital literacy. Thus, equitable public measures should be created considering each specific situation so that all people with disabilities are included in the process of expanding digital literacy.

Table 1: Percentage of elderly tourist respondents who do not use the Internet. (Source: Authors´ elaboration)

a) *By age group*

Age group	Percentage
60-69	0.5
70-79	2.4
+80	7.9

b) By level of education

Level of education	Percentage
Basic or secondary	**6.7**
Vocational/technical training	1.3
Higher	0.6

c) By gender

Gender	Percentage
Men	1.8
Woman	3.7

d) By (dis)ability

(Dis)ability	Percentage
With disability	6.7
Without disability	1.1

d) Residence

Residence	Percentage
Town/city	**1.7**
Countryside	**4.5**

Education and income, governmental policies, family and social supports, personal attitudes and motivations are major contributors to the severe impacts of the age-related digital divide on older adults during the pandemic (Song et al., 2021). The access to the use of ICT is influenced by different social statuses, such as income, education and labour-force participation, which can explain some of the inequality between those with and without disabilities (Dobransky & Hargittai, 2006; Song et al., 2021).

Relative to the use of the QR code and NFC technology, it was observed that few surveyed elderly tourists are familiar with the above-mentioned technologies, as only 18,2% and 11,5% of the respondents use these technologies, respectively. Still, it is important to note that variables such as disability condition and the environment (urban or countryside) in which the surveyed elderly tourists live have no association with the use of these technologies.

Moreover, it was observed that the use of technologies, such as QR code and NFC technology, depends on the age range and the gender of the respondents. It was also possible to see that the QR code usage depends on the level of education. This may be related to the fact that, the higher the level of education of the respondents, the higher their digital competence. Nevertheless, when it comes to the NFC technology, this association was not verified. However, it can be noted that the QR Code is more present in electronic devices than the NFC.

It should be emphasized that the QR code and NCF technology are recent technologies and have been gaining more prominence due to the current pandemic situation, so it is normal that older people are not yet familiar with them (Song et al., 2021). In fact, due to the COVID-19 pandemic, for public health reasons, the use of QR codes has intensified to transmit information, for example, menus in restaurants.

A good measure to promote the use of digital technologies by older people would be to encourage them to learn how to use this equipment through lectures, documentaries, and many other methods, increasing their digital literacy and guaranteeing their inclusion in contemporary society. According to Tavares and Souza (2012, p. 4). "the State should offer resources not only for regular school education, but also for the teaching of new technologies". Alternatively, older adults can teach each other. They could receive more peer-based social support, increasing digital literacy diffusion (McGinty, 2020). The United Nations (2019), governments, civil society and institutions are demanding to work towards achieving full digital inclusion and digital equality.

In order to be able to influence the shape of future technologies, older people need to be actively engaged in identifying and articulating their goals, needs and aspirations, and evaluating and validating alternative options (Olphert et al., 2005). It is essential to integrate elderly people into co-design and co-creation processes, influencing the conception of age-friendly spaces and products, such as the Project ACCES4ALL advocated.

During the COVID-19 pandemic, increased digital technologies are being applied (Song et al., 2021). Digital society has become necessary, so universal access to information and services is needed, and older adults' difficulties must be considered in social inclusion aims (Xie et al., 2020).

Considering the strengths of Project ACCES4ALL, it gives innovative information on the use of the Internet and other digital tools. The survey influenced a collaborative design process to develop inclusive and smart bus stops considering the perceptions of the elderly and/or people with disabilities. The proposed smart and interactive panel has intelligent features to allow its adaptation to different users' needs (Rodrigues et al., 2018). In the case of elderly people, communication is attained, for example, using simple language.

Considering the weakness of the present study, although the sample size of the survey is appreciable, this study has some limitations. The respondent tourists have sufficient health to be mobile at Faro Airport. The most severely ill people (for example, institutionalized) and those with no financial access to tourism experiences, and others were not considered in the study. So, the group of tourist respondents may not generalize all older adults.

Conclusions

Today accessibility in the built environment goes beyond urbanistic aspects. Considering transport systems, it is related to information services provided to passengers (written and auditory information), intelligent systems of orientation for the blind, ticket boxes, and other smart equipment installed in loco, such as bus stops, among others. The implementation of accessible and smart bus stops together with the improvement of the conditions of accessibility of other interfaces in touristic places are considered an essential part of accessible tourism and sustainable mobility.

This innovated digital world has much potential to increase opportunities for people including the elderly and people with disabilities, but demands digital literacy.

This paper analyzed the digital literacy of elderly tourists who chose the Algarve as their destination. The data evidenced that most of the elderly tourists who participated in the study are in some way digitally literate since they use the Internet. It was also noted that the more education the elderly respondents had, the more they used the Internet. In addition, it was perceived that elderly tourists with disabilities use the Internet less than those without. Regarding the QR code and NFC technology, the study showed that many elderly tourists are not familiar with these technologies. These findings reveal that nowadays, most of the elderly tourists possess some digital literacy, although there are still many technologies they do not fully master or are aware of.

Considering the inquired elderly tourists, some do not use the Internet and are not integrated into the digital world, mainly tourists over 80, those with less education, women, people with disabilities or people living in the countryside. They are excluded from the digital world which could have implications in terms of less access to important touristic information.

Nowadays, seniors play an active role in tourism travel planning through relational, information and communication technologies, although there is still a long way to go to reach the inclusion of the elderly and/or people with disabilities in the present digital society.

More research is needed to understand why older people do not use the Internet or access fewer types of digital content, with the aim of creating equitable measures that consider each specific situation, so that all people, including seniors and people with disabilities are included in the process of expanding digital literacy.

Therefore, it is imperative that digital devices and websites enable people with access requirements to operate independently, that is, with autonomy, guaranteeing equitable use (first principle of the Universal Design). The online information has to be presented with multiple communication methods, e. g. text or sound, images, graphics, video, music, and multimedia objects, to guarantee flexibility of use (second principle). The proposed QR codes or technology NFC can increase access to information which would be simple and intuitive to use and guarantee perceptible information (third and fourth principles). Digital travel planning does not require going to travel agencies, guaranteeing low physical effort (sixth principle). For many people, small screen size presents significant constraints, so digital devices must be of adequate size (seventh principle). In other words, devices with structures adaptable to the conditions of people. Usability is an important criteria of design, that guarantees the ease of use and intuitiveness of the product.

In order to be able to influence the shape of future technologies, older people need to be actively engaged in co-design and co-creation processes, influencing the conception of age-friendly spaces, products, services and information systems. Older adults must be considered as active users of technology systems and be included in the user-centred design approach.

There is a strong need to make seniors more aware of the benefits of the Internet and other technologies. For example, when it comes to the tourism sector, the Internet is very useful because it allows people to have more access to information related to travel arrangements and the country of destination, whenever they need it. These are only a few of many advantages of using digital equipment. Apart from this, a good measure to promote the use of digital technologies by older people, would be to encourage them to learn how to use this equipment, through lectures, documentaries, and many other methods, that increase their digital literacy and so guarantee their inclusion in contemporary society.

In addition, tourism services should be welcoming and provide safety for the elderly and people with disabilities in order to respect their personal values; support the use of technological tools; and have a list containing other suitable tourist services in the area, such as restaurants, museums, among others, and with accessibility for all clients.

It is believed that this research will sensitize society and organizations to the importance of implementing public policy measures by developing effective strategies that contribute to increasing digital literacy of the elderly, also allowing the elderly themselves to see its usefulness.

Presently, in smart cities there is a large focus on technology, energy and water resource efficiency, low carbon society to emphasise their innovative identity. Some good examples are emerging associated with social inclusion, but efforts in this field must be greater and systematic. It is imperative to reduce inequalities “no one is left behind”, as the 2030 Agenda for Sustainable Development recommends.

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ONE STEP CLOSER TO ACHIEVING INCLUSIVE DESIGN: DESIGN CONSIDERATIONS FOR CLIENTS WITH LOW-VISION

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Abstract**:** While the low-vision population in America continues to increase, few empirical studies have been completed investigating how environmental factors affect a low-vision person's ability to perceive the interior environment accurately. By using quantitative research methods to understand the critical relationship between contrast levels within the built environment and the ability of the low-vision and normal-sighted population to perceive that environment accurately, researchers can investigate safer and more inclusive interior spaces. Specifically, this study explores the environmental factor of contrast and how varying levels of contrast within interior spaces might affect the behaviour of low-vision participants within the interior environment. The findings demonstrate a preference among normal-sighted and low-vision participants for high-contrast environments, and their innate cues of high contrast.

Keywords: low-vision, interior design, contrast, accessibility, behaviour.

Introduction

Every design decision made throughout the design process can create a positive or negative experience within the interior built environment, especially for a person with low-vision relying on contrast and their other senses. Research has shown that it can affect the level at which they are willing to participate within that environment (Jenkins et al., 2015). As designers, we strive to create an inclusively designed space to accommodate people with many different mobility, cognitive, visual and hearing ability levels; many professionals equate this to creating projects compliant with the Americans with Disabilities Act (ADA). However, these requirements favour those with mobility limitations, and only address issues of protruding objects and signage for the blind—it does little for those with limited vision (Sokol, 2007). The number of people with visual limitations is expected to increase by 6.31 million by the year 2020 due to the ageing population of baby boomers (Akpek & Smith, 2013) as well as those genetically predisposed to have low-vision. This drastic increase elevates the need for consideration in the design of interior spaces, specifically the contrast of finished materials, to allow this combined population of people to safely and independently navigate and participate in the built environment.

Low Vision

Low vision is defined as a visual impairment that makes everyday activities difficult, and that cannot be corrected with glasses or surgery (National Eye Institute, 2019). Low vision describes a severe loss of vision, which can be defined by a visual acuity level of 20/70 or worse after surgery has been performed, or corrective lenses have been worn (Dandona & Dandona, 2006). A person with a visual acuity level of 20/200 or worse is considered clinically blind. While low vision usually cannot be cured, advances in ocular medicine and technology can help to improve their quality of life. The four most common low-vision diagnoses are age-related macular degeneration, cataracts, diabetic retinopathy, and glaucoma (National Eye Institute, 2019). These diagnoses describe several symptoms and limitations that can be helped but not eliminated.

Inclusive Design

The inclusive design strives to go a step further than the Americans with Disabilities Act which provides requirements for how to make an interior environment accessible to people with mobility, visual, and hearing impairments (Nussbaumer, 2012). It strives to create an environment or product that integrates accessibility in a way that is seamless in design, with functional requirements of the space for people of all abilities. Nussbaumer suggests the implementation of high-contrast, large text signage on the wall as a wayfinding method for people with low vision. But is there a way to combine this method with floor patterns and strategic lighting placement to reinforce, or highlight, the wayfinding system in a way that is helpful to all building occupants?

Sensory cues within the built environment

Sensory cues are one way to help people with low vision navigate the environment. Jenkins et al. propose that the environment plays a role in whether a person with low vision will take an active role in participating within that environment (2015). They also state the importance of understanding the sensory characteristics present that will help a person with low vision develop an understanding of the space in which they are attempting to work by providing accurate orientation cues, contributing to safe travel and wayfinding through the environment. Their study identifies three main themes discovered from the participant's survey responses discussing their experiences in multi-sensory environments: barriers, supporters, and context-dependence.

The barriers identified addressed environmental factors such as inconsistent lighting design, uneven floor surfaces and extreme sensory backgrounds. Supporters identified sensory characteristics in the built environment such as "audible cues and echoes, smells, tactile quality of the ground characteristics embedded in public spaces and the proximity to the sensory cues" (Jenkins et al., 2015, pp. 8644). The authors claim that these multisensory environments not only supported or inhibited a person with low vision activity participation level, but that it was also a context-dependent relationship, referring to the sensory cues of the environment and the activity being performed within the environment. This supports the belief that the environment in which a person with low vision occupies can affect that person's engagement level within the space. Therefore, careful consideration of finish materials could lead to more productive, comfortable and safe spaces.

Finish Materials

When a designer selects finish materials, there are many aspects to evaluate and consider, such as the composition of the material, the thickness of the material, what transition strips are available, the surface texture and light reflectance value, as well as where and how the product has been approved for use should also be considered. Schambureck & Parkinson's (2018) qualitative study outlines a typology system for designers to determine whether a space is a supportive or a non-supportive space for the low-vision population using four main categories: luminance contrast, value contrast, luminance placement, and object placement. Within the value contrast typology, detectable warnings, ghosting and deception typologies all relate to the amount of contrast needed within the interior environment for a person with low vision to develop spatial awareness and understanding.

Lighting

Lighting is another important environmental factor to consider when designing for the low-vision population. The standard measure of lighting levels is described in lux, which is defined as a "unit of illumination equal to the direct illumination on a surface that is everywhere one meter from a uniform point source of one candle intensity or equal to one lumen per square meter" (Merriam-Webster, n.d.). Most residences do not meet the recommendations for lighting levels provided by the Illumination Engineering Society of North America because they are too dim (Perlmutter et al., 2013). The literature currently does not address the needed lighting levels for people with low vision in commercial spaces, though it can be hazardous to have too much as well. Hotspots, or glares, can confuse a person with low vision (Barstow et al., 2011; Perlmutter et al., 2013). Lighting in transitional spaces can cause shock; going from a very bright exterior (65,000 - 130,000 lux) to a dim interior (37 – 59 lux) can happen in the span of ten seconds (Lasagno et al., 2014).

Human Relation and Low-Vision Behaviors

A study conducted by Freedman et al. (2019) found that low-vision participants exhibited gaze behaviours toward the floor and wall boundary during navigation which served as a high contrast cue. This resulted in them missing the object and letter cues provided as the task during the observation experiment. This may provide insight into why many people with low vision look down while walking.

Other behaviours which may be exhibited by people with low vision when attempting to navigate the environment include eye blinking (Jones & Landa, 2011), poking or pressing the eyes (American Printing House for the Blind, 2019), slowing their walking pace, reaching for a wall while walking, stopping to ask for assistance (Hughes et al., 2018), or avoiding a space altogether (Jenkins et al., (2015). This study attempts to determine whether contrast in the interior space contributes to the exhibition of these behaviours by the low-vision population.

Methodology

Purpose of this Study

The main purposes of this research are:

- To understand how the contrast between finish materials in the interior environment impacts the behaviour of people with low vision.
- To generate design guidelines that will support the needs of these people with low vision.

Hypothesis

Hypothesis 1: There is a relationship between the contrast levels of interior finish materials and the accuracy of a person with low vision's perceptions of the interior environment.

Hypothesis 2: There is a correlation between the contrast of finish materials and the level at which a person with low vision is willing to participate within that environment.

Methodology for Phase I: Online Survey

Purpose

The first phase of this research study was an online survey for low-vision and normal-sighted participants to complete from the comfort of their own home or work environment. The main objectives of this survey were to assess the role that contrast played in a person’s ability to accurately perceive the interior environment and to identify behaviours exhibited in an environment due to too-high or too-low levels of contrast. The survey instrument can be found in Appendix A.

Participants

The researcher set forth the goal of obtaining 100 low-vision and 100 normal-sighted participants' survey responses. Due to the location of the Phase II, getting more than 10 – 15 low-vision participants would be difficult, so the large number of survey responses would provide valuable data for analysis. Recruitment of participants

Data collection was conducted from August 20, 2019, to October 10, 2019. The survey was approved by the Mississippi State University Institutional Review Board for Human Subjects on August 19, 2019.

Instrument

The Phase I Survey consisted of 32 questions which addressed the impact of contrast levels within the interior environment on both people who are normal-sighted and those that have low vision. Six additional questions addressed the participant’s demographic information, and low-vision participants were also asked for comparative analysis. The survey identified the preferred level of contrast present in the interior environment, and behaviours associated with too high or too low levels of contrast. A five-point Likert scale was used for participants to rank the importance of contrast in the interior environment, with photographs illustrating the principle in question where appropriate. Participants were also asked to identify behaviours they exhibited in environments with too little or too high contrast levels, with a final open-ended question provided to add any additional behaviours not addressed in the survey. The survey instrument can be found in Appendix A. For low-vision participants, the survey was made accessible via voice-to-text answers and its ability to be easily read and described.

Procedure

The National Research and Training Center for Blindness and Low Vision located at Mississippi State University agreed to distribute a research announcement via email to their database, consisting of over 400 low-vision members. The National Federation for the Blind also reviewed, approved, and agreed to distribute the survey electronically to its national member database. This allowed the study to include a much larger number of potential research participants and gave more valuable data for analysis. This also helped to overcome the rural location of the researcher; a wider range of participants could respond, low-vision participants didn't need to worry about transportation. A reminder-to-respond email was sent out two weeks after the initial announcement encouraging responses, which doubled the number of surveys collected. Participants with normal vision were recruited through the snowball recruitment technique using Facebook, Twitter, and word-of-mouth. A link was provided via the posts connecting to a Qualtrics survey with the 'prevent ballot box stuffing' feature to ensure each participant answered only once.

Methodology for Phase II: Virtual Reality Behavioural Observation

Purpose

Phase II consisted of an observation study utilizing a virtual reality environment to investigate the preferred level of contrast present in the interior environment for a small low-vision and normal-vision population within a controlled setting. A single room was modelled; the finish materials on the wall and floors were changed to show nine different study environments, Figure 1.

Figure 1. Shows the virtual reality equipment setup at the lighting lab in Mississippi State University's Interior Design Program.

Participants

Purposeful sampling was utilized for this study, as both normal and low-vision participants are needed. Visual acuity levels between 20/20 and 20/70 were classified as normal-sighted, and participants with a visual acuity level between 20/70 and 20/1000 were categorized as low-vision. The sampling resulted in a combination of 17 low-vision and 17 normal-sighted participants.

Recruitment of Participants

Data collection was conducted from October 3, 2019, to October 20, 2019. The observation was approved by the Mississippi State University Institutional Review Board for Human Subjects on August 19, 2019.

Site Selections

Phase II was conducted in multiple locations in rural Mississippi in order to reach a larger number of participants with vision impairments. This also helped to alleviate the risk associated with travel for some participants with vision impairments and made participating in the study more convenient.

Site Selection A

The first study site selected was the 10-foot by 20-foot lighting laboratory with no windows of the Interior Design Program at Mississippi State University. The walls were painted eight different colours with divider strips separating each colour and tackable cork strips; an art piece hangs on the right wall and a mirror hangs on the front wall. HTC Vive sensors were placed in the front right and back left corners of the room to establish boundaries; a table and chair, a monitor, the HP backpack computer, and virtual reality goggles were located at the back of the room. A total of 10 participants were observed at this location.

Site Selection B

The second study site selected, shown in Figure 2, was a Sunday school room at Beersheba Church in Columbus, MS. This rectangular room was 18 feet by 26 feet with eight windows and two doors. HTC Vive sensors were placed in the front right and back left corners of the room to establish the room’s boundaries. The same equipment listed above was located on the right side of the room. A total of 16 participants were observed at this location.

Figure 2. Shows Beersheba Church's Sunday school room with virtual reality equipment.

Site Selection C

The third study site selected, Shown in Figure 3, was an open area in a fellowship hall at First Presbyterian church in Louisville, MS. This rectangular area was 16 feet by 30 feet with two windows in the study area. HTC Vive sensors were placed in the front right and back left corners of the room to establish the room's boundaries. The same equipment listed above was located on the right side of the room. A total of 8 participants were observed at this location and this was the only site where all observations were completed in one day.

Figure 3 Shows the study area in First Presbyterian Church's Fellowship Hall with VR equipment.

The observation documented preferred contrast levels between floor, base, and wall materials as well as behaviours exhibited by participants through behavioural frequency recordings in each location, Appendix B.

Study Environments

Since this study aimed to pinpoint the preferred level of contrast desired by people with low vision in wall to wall and floor to floor transitions, nine different study environments were created to obtain feedback from research participants. Each study environment was classified as a high, medium, or low-contrast environment by collecting the light reflectance values of the wall and floor materials and using subtraction to determine the difference between them (Schambureck & Parkinson, 2018). The following number ranges were used to determine the classification of low, medium and high contrast environments: High (30 – 45), Medium (15 – 29.9), Low (0 – 14.9). Scenes that feature a light wall and floor material were categorized as a low-contrast environment while scenes featuring a light wall with a dark floor were categorized as a high-contrast environment, and scenes with a combination of light wall materials and medium floor materials were categorized as a medium contrast environment.

Study Environment A

This environment features the lightest grey wall paint with the lightest carpet selection as seen in Figure 4. The specific finish material selections are indicated in Table 1. This environment will be classified as a low-contrast environment for the purposes of this study.

Figure 4. Illustrates study environment A's finish material placement and design.

Table 1. Study Environment A Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7064 Passive
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Limit 64515

Study Environment B

This environment features the lightest grey wall paint with medium-dark carpet selection, and a medium grey base material is located at the wall-to-floor transition material as seen in Figure 5. The specific finish material selections are indicated in Table 2. This environment will be classified as a medium-contrast environment for the purposes of this study.

Figure 5. Illustrates study environment B's finish material placement and design.

Table 2. Study Environment B Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7064 Passive
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Verge 64555

Study Environment C

This environment features the lightest grey wall paint with the darkest carpet, and a medium grey base material is located at the wall-to-floor transition selection as seen in Figure 6. The specific finish material selections are indicated in Table 3. This environment will be classified as a high-contrast environment for the purposes of this study.

Figure 6. Illustrates study environment C's finish material placement and design.

Table 3. Study Environment C Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7064 Passive
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Fringe 64585

Study Environment D

This environment features the medium grey wall paint with the lightest carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 7. The specific finish material selections are indicated in Table 4. This environment will be classified as a medium-contrast environment for the purposes of this study.

Figure 7. Illustrates study environment D's finish material placement and design.

Table 4. Study Environment D Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 9163 Tin Lizzie
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Limit 64515

Study Environment E

This environment features the medium grey wall paint with the medium dark carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 8. The specific finish material selections are indicated in Table 5. This environment will be classified as a low-contrast environment for the purposes of this study.

Figure 8. Illustrates study environment E's finish material placement and design.

Table 5. Study Environment E Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 9163 Tin Lizzie
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Verge 64555

Study Environment F

This environment features the medium grey wall paint with the darkest carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 9. The specific finish material selections are indicated in Table 6. This environment will be classified as a medium-contrast environment for the purposes of this study.

Figure 9. Illustrates study environment F's finish material placement and design.

Table 6. Study Environment F Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 9163 Tin Lizzie
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Fringe 64585

Study Environment G

This environment features the darkest grey wall paint with the lightest carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 10. The specific finish material selections are indicated in Table 7. This environment will be classified as a high-contrast environment for the purposes of this study.

Figure 10 Illustrates study environment G's finish material placement and design.

Table 7. Study Environment G Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7674 Peppercorn
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Limit 64515

Study Environment H

This environment features the darkest grey wall paint with the medium-dark carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 11. he specific finish material selections are indicated in Table 8. This environment will be classified as a medium-contrast environment for the purposes of this study.

Figure 11. Illustrates study environment H's finish material placement and design.

Table 8. Study Environment H Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7674 Peppercorn
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Verge 64555

Study Environment I

This environment features the darkest grey wall paint with the darkest carpet selection, and a medium grey base material is located at the wall-to-floor transition. as seen in Figure 12. The specific finish material selections are indicated in Table 9. This environment will be classified as a low-contrast environment for the purposes of this study.

Figure 12 Illustrates study environment I's finish material placement and design.

Table 9. Study Environment I Finish Materials

Finish Location	Manufacturer/Style	Color
Wall Finish	Sherwin Williams	SW 7674 Peppercorn
Base Finish	Johnsonite	28 Medium Grey
Floor Finish	Shaw Contract/Minimal	Fringe 64585

Instrument

Throughout the observation the researcher tallied each time a studied behaviour was observed on the Behavior Observation form, which lists each behaviour in chart form. After this walkthrough, the participants were asked to rank the environments in which they saw best. The rankings were recorded on The Study Environments Ranking form, Appendix C; a one for most preferred and three for the least preferred.

Procedure

Phase II consisted of an observation study which utilized a virtual reality environment to investigate the preferred level of contrast present in the interior environment, and behaviours exhibited within that environment for a small low-vision and normal-sighted population within a laboratory setting. A single room was modeled three-dimensionally on the computer, and the finish materials on the wall and floors were changed to reflect the nine different study environments. A piece of art was modelled on one wall, and a chair was digitally placed in the middle of the room.

This observation utilized virtual reality technology, which most research participants were unfamiliar with, so detailed instructions and were given prior to placing the virtual reality goggles on the participant's head while a few minutes of acclimation were given after. The researcher explained that the room was empty other than the VR equipment, and that the chair shown in the virtual reality room was not actually present at the study site.

Once the study began, the researcher placed the participants at the back of the room and gave them instructions to walk to the front of the room and touch the piece of art shown on the wall. In order to do this, the participant was required to walk around the chair shown in the middle of the virtual reality environment. After touching the piece of art, they were asked to return to the back of the room. The researcher asked the participant to complete this each time she switched the study environments. The researcher was observing whether the participant could complete this task while recording the frequency in which any of the observed behaviours were exhibited. The researcher used a printed behavioural frequency chart located in Appendix B, and tallied each behaviour exhibited while also noting which environment the behaviour was exhibited within.

After completing the walkthrough of each study environment, the researcher presented each of the nine environments in groups divided by wall colour. The light grey wall grouping consisting of study environments A, B, and C was shown first. The participant was asked to identify the study environment that they saw best in, and then the environment that they had the hardest time seeing in. The same procedure was completed for the medium and dark wall groupings. After reviewing all nine study environments and selecting the best and worst environments for each of the three groupings, the researcher cycled through all 9 environments and asked the participant to select the study environment that they saw the best in, recording their responses on the Environment Ranking form found in Appendix C. Observations were video recorded to verify the researcher's notes, and lasted twenty minutes or less per participant.

Measurement Techniques

Behavioural observations of the research participants were based on the literature review, a previously conducted observational study, and the results of the survey from Phase I of this research.

Coding the Participants

A three-digit code was assigned to each participant to de-identify them, and protect their privacy. Once each participant was coded, the researcher input the codes into the SPSS software.

Selecting and coding the observed behaviours

A total of 6 behaviours were observed, coded from A to F. Observed behaviours were selected due to literature reviews and accounts of previous observations by the researcher of low-vision research participants.

Behavior Definitions

The following behaviours were identified through literature and previous accounts of interactions with people with low vision:

- Eye blinking: An involuntary response that protects and hydrates the eye (Jones & Landa, 2011). Rapid eye blinking was observed by the researcher in previous observations with low-vision participants in environments described to be confusing by research participants.
- Slowing pace: During previous observations, research participants slowed their pace in an interior environment that was described as hard to navigate (Hughes et al. 2018).
- Stopping to touch the wall: While walking/wayfinding, a low-vision research participant may stop to reach for or touch the wall when they are unsure of their surroundings or having issues with depth perception due to a lack of contrast. Hughes et al.(2018) observed research participants in a low-contrast environment who repeatedly stopped and touched the wall when they were unsure of their surroundings.

- Stopping to ask for assistance or a guide: Hughes et al. (2018) also observed a low-vision research participant stop to ask for an assisted guide, as they were not confident in their perception of the space. This behaviour could include asking for help, asking for directions, or asking for a person to guide them to their desired location.
- Avoiding a space: Jenkins et al. (2015) suggest that the interior environment plays a role in whether a person with low vision will attempt to participate in the environment. They suggest that if a person with low vision cannot understand the environment in which they are in, they may leave or avoid entering that environment completely, or leave the space quickly after entering.
- Eye poking or pressing: Some people with visual impairments may repetitively poke their eyes with their fingers or press their eyes firmly. (American Printing House for the Blind, 2019)

Video Recording

Prior to conducting the observation, permission to video record the study was requested. If the permission was refused, the researcher took notes throughout the study including detailed descriptions of what was observed and discussed. If permission to video-record the observation was granted, then the observation was recorded in its entirety to verify the behaviour frequencies recorded were accurate, and the video was transcribed within a week from the time the study was completed before being deleted.

Virtual Reality Equipment

The researcher chose to test the hypothesis for this study by utilizing a virtual reality environment so that the research participants could experience different materials within the same room. The use of the virtual reality backpack computer allows the participant to move around the space freely without fear of tripping over any cords.

HP Z VR Backpack Computer

For this observational study, the researcher utilized an HP Z Virtual Reality computer, which can be mounted in a stationary dock and connected to the VR goggle headset by a twelve-foot-long connection cord or attached to a backpack for a free roam experience (HTC, 2019). Portable batteries are stored in a holster in the backpack to provide power to the computer (Hewlett Packard, 2019). Once the application is opened, the researcher can toggle through each of the environments via the keyboard, and a monitor is connected so the researcher and research participant can see the same views simultaneously. The researcher chose to use the backpack computer as it would reduce the risk of participants tripping on a long cord. A research assistant held the backpack and followed the research participant so that they would have a more authentic experience while wearing the headset and travelling through the virtual reality environment without the weight or restriction of motion. This also allowed the research participant to provide assistance to the participant if needed.

HTC Vive Virtual Reality Headset System

The HTC Vive virtual reality headset system includes a headset, two room boundary sensors, and hand controls (HTC, 2019). The headset connects to three ports at the top of the computer system. It is powered by the portable batteries located within the backpack. Due to the simplistic nature of the study environment used for this research, the hand controls were not needed and therefore were not utilized.

Two room sensors were placed at approximately eight feet above the finished floor in two opposite corners of the room, and the room dimensions were synchronized with the SteamVR program. This allowed participants to move around the room naturally without the danger of running into any walls. If a participant reaches the sensor’s established boundaries, the room’s natural walls, the room scene goes away, and a blue grid appears warning the participant to stop.

Phase 1 Analysis and Results

Participant Demographics

A total of 240 people participated in Phase I of the study, of which 118 self-reported as low-vision and 122 self-reported as normal-sighted. 80% of participants were female, while 20% were male. The ages of the participants were reported as falling in the following groupings can be seen in Fig. 13 below. The racial composition of the participants can be seen in Fig. 14 below. Of the normal-sighted participants, 70 self-reported normal vision and 52 self-reported near-normal vision. The ages of the normal-sighted participants were reported as falling in the following groupings: 18-25 (n = 72); 26-35 (n = 14); 36-45 (n = 10); 46-55 (n = 6); 56-65 (n = 14); 65-75 (n = 6); 76 and older (n = 2); and Prefer not to answer (n = 0). 81% of participants were female, while 18% were male. The racial composition of the participants was comprised of 68.03% Caucasian/White, 27.87% African American/Black, and 4.1% other.

Of the low-vision participants, 48 self-reported a severe visual impairment, 43 self-reported a moderate visual impairment, and 27 self-reported a profound visual impairment. Low-vision participants reported a wide range of low-vision diagnoses, with the highest frequencies being optic nerve hypoplasia (n = 12), glaucoma (n = 11), macular degeneration (n = 10), retinitis pigmentosa (n= 9), and other diagnoses not listed (54). The ages of the low-vision participants were reported the same as above. Seventy-seven percent of participants were female, while twenty-two percent were male. The racial composition of the participants was comprised of 72.03% Caucasian/White, 16.18% African American/Black, 3.39% Hispanic and 8.4% other.

Comparison Groups

For the purposes of analysis, two groups of individuals were identified from the data based on the responses to the question; How would you identify your level of visual impairment? This survey item allowed for five response options: Normal Vision (20/12-20/25); Near Normal (20/30-20/70); Moderate (20/80-20/160); Severe (20/160-20/400); Profound (20/400 – 20/1000). The division

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of the two groups was based on the definition of low-vision which requires a visual acuity level of 20/80 or higher to be considered low-vision. The first group included all individuals with normal and near normal vision (n = 122), and the second group included those with moderate, severe, and profound visual impairment (n = 118). For statistical purposes, this grouping provided two groups of near equal size and served as the independent variable for this study.

Because there was some concern that the independent variable as described above did not adequately measure the extreme differences along the continuum of visual acuity, a second grouping method was employed for purposes of additional analysis. This second grouping method restricted the sample to only those who either reported as having perfect vision versus those with severe or profound visual impairment. For this second grouping variable, the first group included all individuals with normal vision (n = 70), and the second group included those with severe and profound visual impairment (n = 75).

Scale Construction

For purposes of analysis, multiple constructs required robust measurement. This was achieved through the construction of the following six scalar measures: Contrast Level Importance Scale; High Contrast Importance Scale; Medium Contrast Importance Scale; Low Contrast Importance Scale; High Contrast Behavioral Reaction Scale; and Low Contrast Behavioral Reaction Scale. The Contrast Level Importance Scale can be found in Table 10a and Table 10b.

Table 10a. Survey Scale Composition

Contrast Level Importance Scale	
Q6	Please evaluate the importance of these aspects for you in the interior environment. Contrast levels within the interior environment is an important issue for a person with your level of vision.
Q7	Please evaluate the importance of these aspects for you in the interior environment. Contrast levels between wall and floor finishes is an important issue for a person with your level of vision.
Q11	Please evaluate the importance of these aspects for you in the interior environment. Contrast levels between floor finish materials at flooring transitions are an important issue for people with your level of vision.
Q15	Please evaluate the importance of these aspects for you in the interior environment. The contrast level of base materials from wall and floor finishes are an important issue for people with your level of vision.
Q19	Please evaluate the importance of these aspects for you in the interior environment. Contrast levels within a floor finish pattern is an important issue for people with your level of vision.
Q23	Please evaluate the importance of these aspects in affecting the behavior of people with your level of vision. Contrast levels within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Contrast Level Importance Scale	
High Contrast Importance Scale	
Q8	Please evaluate the importance of these aspects for you in the interior environment. High contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q12	Please evaluate the importance of these aspects for you in the interior environment. High contrast at flooring transitions is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q16	Please evaluate the importance of these aspects for you in the interior environment For people with low-vision. High contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q20	Please evaluate the importance of these aspects for you in the interior environment. High contrast within a floor finish pattern are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.
Q24	Please evaluate the importance of these aspects in affecting the behavior of people with your level of vision. High contrast within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Contrast Level Importance Scale	
Medium Contrast Importance Scale	
Q9	Please evaluate the importance of these aspects for you in the interior environment. Medium contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q13	Please evaluate the importance of these aspects for you in the interior environment. Medium contrast at flooring transitions is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q17	Please evaluate the importance of these aspects for you in the interior environment. Medium contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q21	Please evaluate the importance of these aspects for you in the interior environment. Medium contrast within a floor finish pattern are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.
Q25	Please evaluate the importance of these aspects in affecting the behavior of people with your level of vision. Medium contrast within the interior environment can

Contrast Level Importance Scale	
	affect the level in which people with your level of vision are willing to participate in that environment.
Low Contrast Importance Scale	
Q10	Please evaluate the importance of these aspects for you in the interior environment. Low contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q14	Please evaluate the importance of these aspects for you in the interior environment. Low contrast at flooring transitions is helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q18	Please evaluate the importance of these aspects for you in the interior environment. Low contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.
Q22	Please evaluate the importance of these aspects for you in the interior environment. Low contrast within a floor finish pattern are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.
Q26	Please evaluate the importance of these aspects for you in the interior environment. Low contrast within the interior environment can affect the level in which people with your level of vision are willing to participate in that

Contrast Level Importance Scale	
	environment.
High Contrast Behavioral Reaction Scale	
Q27	Please indicate whether you have exhibited the following behaviors in response to high levels of contrast in the interior environment. Blinking eyes in an attempt to understand the interior environment.
Q28	Please indicate whether you have exhibited the following behaviors in response to high levels of contrast in the interior environment. Slowing your pace while walking in an attempt to understand the interior environment.
Q29	Please indicate whether you have exhibited the following behaviors in response to high levels of contrast in the interior environment. Stopping to touch the wall while walking in an attempt to understand the interior environment.
Q30	Please indicate whether you have exhibited the following behaviors in response to high levels of contrast in the interior environment. Stopping to ask for assistance or a guide while attempting to navigate the built environment.
Q31	Please indicate whether you have exhibited the following behaviors in response to high levels of contrast in the interior environment. Pressing or poking eyes while attempting to understand the built environment.
Low Contrast Behavioral Reaction Scale	
Q32	Please indicate whether you have exhibited the following behaviors in response

Contrast Level Importance Scale	
	to low levels of contrast in the interior environment. Blinking eyes in an attempt to understand the interior environment.
Q33	Please indicate whether you have exhibited the following behaviors in response to low levels of contrast in the interior environment. Slowing your pace while walking in an attempt to understand the interior environment.
Q34	Please indicate whether you have exhibited the following behaviors in response to low levels of contrast in the interior environment. Stopping to touch the wall while walking in an attempt to understand the interior environment.
Q35	Please indicate whether you have exhibited the following behaviors in response to low levels of contrast in the interior environment. Stopping to ask for assistance or a guide while attempting to navigate the built environment.
Q36	Please indicate whether you have exhibited the following behaviors in response to low levels of contrast in the interior environment. Pressing or poking eyes while attempting to understand the built environment.

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Table 10b. Light Wall Environmental Ranked "Hardest to see and accurately perceive the interior environment"

Normal Sighted	Environment A	Environment B	Environment C
Count	11	3	3
Percent within Grouping	64.7%	17.6%	17.6%
Visually Impaired			
Count	7	2	8
Percent within Grouping	41.2%	11.8%	47.1%
All Partipants Combined			
Count	18	5	11
Percent within Grouping	52.9%	14.7%	32.4%

The construction of all scales was based on the face validity of the items being grouped. To statistically validate the scalar measures, a test of internal consistency was conducted for each scale. These tests yielded Cronbach's alpha values that were sufficiently high, such that all six scales are considered reliable (See Table 11).

Table 11. Tests of Internal Consistency for Scalar Measures

Scale	α
Contrast Level Importance Scale	.84
High Contrast Importance Scale	.78
Medium Contrast Importance Scale	.69
Low Contrast Importance Scale	.74
High Contrast Behavioral Reaction Scale	.78
Low Contrast Behavioral Reaction Scale	.78

The resulting scores on the six scalar measures exhibited normal or near normal distributions. Measures of central tendency and variation for the six scales are outlined in Table 12.

Table 12. Descriptive Statistics for the Scalar Measures

Scale	Min	Max	*M*	*SD*
Contrast Level Importance Scale	6	30	22.3	4.9
High Contrast Importance Scale	5	25	19.1	4.0
Medium Contrast Importance Scale	5	25	17.3	3.4
Low Contrast Importance Scale	5	25	14.4	4.1
High Contrast Behavioral Reaction Scale	5	25	14.9	4.8
Low Contrast Behavioral Reaction Scale	5	25	16.0	4.8

Test of Statistically Significant Differences Between Groups

Full Sample Comparisons (Grouping Method I)

To determine whether there were differences between the two groups with regard to their preferences for, and behavioural reactions to, environments with varying degrees of contrast, independent-Sample T Tests were conducted for each scalar measure with the first independent variable that included all participants (n = 240). Statistically significant differences between the normal-sighted and visually impaired groups were found for three of the six scalar measures. For the Contrast Level Importance Scale there was a statistically significant difference in scores for the participants with visual impairments (M = 23.5 ± 4.9) and normal sighted (M = 21.2± 4.5) participants; t (238) = -3.80, p = 0.00. For the High Contrast Importance Scale there was a statistically significant difference in scores for participants with visual impairments (M = 20.0± 4.1) and normal sighted (M =± 3.8) participants participant; t (238) = -3.31, p = 0.00. These results indicate that participants that were visually impaired participant rated high contrast environments as having greater importance for their ability to accurately perceive the interior environment. For the Low Contrast Importance Scale there was a statistically significant difference in scores for the participants with visual impairments (M = 13.4± 4.3) and normal sighted (M = 15.3± 3.7) participants; t (238) = 3.73, p = 0.00. These results indicate that normal-sighted participants rated low-contrast environments as having greater importance for their ability to accurately perceive the interior environment. The other three scalar measures did not yield statistically significant differences for the two groups, as seen in Tables 14 through 18.

Table 14. Test Statistics for the Behavioural Reactions to Differing Environmental Contrast Levels Grouping Method I

High Contrast	*n*	*M*	*SD*	*t*	*df*	*p*
Normal-Sighted	17	.06	.24	-1.87	32	0.07
Visually Impaired	17	.53	1.01			
Medium Contrast						
Normal-Sighted	17	.35	.70	-1.76	32	0.09
Visually Impaired	17	1.35	2.23			
Low Contrast						
Normal-Sighted	17	.24	.752	-1.414	32	0.17
Visually Impaired	17	.76	1.348			

Partial Sample Comparisons (Grouping Method II)

Additional Independent-Sample T Tests were conducted for each scalar measure with the second independent variable that included only those participants with perfect vision versus those with severe and profound visual impairment (n = 145). Statistically significant differences between these two groups were found for four of the six scalar measures. For the Contrast Level Importance Scale there was a statistically significant difference in scores for the participants with severe/profound visual impairments (M = 24.2± 4.7) and the participants with normal sight (M = 20.3± 4.6); t (143) = -5.03, p = 0.00. These results indicate that those with visual impairments attributed a higher level of importance to contrast level, on average, than those with normal-sight. For the High Contrast Importance Scale there was a statistically significant difference in scores for the participants with severe/profound visual impairments ($M = 20.4 \pm 4.1$) and participants with normal sight ($M = 17.8 \pm 4.0$); $t(143) = -3.90$, $p = 0.00$. These results indicate that participants with visual impairments rated high contrast environments as having greater importance for their ability to accurately perceive the interior environment. For the Low Contrast Importance Scale there was a statistically significant difference in scores for the participants with severe/profound visual impairments ($M = 12.7 \pm 3.9$) and participants with normal sight ($M = 15.6 \pm 3.4$); $t(143) = 4.77$, $p = 0.00$. These results indicate that normal-sighted participants rated low-contrast environments as having greater importance for their ability to accurately perceive the interior environment. For the Low Contrast Behavioral Reaction Scale there was a statistically significant difference in mean scores for the participants with severe/profound visual impairments ($M = 16.8 \pm 4.3$) and participants with normal sight ($M = 14.8 \pm 5.0$); $t(142) = -2.57$, $p = 0.01$. These results indicate that participants with severe/profound visual impairments reported a higher number of behavioural reactions to low-contrast environments than did normal-sighted participants. The other two scalar measures did not yield statistically significant differences for the two groups, as indicated in Figs. 15 and 16.

Phase II Analysis and Results

Participant Demographics

A total of 34 people participated in Phase II of the study, of which 17 self-reported as low-vision and 17 self-reported as normal-sighted. 68% of participants were female, while 32% were male. The ages of the participants were reported as falling in the following groups: 18-25 (n = 3); 26-35 (n = 4); 36-45 (n = 6); 46-55 (n = 1); 56-65 (n = 7); 65-75 (n = 7); 76 and older (n = 5); and Prefer not to answer (n = 1). The racial composition of the participants was comprised of 88.2% Caucasian/White and 11.8% African American/Black.

Comparison Groups

For the purposes of analyzing the observational data, the same grouping methods as those used with the survey data were employed. Responses to Q4 provided the requisite information to divide the sample into two groups, normal-sighted and low-vision. The two groups were of equal size (n = 17), though the second grouping was restricted to sample only those who responded with near-perfect vision.

Behavioral Response Tabulations

Behavioural observations of participants' reactions to the three environmental contrast levels were tabulated. This was achieved through summing the total number of observed behavioural reactions to the three environmental contrast levels: Total Behavioral Reactions to High Contrast Environments; Total Behavioral Reactions to Medium Contrast Environments; and Total Behavioral Reactions to Low Contrast Levels. See Table 13 below.

Table 13. Beahvioral Response Tabulations

Total Behavorial Reactions to High Contrast Environments	Total Count
Normal-sighted	1
Visually Impaired	9
Total Behavorial Reactions to Medium Contrast Environments	
Normal-sighted	6
Visually Impaired	23
Total Behavioural Reactions to Low Contrast Environments	
Normal-sighted	4
Visually Impaired	13

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Test of Statistically Significant Differences Between Groups

Full Sample Comparisons (Grouping Method I)

To determine whether there were differences between the two groups of participants with regard to the mean number of observations recorded, Independent-Sample T Tests were conducted for each environmental contrast level. No statistically significant differences were found between the two groups on any of the environmental contrast levels (See Table 15). The results of the Independent Sample T tests and descriptive statistics for the three environmental contrast levels are outlined in Table 14.

Table 15. Test Statistics for the Behavioral Reactions to Differing Environmental Contrast Levels Grouping Method II

High Contrast	*n*	*M*	*SD*	*t*	*df*	*p*
Normal-Sighted	10	.00	.00	-2.31	16	0.04
Severe/Profound Impairment	8	.38	.52			
Medium Contrast						
Normal-Sighted	10	.00	.00	-2.39	16	0.03
Severe/Profound Impairment	8	2.00	2.7			
Low Contrast						
Normal-Sighted	10	.00	.00	-2.52	16	0.02
Severe/Profound Impairment	8	1.25	1.6			

Partial Sample Comparisons (Grouping Method II)

For the second grouping method of the independent variable, additional Independent-Sample T Tests were conducted for each of the three environmental contrast levels. Statistically significant differences were found across all three contrast levels (See Table 15).

Preference for Environmental Contrast Levels

Light wall environmental contrast preferences

Study environments A, B, & C were ranked by participants while wearing virtual reality goggles. Participants identified the environment which they could see best in, and the environment which was hardest to see in. Environment A (Fig. 4) was preferred by 23.5% of overall participants; 11.8% of normal-sighted participants, and 35.5% of low-vision participants. Environment B (Fig. 5) was the selected by 26.5% of overall participants; 35.3% of normal-sighted participants, and 17.6% of low-vision participants. Environment C (Fig. 6) was preferred by 52.9% of normal-sighted participants and 47.1% of low-vision particpants.

Study Environment A (Fig. 4) was selected as the hardest environment to see in by 64.7% of normal-sighted participants, while Study Environment C (Fig. 6) was identified as the hardest to see in by 47.1% of participants with low vision. Study Environment A (Fig. 4) was identified as the hardest environment to see in by 52.9% of all participants.

Medium wall environmental contrast preferences

Study environments D, E, & F were ranked by participants while wearing virtual reality goggles. Participants identified the environment which they could see best in, and the environment which was hardest to see in Environment D (Fig. 7) was preferred by 38.2% overall; 23.5% of normal-sighted participants, and 52.9% of low-vision participants. Environment E (Fig. 8) was preferred by 14.7% overall; 17.6% of normal-sighted participants, and 11.8% of low-vision participants. Environment F (Fig. 9) was preferred by 47.1% overall; 58.8% of normal-sighted participants and 35.3% of low-vision participants.

Study Environment D (Fig. 7) was selected as the hardest environment to see in by 58.8% of normal-sighted participants, while Study Environment F (Fig. 9) was identified as the hardest to see in by 52.9% of low-vision participants.

Study Environment D (Fig.7) was identified as the hardest environment to see in by 44.1% of all participants; see Table 17.

Table 17. Medium Wall Environment Ranked "Hardest to see and accurately perceive the interior environment"

Normal Sighted	*Environment D*	*Environment E*	*Environment F*
Count	10	4	3
Percent within Grouping	58.8%	23.5%	17.6%
Visually Impaired			
Count	5	3	9
Percent within Grouping	29.4%	17.6%	52.9%
All Participants Combined			
Count	15	7	12
Percent within Grouping	44.1%	20.6%	35.3%

Dark wall environmental contrast preferences

Study environments G, H, & I were ranked by participants while wearing virtual reality goggles. Environment G (Fig.10) was preferred by 52.9% overall; 52.9% of normal-sighted particpants, and 52.9% of low-vision participants. Environment H (Fig. 11) was the preferred environment by 23.5% of normal-sighted participants, and 11.8% of low-vision participants. Envrionment F (Fig. 9) was preferred by 23.5% of normal-sighted participants and 35.3% of low-vision participants.

Study Environment I (Fig. 12) was selected as the hardest environment to see in by 41.2% of normal-sighted participants and 52.9% of low-vision participants. Study Environment I (Fig. 12) was identified as the hardest environment to see in by 47.1% of all participants. See Table 18 below.

Table 18. Dark Wall Environment Ranked "Hardest to see and accurately perceive the interior environment"

Normal Sighted	*Environment G*	*Environment H*	*Environment I*
Count	4	6	7
Percent within Grouping	23.5%	35.3%	41.2%
Visually Impaired			
Count	5	3	9
Percent within Grouping	29.4%	17.6%	52.9%
All Partipants Combined			
Count	9	7	16
Percent within Grouping	26.5%	26.5%	47.1

Overall environmental contrast preference

Participants were asked to identify the environment that was easiest for them to see in and accurately perceive the interior environment while wearing virtual reality goggles. Environment A (Fig. 4) was the most preferred by 29.4% normal-vision participants and 35.3% of low-vision participants.

Discussion

This study investigated the preferred level of contrast between floor and wall finishes within a space for both normal-sighted and low-vision participants. The findings suggest a high contrast. However, designers should be careful when specifying dark floor colours, as they may cause people with low vision to have anxiety towards walking on those floors. This validates a study conducted by Hughes et al. (2018).

This study also investigated the effect of contrast levels within the interior environment on a person's behavior within that environment. Participants with severe/profound vision loss exhibited a higher number of behavioural reactions to contrast levels within the interior environment than normal-sighted participants who exhibited no behavioural reactions. Low-vision participants exhibited the highest number of behavioural reactions in medium-contrast environments and the lowest number of behavioural reactions in high-contrast environments. Therefore, high-contrast environments proved to be the easiest to navigate while triggering the least number of behavioural reactions to contrast levels within the environment.

The knowledge gained through this study should be used to educate designers on the importance of designing environments with high levels of contrast between the wall and floor surfaces for purposes of navigation, as it is important for people of all visual abilities, especially for people with low vision.

Contrast Level Preferences: Phase I interpretations

For the Contrast Level Importance Scale there was a statistically significant difference in scores for the severely/profoundly visually impaired under Grouping Methods I and II. The results indicate that low-vision participants attributed a higher level of importance to contrast level, on average, than normal-sighted participants.

For the Low Contrast Importance Scale there was a statistically significant difference in scores for the participants with severe/profoundly visual impairments under Grouping Methods I and II. The results indicate that normal-sighted participants rated high contrast environments as having greater importance for their ability to accurately perceive the interior environment.

Contrast Level Preferences: Phase II Interpretations

The Phase II Observations results reveal that both normal-sighted and low-vision participants reported high contrast environments to be more helpful in their ability to accurately perceive the interior environment. This observation will allow future designers to create better spaces for study and concentration, while also considering those with and without visual impairments.

Environments with Light Colored Walls

Participants were asked to identify the environment that was easiest for them to see in and accurately perceive the interior environment while wearing virtual reality goggles. Overall, participants selected Environment C (Fig. 6), a high-contrast environment, as their preferred environment. Overall, participants reported Environment A (Fig. 4), a low contrast environment, as the hardest environment to see in. Some low-vision participants reported Environment C as the hardest environment to see in, stating that they are uncomfortable walking in rooms with very dark floors. These supported observations made by Hughes, Carroll, and Miller (2018).

Environments with Medium Colored Walls

Participants with normal-sight and visual impairments did not agree on a preferred environment. Normal-sighted participants selected Environment F (medium grey wall with dark grey floor), a medium contrast environment, as their preferred environment, while low-vision participants selected Environment D (medium grey wall, light grey floor), also a medium contrast environment, as their preferred floor. The same was true of the environments ranked hardest to see in. Normal-sighted participants reported Environment D (medium grey wall and light grey floor), a medium contrast environment, as the hardest environment to see in, while low-vision participants reported Environment F (medium grey wall with dark grey floor), a medium contrast environment, as the hardest environment to see in. Low-vision participants reported a preference for lighter floors and restated their unease of walking in rooms with very dark floors.

Environments with Dark Colored Walls

Overall, participants agreed Environment G (Fig. 10), a high-contrast environment, was their preferred environment. The participants also agreed that Environment I (Fig. 12), a low-contrast environment, was hardest to see in. Low-vision participants reported a preference for lighter floors and restated their unease of walking in rooms with very dark floors.

Behavior and Contrast

Phase I Interpretations

For the Low Contrast Behavioral Reaction Scale there was a statistically significant difference in mean scores for the participants with severe/profound visual impairment when Grouping Method II was employed. The results indicate that participants with severe/profound visual impairments reported a higher number of behavioural reactions to low-contrast environments than normal-sighted participants. The High Contrast Behavioral Reaction Scale did not yield statistically significant differences between low-vision and severe/profound visual impairments.

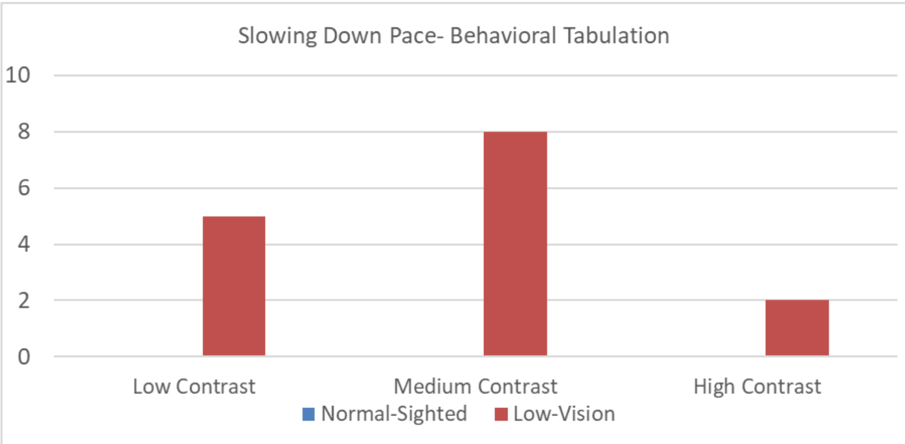
Phase II Interpretations

A statistically significant difference between mean scores for the participants with severe/profound visual impariments and those with normal-sight were found across all contrast levels when Grouping Method II was employed. The results indicate that participants with severe/profound vision exhibited a higher number of behavioural reactions to environments of all contrasts than normal-sighted participants. The mean scores suggest that low-vision participants exhibited the highest number of behavioural reactions in a medium-contrast environment and the lowest number of behavioural reactions in high-contrast environments.

Of the six studied behaviours, only three were exhibited by participants during the observations. These three observed behaviours included: Slowing down the pace while walking, Touching or reaching to touch the wall, and asking for assistance or guidance. Slowing down the pace while walking was exhibited a total of 15 times by low-vision participants, but was not exhibited by any normal-sighted participants. The environments in which low-vision participants exhibited the slowing down pace behaviour are broken down by the following environmental contrast levels: Low – 5; Medium – 8; and High – 2.

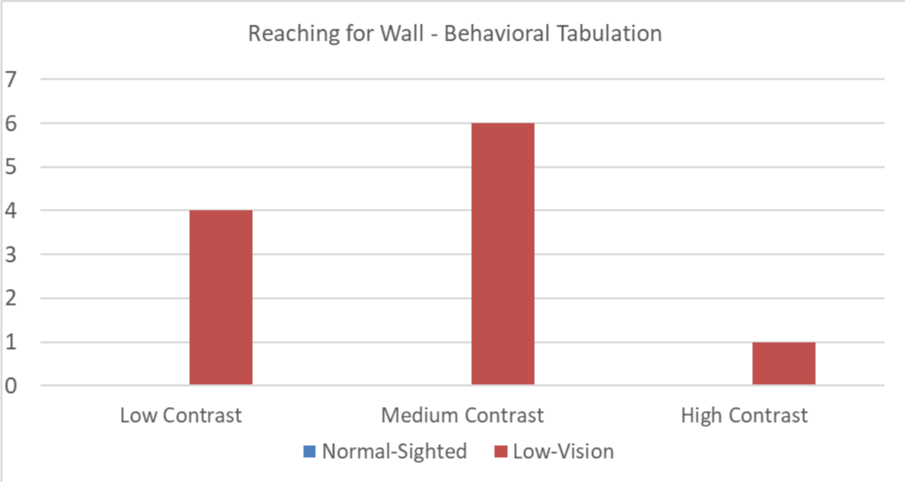
Slowing down the pace while walking was exhibited a total of 15 times by low-vision participants, but was not exhibited by any normal-sighted participants. The environments in which low-vision participants exhibited the slowing down pace behaviour are broken down by the following environmental contrast levels: Low – 5; Medium – 8; andHigh – 2. The results indicate that this behaviour is exhibited more times on average in medium-contrast environments than in low or high-contrast environments. Raising the level of contrast in a room may decrease the number of times this behaviour will be exhibited by people with low vision. See Figure 15 below.

Figure 15. Illustrates participant's slowing down pace.



Reaching for or touching the wall while walking was exhibited a total of 11 times by low-vision participants, but was not exhibited by any normal-sighted participants. The environments in which low-vision participants exhibited the reaching for or touching wall behaviour are broken down by the following environmental contrast levels: Low – 4; Medium – 6; and High – 1. The results indicate that this behaviour is exhibited more times on average in medium-contrast environments than in low or high-contrast environments. Raising the level of contrast in a room may decrease the number of times this behaviour will be exhibited by people with low vision. See Figure 16 below.

Figure 16. Illustrates participant's reaching for wall frequencies.



Asking for assistance while navigating was exhibited a total of two times by low-vision participants, but was not exhibited by any normal-sighted participants. The environments in which low-vision participants asked for assistance are broken down by the following environmental contrast levels: Low – 1; Medium – 1; and High – 0. The results indicate that while this behaviour was exhibited in low and medium-contrast environments, the small frequency of exhibited behaviours prohibits the researcher from directly linking this behaviour to the contrast level within the environment.

Limitations of the Study

Research Type

While the quantitative research design gave the researcher access to a large quantity of data, the addition of qualitative interviews may have helped to provide additional explanations for why normal-sighted and low-vision participants preferred different environments.

Site Locations and Number of Observations

While the study was conducted at three different sites, it would be beneficial to expand the geographical location of the study sites to reach a larger number of low-vision and normal-sighted participants. Increasing the number of observations would give more valuable data for analysis and expand the types of analysis that could be done.

Behaviours and Sample Size

The number of observations performed needs to be increased greatly in order to fully evaluate the behaviours exhibited within the environment on an individual basis. Because of the small number of low-vision participants (n = 17) and even smaller number of severe/profound low-vision visual acuity (n = 8), the number of observed behaviours was small, even though it was statistically different from the low-vision participants. The small sample size limited the analysis. A chi square test could not be performed on the behavioural reaction dataset because of the small sample size.

Behaviours and Virtual Reality Equipment

The inclusion of virtual reality equipment in this research project offered many benefits, but it did limit the researcher's ability to observe some studied behaviours. The HTC Vive Pro reality headset did not include the appropriate eye-tracking software to detect the first desired behaviour, rapid eye blinking. Therefore, this behaviour was not studied as part of this research.

Virtual Reality Observations

While the use of virtual reality equipment did allow the researcher to investigate many different finish combinations within the same interior environment while maintaining control over external factors associated with multiple study site locations, it is important to recognize that a virtual reality environment may not accurately emulate a real-world environment. The results of the study may not apply directly to the design of an actual interior environment.

Order Effect

The order each study environment was presented in was consistent from start to finish across all participants. This may explain why after viewing all nine study environments, the highest percentage of participants selected Study Environment A (light grey wall and light grey floor) as their preferred environment. This was inconsistent with the preference shown for high environmental contrast when evaluating three study environments grouped by wall colour at a time. The researcher suspects that this was a result of Study Environment A being the first environment seen after the least preferred environment, Study Environment I (dark wall, dark floor) was shown.

Conclusion

Future Studies

Future studies should be conducted to investigate the role of contrast between floor materials where transitions occur, and the role of contrast within flooring patterns and specifically carpet patterns. Are certain patterns more helpful? Are certain patterns less distracting? Are contrast levels within the patterns helpful or distracting? All of these questions are yet to be answered through empirical research.

While the findings of this study are compelling, they leave room for future investigation. A future study utilizing a higher number of participants and a more complex virtual reality environment could expand upon the connection of specific behaviour types and contrast levels of the environment.

Closing Statement

While the results of this body of research confirm the importance of designing an interior environment with high contrast between the wall and floor surfaces and links behavioural reactions to medium and low-contrast environments, there is still a gap in the body of knowledge regarding contrast in the interior environment and its effect on the low-vision population. More empirical research is needed within an environmental setting to investigate the role that contrast plays within the interior environment on both the normal-sighted and low-vision populations.

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Appendix A: Survey Instrument

Demographic Information

1. What is your age?

    - 18-25
    - 26-35
    - 36-45
    - 46-55
    - 56-65
    - 66-75
    - 76 or older

2. What is your gender?

    - Male
    - Female
    - Prefer not to answer

3. What race do you most closely identify yourself with?

    - Caucasian/White
    - African American
    - American Indian
    - Hispanic
    - Other

4. How would you identify your level of visual impairment?

    - Near normal (20/30 – 20/70)
    - Moderate (20/80 – 20/160)
    - Severe (20/160- 20/400)
    - Profound (20/400 – 20/1000)

5. What is your low-vision diagnosis?

    - Diabetic Retinopathy
    - Temporal Arteritis
    - Corneal Transplant
    - Optic Neuritis

- Optic Nerve Hypoplasia or Nystagmus
- Central areolar choroidal dystrophy
- Coloboma or glaucoma
- Myopic Macular Degeneration
- Age-related Macular Degeneration
- Other, please identify:

  ____

Q6. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

a. Contrast levels within the interior environment is an important issue for people with your level of vision.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q7. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

b. Contrast levels between wall and floor finishes is an important issue for people with your level of vision.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with high contrast between wall and floor

Q8. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

c. High contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with medium contrast between wall and floor colors

Q9. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

d. Medium contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with low contrast between wall and floor colors

Q10. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

e. Low contrast between wall and floor finishes is helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q11. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

f. Contrast levels between floor finish materials at flooring transitions are an important issue for people with your level of vision.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with high contrast at flooring transition

Q12. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

g. High contrast at flooring transitions is helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

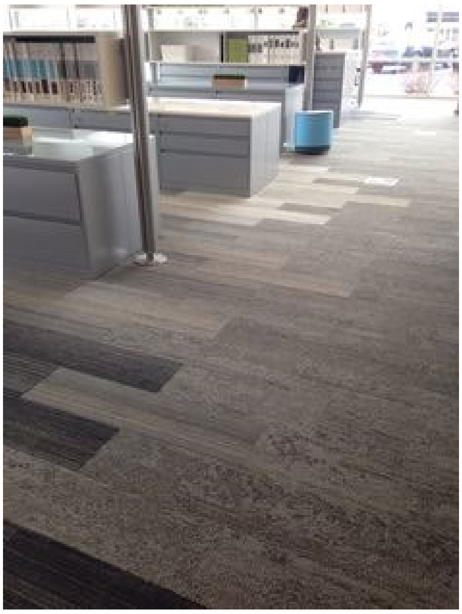

Image: Space with medium contrast at flooring transition

Q13. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

h. Medium contrast at flooring transitions is helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with low contrast at flooring transition

Q14. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

i. Low contrast at flooring transitions is helpful in aiding a person your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q15. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

j. Contrast level of base materials from wall and floor finishes are an important issue for people with your level of vision.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with high contrast of base materials from wall and floor finishes

Q16. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

k. High contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with medium contrast of base materials from wall and floor finishes

Q17. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

l. Medium contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with low contrast of base materials from wall and floor finishes

Q18. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

Q19. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

m. Low contrast of base materials from wall and floor finishes are helpful in aiding a person with your level of vision to accurately perceive the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q20. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

n. Contrast levels within a floor finish pattern is an important issue for people with your level of vision.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

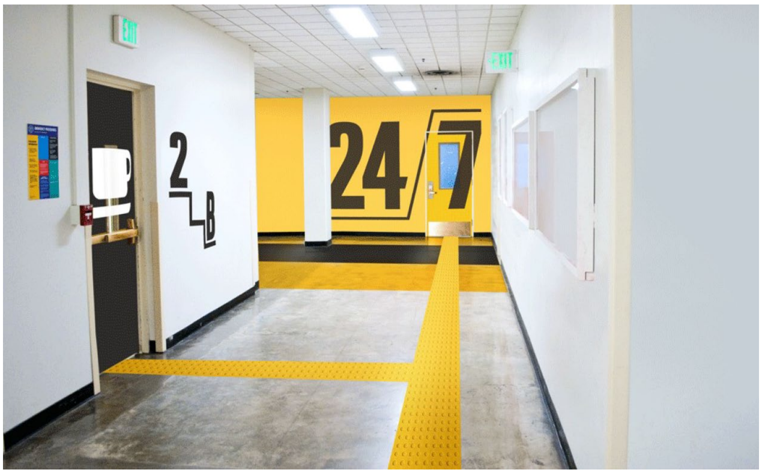

Image: Space with high contrast within floor finish pattern

Q21. Please evaluate the importance of these aspects of the interior environment for people with low vision.

o. High contrast within a floor finish patterns are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Image: Space with medium contrast within floor finish pattern

Q22. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

p. Medium contrast within a floor finish patterns are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

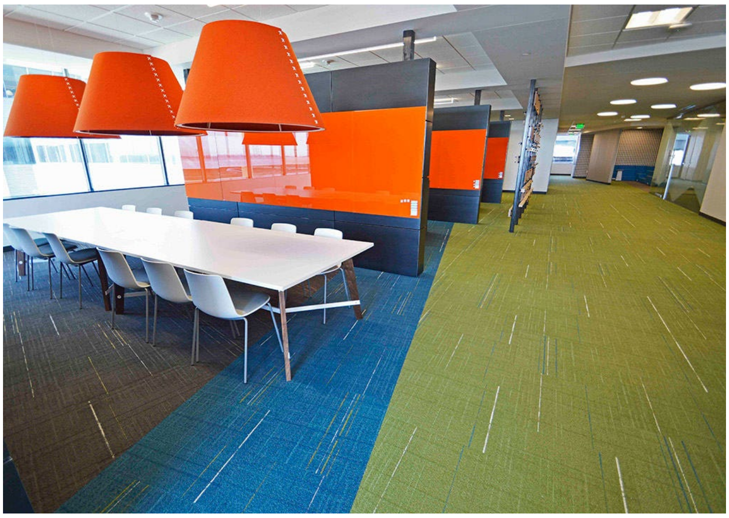

Image: Space with low contrast within floor finish pattern

Q23. Please evaluate the importance of these aspects of the interior environment for people with low-vision.

q. Low contrast within a floor finish pattern are helpful in aiding a person with your level of vision to accurately perceive the interior environment and aide in navigation.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q24. Please evaluate the importance of these aspects in affecting the behaviour of people with your level of vision.

a. Contrast levels within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q25. Please evaluate the importance of these aspects in affecting the behaviour of people with your level of vision.

b. High contrast within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q26. Please evaluate the importance of these aspects in affecting the behaviour of people with your level of vision.

c. Medium contrast within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q27. Please evaluate the importance of these aspects in affecting the behaviour of people with your level of vision.

d. Low contrast within the interior environment can affect the level in which people with your level of vision are willing to participate in that environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q28. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

a. Blinking eyes in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q29. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

b. Slowing your pace while walking in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q30. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

c. Stopping to touch the wall while walking in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q31. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

d. Stopping to ask for assistance or a guide while attempting to navigate the built environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q32. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

e. Pressing or poking eyes while attempting to understand the built environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q33. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

Q34. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

a. Blinking eyes in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q34. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

b. Slowing your pace while walking in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q35. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

c. Stopping to touch the wall while walking in an attempt to understand the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q36. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

d. Stopping to ask for assistance or a guide while attempting to navigate the built environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q37. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

e. Pressing or poking eyes while attempting to understand the built environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

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Q38. Please indicate whether you have exhibited the following behaviours in response to **low levels of contrast** in the interior environment.

f. Avoided a space due to lack of contrast in the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q39. Please indicate whether you have exhibited the following behaviours in response to **high levels of contrast** in the interior environment.

g. Avoided a space due to too much contrast in the interior environment.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1	2	3	4	5

Q40. Please provide an answer to the following questions.

a. What types of behaviors have you exhibited due to contrast levels in the interior environment?

Appendix B: Behavioural Observation Form

Participant #:

Observer:

A) Behaviours Observed:

B) Blinking Eyes

C) Slow down

D) Reaching for/touching the wall

E) Stopping to ask for assistance

Avoid/leave the space Behaviour Observed	Environment/ Level of Contrast	Number of Occurrences	Totals
A – Rapidly Blinking Eyes	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall-Comment** A. B. C.	**1. Light** A. B. C.
A – Rapidly Blinking Eyes	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.

Avoid/leave the space Behaviour Observed	Environment/ Level of Contrast	Number of Occurrences	Totals
A – Rapidly Blinking Eyes	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.
B- Slow Down Pace	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall- Comments** A. B. C.	**1. Light** A. B. C.
B- Slow Down Pace	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.
B- Slow Down Pace	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.

Avoid/leave the space Behaviour Observed	Environment/ Level of Contrast	Number of Occurrences	Totals
C -Touch the Wall	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall-Comments** A. B. C.	**1. Light** A. B. C.
C -Touch the Wall	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.
C -Touch the Wall	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.
D - Ask for assistance	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall-Comments** A. B. C.	**1. Light** A. B. C.

Avoid/leave the space Behaviour Observed	Environment/ Level of Contrast	Number of Occurrences	Totals
D - Ask for assistance	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.
D - Ask for assistance	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.
E - Avoid/Leave	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall-Comments** A. B. C.	**1. Light** A. B. C.
E - Avoid/Leave	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.

Avoid/leave the space Behaviour Observed	Environment/ Level of Contrast	Number of Occurrences	Totals
E - Avoid/Leave	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.
F- Poke or Press Eyes	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor	**1. Light Wall-Comments** A. B. C.	**1. Light** A. B. C.
F- Poke or Press Eyes	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.
F- Poke or Press Eyes	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor I. Dark Wall/ Dark Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.

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Appendix C: Study Environment Rankings Form

Participant #:

Observer:

Preferred Contrast Levels:	**Wall/Floor Conditions**	**Participant Comments**	**Preference Rankings**
Rank each study environment in order of preference with 1 being the most preferred and 3 being the least preferred.	**1. Light Wall** A. Light Wall/ Light Floor B. Light Wall/ Medium Floor C. Light Wall/Dark Floor I. Dark Wall/ Dark Floor	**1. Light Wall- Comments** A. B. C.	**1. Light** A. B. C.
Rank each study environment in order of preference with 1 being the most preferred and 3 being the least preferred.	**2. Medium Wall** D. Medium Wall/Light Floor E. Medium Wall/ Medium Floor F. Medium Wall/Dark Floor	**2. Medium Wall** D. E. F.	**2. Medium** D. E. F.

Preferred Contrast Levels:	Wall/Floor Conditions	Participant Comments	Preference Rankings
Rank each study environment in order of preference with 1 being the most preferred and 3 being the least preferred.	**3. Dark Wall** G. Dark Wall/Light Floor H. Dark Wall/ Medium Floor	**3. Dark Wall** G. H. I.	**3. Dark** G. H. I.

UNIVERSAL DESIGN APPROACH TO ANALYSIS OF PHYSICAL ENVIRONMENT FOR USERS WITH MULTIPLE SCLEROSIS

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***Abstract*:** The concept of Universal Design aims for the utilization of every product and environment for every individual without the need for further adaptation. The frequent occurrence of Multiple Sclerosis (MS) in societies has necessitated a more innovative and exploratory approach to the field of design. Many of the products and built environments encountered by individuals with MS in their daily lives fall short in terms of meeting safety and accessibility needs. It is essential to establish the correct design approach so that users with MS can meet their needs easily and safely without depending on others. In this research, the problems encountered by users with MS in their residences were evaluated within the framework of Universal Design principles, and design recommendations were stated using a sample case in Turkey. Throughout the study, accessibility challenges, mobility, fatigue and balance problems, vision and lighting conditions, climatization and noise sensitivity, and psychological issues were primarily considered. The residence of the sample user with MS was examined in detail, and an in-depth interview was conducted during the research. The difficulties and life routines of the user with MS were observed and identified. Home design solutions associated with Universal Design principles were represented so that the users with MS have safe and accessible housing regarding their physiological and psychological conditions. The highlighted proposals may contribute to architectural design to make modifications for comfortable and safe housing in related cases having similar symptoms with MS. Future research can benefit from these findings and proposals to provide innovative approaches, develop policies, and conduct interdisciplinary studies on related design issues.

Keywords: Universal Design, Multiple Sclerosis, MS, home design, accessibility

Introduction

Any item and equipment we utilize in our daily lives and any place we spend time in have to meet the physical standards of safety and health. It should be ensured that all kinds of actions and activities in our daily life are carried out without risk and any danger to ourselves or other individuals. When taking into consideration the liberty of individuals to access all designs under equal and fair conditions, Universal Design Approach acts as a salient guide. This guidance substantiates to be even more important when users of the products range in terms of physical features and age.

Practical studies are carried out to reinforce and adopt the concept of Universal Design and to support it as a guide in daily life. Denizou (2016) conducted a study about the approach of the design team and the use of the regulatory framework to create better homes in Norway and develop dwellings with innovative and functional solutions. Universal Design was taken as a tool and a method in the study to improve housing quality and usability considering the needs of various resident groups. Mattie, Borisoff, Wong & Miller (2016) evaluated user perspectives of existing home access solutions and an experimental device used in their research. Participants were chosen from different age groups with mobility limitations. Their study was held to investigate user needs which were necessary for designers and researchers. An initiative of Rebuilding Ireland and the Centre for Excellence in Universal Design had a call for ideas that demonstrated innovation in the design and delivery of solutions for adaptable and smart homes. One of the solution areas was the adaptation of existing houses to meet the needs of older people, and the winning project was an innovative solution aligned with a multi-faceted Universal Design approach. The initiative demonstrated that; by the Universal Design approach, innovative solutions can be found through diverse stakeholder collaboration that enable people of all ages, sizes, abilities, and disabilities to live and thrive in their own homes and communities (Rebuilding Ireland, 2017). Lantz & Fenn (2017) pointed out in their report that it was important to include Universal Design features in any new housing unit considering visitors of all ages and adaptation to changing needs of residents. Cho, MacLachlan, Clarke & Mannan (2016) searched the health and social effects of home environments for participants of all ages with physical or cognitive limitations. They observed that interventions to enhance the accessibility of homes have positive effects on health and social issues. They pointed the future research to be more specific about the types of functional limitations for different accessibility features related to mobility or cognitive impairments.

This study has been carried out to support other research in different disciplines to facilitate the daily lives of users with MS and raise awareness through the Universal Design approach. With the advances in diagnosis, more numbers of persons with MS are identified. Any design realized by adopting the Universal Design concept will serve the safety and needs of MS users. In this study based on the research of the physical environment of a user with MS, design proposals are developed in the residence as a daily living space.

Universal Design and User Characteristics

The concept of Universal Design is basically about enabling the use of design products or environments by all people without any adaptation or specialized design. Mace, Hardie & Place (1991) defines Universal Design as simply designing all products, buildings, and exterior spaces to be usable by all people to the greatest extent possible. The Universal Design approach aims to decrease the amount of negativity a person may encounter during lifetime either because of changes that take place in life or an unexpected disability. Universal Design Approach targets to create environments and products that provide equal use for all individuals regardless of their variable features. Universal Design considers the population as a whole with various human bodies with different abilities (Pritchard, 2014). Hence, the Universal Design approach is not a trend or a temporary approach but rather the means to ease living and provide user-friendly environments by designing within the framework of this approach.

Universal Design Concept and Approach

The Universal Design concept has historically emerged from the conditions of accessibility. In the 1990s, almost simultaneously, two designers R. Mace and S. Goldsmith who had both used wheelchairs; came up with the idea with a common perspective that it was time to consider designing for everyone. The accessibility concept was quite restricted in a world where variations were burgeoning. Principles regarding Universal Design were elucidated by different experts from North Carolina State University Universal Design Center and confirmed with copyright. The seven basic principles of Universal Design denominated a common understanding of products that everyone could use without the need to make adaptations or form a special design (IHDC, 2019). These principles can be applied to the evaluation of existing designs, the guidance of the design process, and training both designers and users on the features of the more usable product and the environment (The Center for Universal Design, 1997) (Table 1).

Table 1. The Seven Principles of Universal Design

No	Principles	Descriptions
1	Equitable use	The design is useful and marketable to people with diverse abilities
2	Flexibility in use	The design accommodates a wide range of individual preferences and abilities
3	Simple and Intuitive use	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills or current concentration level
4	Perceptible information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
5	Tolerance for error	The design minimizes hazards and the adverse consequences of accidental or unintended actions
6	Low physical effort	The design can be used efficiently and comfortably and with minimum fatigue
7	Size and space for approach and use	Appropriate size and space are provided for approach, reach, manipulation, and use regardless of the user's body size, posture, or mobility.

The products and environmental designs under these seven principles will be appropriate, safe, and user-friendly for a wide variety of user profiles. The demand for designs in accordance with Universal Design principles is inevitable for various permanent or temporary situations we encounter in our daily lives. The need for the Universal Design concept is not only for disadvantageous physical conditions such as congenital or acquired vision, hearing, and limb loss, but also for special conditions such as excessive weight gain, pregnancy, and old age. Every individual should be entitled to the accessibility of these products on equal terms, and this view should be supported in all relevant platforms.

In the guidebook of The Centre for Excellence in Universal Design (CEUD) established by the NDA in January 2007 under the Disability Act 2005 a part of the National Disability Authority (NDA), it is pointed out that there is a 60% chance that a new estate may be occupied by a person with a form of any disability. During their lives, people have changing needs at different stages. Homes built with Universal Design principles can adapt and change with the users. Flexibility and adaptation to changing needs have to be in cost-effective way. Sustainable design for comfort and energy efficiency and smart technologies for easy living become important issues in the design and construction phases (CEUD, 2015).

The Scope of Universal Design for users with MS

Any environment designed in compliance with the product and services for everyone's scope of Universal Design can meet the requirements of different users. However, many projects designed up until now have not been able to meet the requirements of the Universal Design approach. In the case of acquired disabilities, which necessitate compulsory changes in lifestyle, existing designs may fail to be adequate and they may even turn out to be unsafe. This inadequacy unleashes itself in environments that do not conform to the principles of Universal Design. Users who encounter symptoms of MS at some stage of their lives adapt to continue their lives depending on these symptoms. Users with MS need efficient solutions in their living environment for comfort and safety. Pursuing their lives at home, in the workplace, at school, in transportation, and in recreational areas without much difficulty and being able to benefit from all design items without any help are becoming more significant for users with MS. When the increasing number of users with MS is taken into consideration, it is essential to prioritize designs and design details while raising awareness for their needs. Many users with MS do not have the opportunity to reside in environments planned according to the Universal Design principles. In such conditions, the Universal Design approach can be utilized for the modification of the existing spaces and products. The most common home modification methods are home adaptation and renovation which requires the assistance of certain devices and technology (Sabata & Lowenstein 2013). The inaccessibility of a house can cause significant costs in long term and various negative health outcomes (Sheppard-Jones et al., 2013).

Living with MS

Multiple Sclerosis (MS) is a Central Nervous System (CNS) disease that affects the immune system, characterized by inflammation, loss of myelinization, and axon damage. Many symptoms associated with CNS damage can occur in persons with MS. Among these symptoms are physical ones such as weakness in arms and legs, sensory problems, loss of balance, fatigue, bladder control problems, double vision, blurriness, and cognitive ones like speech impediment, and memory-concentration-attention disorders which are commonly observed. The severity and the length of these symptoms in the long term may differ from person to person. Some patients experience clinical declines defined as attacks more frequently, while others can have no attacks for a long period of time. In the most common type of MS, attacks are followed by healing periods where neurological symptoms that emerge from the attacks may either decline or disappear completely. MS is commonly observed among young adults. The incidence of MS varies between 2 and 200 in 100,000, depending on geographical features. There are three million persons with MS around the world, nearly 70,000 of whom are in Turkey. MS is observed among females twice more than males and it emerges mostly between the ages 20-40 (Efendi, 2018).

MS causes a loss of independence in the most productive, active, and reproductive stage of life. The living quality of the patient deteriorates, and they become dependent as MS causes handicaps in walking, coordination, balance, and vision (Dehghani, Khoramkish & Isfahani, 2019). They have physical symptoms like loss of muscle strength, clumsiness, altered sensation, decreased vision, or reduced perception of the position of the body or limbs in space (Guarnaccia & Booss, 2005). It is known that; environmental and individual factors affect the physical functions and structures of the body, activities, and participation in activities (Karaduman & Özberk, 2011; Hadgkiss, Jelinek, Weiland, Rumbold, Mackinlay, Gutbrod & Gawler, 2012). Fortunately, by redesigning the environment of persons with MS, the restriction in their daily life activities can be reduced. From this perspective, the design of the environment of the user with MS may cause more handicaps than the disease itself. Therefore, the characteristics of the users with MS and their environment should be considered separately. However, while it is much easier to adapt changes to a house so that the patient has more freedom of movement, it is more challenging to make necessary modifications in their environment. The majority of users with MS fail to own a house or they cannot afford necessary home modifications (Kettaneh & Umeasiegbu, 2016). These problems will be solved to a great extent by simply designing homes for residents with the Universal Design approach. On the contrary, although new buildings are designed with this approach, many people around the globe have to reside in houses that are deprived of Universal Design (Lien, Steggell, Slaug, & Iwarsson, 2016).

The modification of houses that are not designed within the framework of Universal Design principles for the use of persons with MS will provide more independent and satisfying lifestyles to them (Roessler et al., 2013). In a research, it was observed that home modifications have a positive impact on users' lives by decreasing difficulty and increasing safety (Petersson, Lilja, Hammel, & Kottorp, 2008). In another research; enabling activities by changes in the home environment was observed by users as new opportunities to participate outside more often (Thordardottir, Fänge, Chiatti, & Ekstam, 2019). Also, housing adaptations help users to be more active and social through the changes in their physical environment (Pettersson, Löfqvist, & Malmgren Fänge, 2012).

The symptoms of MS which affect the accessibility, needs, adequacy, mobility, and psychological well-being of a person are still being explored. Decrease in mobility, tremor, coordination problems, and spasticity are among the symptoms which impact the accessibility of a person with MS. Devices such as canes, walkers, or wheelchairs used by people with MS who have difficulty in walking due to reasons such as muscle weakness, muscle stiffness (spasticity) or balance disorders (ataxia) in the lower extremities can become an important problem, especially in narrow spaces. Tremor is a symptom that negatively affects the daily life of people with MS, especially when they reach an object in their upper extremities, where treatments are not very effective.

Fatigue, cognitive impairments, loss of motor skills, and sensory deficits, which are among the most common symptoms in people with MS, may prevent their participation in activities. Especially the modifications in the environmental space minimizing the movement required for activities may be beneficial on fatigue and perceived energy loss.

Vision problems such as double vision (diplopia) in people with MS can become trouble when going up and down stairs. Cognitive dysfunctions, difficulties in problem-solving and organizational complications also affect daily life undesirably (Finlayson, 2013).

Balance deficits are common in people with MS. A person's musculoskeletal and neurological system, motivation, and cognition factors affect balance in daily life, but environmental conditions such as lighting, support surface, and visual distractions can also influence balance strategies (Jackson, Mulcare, Donahoe-Fillmore, Fritz, & Rodgers, 2007). Along with coordination problems, sensory, motor, and vision problems intensify the risk of falling (Kesgin, 2019). In order to reduce fall risk in many cases, proper design of the environment is vital. In a study carried out on persons with MS and their problem of falling, it was found that more than 50% of persons with MS experienced falling and that more than half of them were severely injured. In the study, it was reported that tripping or slipping and then being tired or fatigued were perceived as the most common cause of falling cases (Matsuda et al., 2011).

Another problem, urinary incontinence which is common among around 70% of people with MS (Kalb & Holland, 2008), creates stress and causes them to rush, making to face further problems if the bathrooms/toilets are not appropriately designed for them. Housing accessibility is an important issue as many injuries can be caused by architectural barriers (Smith, Rayer, Smith, Wang & Zeng, 2012).

Case Study: Analysis of the home environment through a volunteer user with MS

Aim, scope, and method

As users with MS spend most of their time at home, it is essential that their home environments comply with Universal Design principles to ensure they carry out their activities in a healthy and productive manner. This paper analyses the house of a 43-year-old user with MS who was diagnosed 20 years ago and suffered from some of the symptoms to pinpoint the housing problems of persons with MS and to come up with specific solutions. The following results were considered by evaluating the user with primary progressive MS (Demiral, Ergor, Unal, Semin, Akvardar, Kivircik & Alptekin, 2006; Kurtzke, 1983; Küçükdeveci, Yavuzer, Elhan, Sonel & Tennant, 2001; Stucki, Kostanjsek, Ustün & Cieza,2008):

- Body and function (impairment) assessment: Expanded Disability Status Scale (EDSS) 7,
- Activities (disability) assessment: Functional Independent Measure (FIM) Motor Score 45, Cognitive Score 35, Total Score 80,
- Life health (emotional role restriction, mental health, vital and social function) assessment: Short Form 36 (SF36) physical health total score 40, mental health total score 60.

An in-depth interview method was used in this study and spatial analysis has been made in the residence of the user with MS. The following steps have been carried out within the scope of the study:

1. Design problems and current dimensions of the spaces, products, and built elements have been identified.

2. Design proposals associated with the Universal Design principles were presented.

3. Design ideas for residents have been developed to reduce the difficulties faced by individuals with MS and people living with similar symptoms.

Challenges and suggestions

In order to cater for both the physical and emotional well-being of a user with MS, the criteria of environmental design should be evaluated prudently. This section of the paper classifies the challenges users with MS encounter under basic concepts of design. Suggestions are proposed and exemplified for a safer and easier life at home within the framework of Universal Design.

Accessibility

The user with MS in the case study experiences difficulties in daily life and in-house activities. The user cannot fulfil daily chores and personal care without assistance and especially need help with walking the main reason being the inefficiency of the design of the house to accommodate a wheelchair. The user can use the wheelchair only outside the residence. However, as the entrance of the building is not designed adequately for a wheelchair, the user's daily life is affected negatively (Figure 1). The user with MS finds it difficult to leave the building for activities like shopping, personal care, regular health checks, and many other accomplishments. The entrance door of the building is not easily perceptible to users.

Figure 1. Building entrance with inadequate design for access

The landing area at the entrance of individual houses should be a minimum of 1500mm x 1500mm and it should be at least 2400mm x 2400mm at the communal entrances to allow different residents to use it simultaneously (NDA, 2019a). The landing area at the entrance of the building has only 1300mm in width for the user with MS. The width of the landing area does not have the ideal dimension. The entrance should be easily perceived and reached by the user, but it is hardly perceivable in the present case. The corridors in the house should have a clear passage distance of a minimum of 1200mm according to the Universal Design approach. For non-public buildings, the recommended optimal width for corridors is 1500mm. The corridor width should be a minimum of 1200mm for wheelchair use (WDU, 2013). The corridor width is measured by only 1130mm in the residence of the user with MS.

The optimal interior door clear opening width should be a minimum of 850mm (NDA, 2019b). The clear opening widths of the inner doors have various dimensions in the residence of the user with MS. The kitchen door has a 760mm clear opening width. The living room has a double wing door and the clear opening widths are 900mm and 420mm. The clear opening width of the bedroom door is only 770mm. The other two rooms have doors with 810mm clear opening widths. The door of the bathroom has a 710mm opening width. Door handles should be designed 800 to 1000mm above floor level, preferably at 900mm height. The height of the door handles is measured at 1020mm in this case study. When the location of the door is decided in a project, it should be designed in line with the optimal door opening (NDA, 2019b). The clear width of the entrance door of the house should be 1000mm (CEUD, 2015). The clear width of the entrance door is 900mm in the residence of the user with MS which means it is 100mm less than the optimum requirement of 1000mm.

Designing inward-opening doors minimize the risks that will be formed by the wings that open to the corridors and halls. Doors need to be designed such that it is easy to open and close them. Designs can be generated without doors in some spaces like open kitchens and living rooms where it is possible. In this case study, the user has a small kitchen with 2830mm x 3280mm dimensions and a living room close to it. The living room has a 4320mm width and 6000mm length with a 2130mm x 2300mm extra balcony.

Thresholds in the house also cause major problems for the user with MS. With the Universal Design Approach, the use of thresholds indoors should be avoided as much as possible. The balcony door has a 60mm height frame on the floor level which makes access difficult for the user with MS. There are level differences between the rooms and corridor by 80mm to 120mm in the case study. If there are level differences between rooms, door threshold ramps can be designed as a solution. Door threshold ramps can easily be facilitated in existing homes between rooms (DLF, 2020).

For users with MS, floor coverings of the house should be smooth and anti-slip. The user with MS has difficulty with slippery wet floor coverings in the bathroom. The floor covering should not cause fatigue while walking. Contrasting colours of flooring and walls will also make the perception of the ground easier. Carpeting should have a low profile and a firm pad. It is also better to use non-slip low-pile carpets for the floor covering. High pile carpets will make both walking and using the wheelchair difficult. In this case study, the user has a high pile of carpets in the bedroom and living room. Non-carpet flooring is also a solution but as the user with MS in the case study has suggested it is not preferable because of issues like the contribution of carpeting to heating in winter, aesthetic concerns, perceiving the warm space, and circulation of dust. Possible solutions to be appropriate to these situations could be underfloor heating systems or wooden covering to create a warm effect.

Among the conclusions reached by a group of multidisciplinary experts involving an architect and physiotherapist by evaluating surveys, interviews, and observations regarding home accessibility; the size of a room, objects, and materials used have an important effect on accessibility. The most inaccessible rooms were the bathrooms and bedrooms of the houses as concluded (Sukkay, 2016).

Bathroom

In a research carried out among users with MS, the most modified and change needing spaces at home were the bathrooms (Bishop et al., 2015). They are complex spaces as they comprise many different activities in terms of accessibility and they need to be designed in line with the individual demand of the user with MS. Bathrooms are one of the places where accidents occur when the wet floor becomes slippery. Considering the movement restrictions of the user with MS, the risk increases even more. For users with MS getting on and especially off the toilet is seriously difficult and requires some modifications or adaptive equipment (Gackle, 2012).

The universal bathroom should support individualization and personalization by design flexibility and diversity (Mullick, 2011). Users with MS usually have major troubles in bathrooms. Bathrooms should be easily accessible and truly safe by design. Users with MS should easily perform bathroom activities preferably on their own. In the case study, the user has difficulty using the toilet and carrying out independent bathroom activities (Figure 2). The bathrooms should have a minimum manoeuvring space of 1500mm turn diameter for the wheelchair (CMHC, 2018). In the case study, the bathroom has 1770mm in width and 2440mm in length including the shower unit. The wheelchair can not be used effectively in the bathroom. The toilet seat is 450mm above the floor level and can not be accessed easily. A wall-mounted toilet seat can be installed at a level convenient for the user with MS (Schwarz, 2017). The raised toilet seat will make it easier to sit down and get up. Grab bars by the toilet can be used to push off (National MS Society, 2019). There are no grab bars to assist the user with MS in the bathroom. Grab bars are essential to get up from the toilet and to maintain balance.

Figure 2. The bathroom having difficulty to access and use

Grab bars can be used also outside the shower. Grab bars should be tubular with a diameter of 32mm-35mm and a clearance of 50mm-60mm to the wall. (NDA, 2019c). It will be comfortable and safe to use a no-threshold shower. Even a low-threshold shower causes trouble while using as it was in our case study (Figure 3). The user with MS cannot reach the shower without the additional help of family members because of the 60mm height of the shower unit above the floor. Floor-level showers will be preferred for easy access and comfortable use. Shower screens should be removed for showers; stylish shower curtains can be used instead (Harmon, 2016; National MS Society, 2019). The user with MS has trouble with the current shower screens and prefers not to use them. The shower unit has a 780mm width and 1290mm length in the case study. The shower cabins should have a minimum size of 9500mm x 9500mm or 7600mm x 1500mm for effective use (WDU, 2013).

Figure 3. The shower threshold causing trouble for the user with MS

A bench in the shower will help to sit easily which could provide more balance than a shower chair. If the width of the space is not adequate, a strong and balanced shower chair can be favoured. The seating unit should be 430mm to 485mm above the bathroom floor (WDU, 2013). The shower controls should be located at a maximum height of 1200mm to reach easily (CMHC, 2018). Simple and intuitive use of the shower should be maintained. An adjustable and handheld shower will help to control water flow. Lever-operated taps and mixers can be used for easy operation. These kinds of faucets can be controlled with the underarm or elbow easily. Sensor-activated faucets also enable hands-free operation for easy use (Adelson, 2004). Mirrors above the hand-wash units should extend 1600mm to 1800mm above floor level and can be tilted forwards to be viewed easily by the users (NDA, 2019c).

Kitchen

Kitchens are spaces to be considered in terms of access and use of persons with MS. Designing countertops with the Universal Design approach that can be removed without the need for plumbing system modification provides many advantages. For wheelchair use, space can be created under the countertop when it is essential. The cabinets under the sink can be removed. Dishwashers can be raised to reach easily. There must be enough space for movement in the kitchen and easy access to the oven and the refrigerator. Kitchens with work surfaces on three sides should have a minimum 2400mm diameter clear space for manoeuvring. Oven controls should be positioned between 750mm and 1050 above floor level according to the Universal Design approach (NDA, 2019d). Countertops can be lowered for wheelchair users. In the case study, the height of the counter is 890mm above the floor and it is difficult for the user with MS to reach it. Storage cabinets should be accessed and operated easily by the user. Easy reach zone is nearly between 3800-4100mm and 1300-1320mm for wheelchair use (Harmon, 2016). The kitchen of the case study is not easily accessible regarding the dinner table, counters, and storage cabinets (Figure 4). Kitchens should have a clear space 1100mm wide between all units (NDA, 2019d). There is only a 1050mm distance between the main counter and the dining table to pass through in the case study. The height of the storage cabinet at the corner of the kitchen is 1400mm above the floor and is difficult to use. The shelf height that can be reached by wheelchair should be a minimum of 38mm and a maximum of 1220 mm (WDU, 2013).

Figure 4. The kitchen of the user with MS

Under-cabinet lights can be installed for better lighting and safety. Most frequently used appliances such as toasters, blenders, or others can be placed on the countertop instead of stored in a cabinet (Schwarz, 2017).

Bedroom

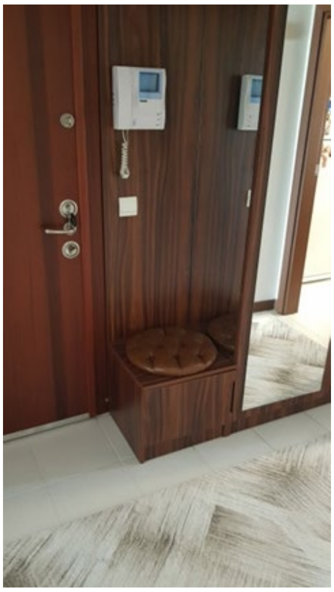
The bed should be positioned far from the walls to allow mobility around it. There should be no objects placed around the bed that may restrict movement. There should be a 1500mm radius area around the bed when using a wheelchair (WDU, 2013). Bedrooms should be easily accessible. In the case study, the commode in the bedroom makes it difficult to enter the room through the door and access the bed (Figure 5). The dimensions of the commode are 550mm x 900mm with a height of 850mm. Adequate transition gaps should be provided especially for individuals using wheelchairs. The bed should be higher than standard so that the individual sits down and gets up easily. In this case study, the height of the bed above the floor is 510mm and the user with MS has difficulty using it. A portable handrail can be used for rising from the bed (Blaustone, 2007). Wall-mounted swing-arm lamps can be installed on the two sides of the bed to use effectively. Bedroom closets should be organized for easy access by making shelves and clothing rods low enough to reach (Schwarz, 2017). Sliding cabinet doors can be designed to operate them easily and gain much space in the room. Dress hanger sticks in the wardrobe should be at a maximum of 1200mm height above the floor for wheelchair use. The depth inside the wardrobe should be a maximum of 530mm for accessibility (WDU, 2013).

Figure 5. The bedroom having difficult access by the user with MS

Fatigue and Balance

Corridors should be planned as short and safe as possible due to loss of balance and fatigue (Halper, 2005). The length of the corridor in the sample case is 4260mm. There must be enough space for the wheelchair to turn around when necessary. The user in the case study prefers some pit stops around the house due to fatigue and to solve this problem a sitting unit has been added to the entrance hall later for this purpose (Figure 6).

Figure 6. The entrance hall and the sitting unit



The user with MS in the case study utilizes a suction balance grab bar to get support and maintain balance. In terms of easy and practical use so that this equipment is not required, specially designed handrails can be used along the corridor and especially in the access routes to wet spaces such as kitchens and bathrooms. Considering that the user does not prefer handrails for aesthetic purposes, holding elements that will provide functional support with up-to-date and stylish designs can be provided. In wet areas, materials like stainless chrome can be used and in corridors and rooms, adjustable handrails made of wood could be installed to create a warm effect. All the mirrors and pictures in the house should be firmly fixed onto the walls for safety. Design products should not contain any sharp and dangerous edges.

Vision and Lighting

Adequate and appropriate lighting is extremely important for users with MS to eliminate vision difficulties. It is essential to avoid the glossary on surfaces. Colour contrast can be used between surfaces and walls, stair treads, and risers for easy recognition of their junction and to prevent vision problems (The Center for Universal Design, 2006). The walls and doors of the house can be in contrasting colours to maintain visual clarity. In the case study, the user with MS cannot stand and look at white light as it disturbs the user's pupils and makes the eyes tired. Furniture and home textile of plain colours with no patterns will provide a comforting effect and on the contrary, complex patterns, dark and warm colours will not support the feeling of spaciousness and will make perception difficult.

For users with MS choosing the correct lighting will improve safety and help to reduce certain types of fatigue (Harmon, 2016). Light switches should be easy to operate for users with MS. Rocker-style light switches will be suitable as they require less hand pressure or pressure-sensitive switches can be used. Dimmer switches allow to adjust the intensity of lights for personal use (Schwarz, 2017). Light switches can be lowered for accessible use. Remote control switches are better solutions as the user can control the lights easily from any distance. Remotes can also have motion and light sensors or can be controlled by applications on smartphones. Electrical sockets can be raised for easy access. The user with MS in the case study usually feels uncomfortable with direct lighting in the house. The user feels more comfortable using indirect lighting instead of hanging fixtures from above and mostly prefers to use floor lamps.

A study done on the benefits of sunlight indicates that sunlight intake and vitamin D3 play a positive role in reducing the symptoms of MS (Mayne, Spanier, Rellan, Williams & Hayes, 2011). The psychological benefits of sunlight on users with MS also guide and inspire designers. Wide-span windows, balconies, skylights, and terrace designs that receive as much natural light as possible will make a positive contribution. Using the balcony in the house for the maximum intake of sunlight may seem like a feasible idea but the threshold at the entrance of the balcony challenges accessibility. It is highly advantageous that the user's house faces east, south, and west facades, which allows all rooms to receive direct sunlight. The patient prefers the curtains to stay open but finds it difficult to manage them. In order to solve this problem, curtain systems can be remotely controlled by a smart curtain motor or by smartphone applications/voice assistants like Google Home or Amazon Alexa (Smith, Martinez, Marlowe, C. & Claypool, 2019).

Climatization

As temperature, humidity and ventilation affect comfort levels and feelings; users with MS are usually sensitive to heat and warm spaces (Harmon, 2016). Using cool colours for the perception of low temperature will comfort users with MS. The user in this case study does not favour the use of air conditioning unless it is too hot. A climatization system that can be controlled and managed easily would provide a lot of benefits for the users of the house.

Noise sensitivity

Unpleasant noises usually disturb users with MS in their environment. The user in this case study is also getting stressed by the noise of neighbours frequently. The walls of the house can be soundproofed to eliminate such noise problems (Harmon, 2016). Double-glazed windows and well-sealed doors will help to reduce noise. Room placement of the building far from noise sources in the designing stage can help to reduce the impact of noise in rooms with the most sensitivity to noise such as bedrooms and study rooms (Urban Land Institute, 2015).

In this study, design recommendations were presented in the housing example of the user with MS which was examined as a case study considering the difficulties experienced by individuals with MS in their houses. The summary of the design items for the users with MS discussed in the study under the title of Universal Design principles is presented in Table 2, Table 3 and Table 4.

Table 2. Home design proposals for accessibility items

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Building Entrance	Equitable Use	Poorly accessible building entrance with slope and threshold	Designing a common accessible entrance with appropriate dimensions for everyone's use
Building Entrance Door	Simple and Intuitive Use	Poorly perceived building entrance door	Designing a distinctive and perceivable entrance door for easy detection with less effort
Corridors	Size and Space for Approach and Use	Width is under 1200mm in the main corridor	Moving any furniture out of the corridor, stabling mirrors and pictures on walls properly
Inner doors	Size and Space for Approach and Use	Unaccessible inner doors by narrow clear width for wheelchair	Providing inner doors with 8500mm effective clear width

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Thresholds	Tolerance for Error	Trouble causing thresholds in rooms, corridor, hall and entrances.	Floor covering with the same level with appropriate material for each space
Floor covering	Low Physical Effort	Carpets make it difficult to move	Low-pile carpets or non-carpet floors
	Tolerance for Error	Hazardous ceramic floor covering	Reducing glare and slip on floor surfaces by using non-glare and anti-slip floor covering

Table 3. Home design proposals for basic rooms

a)Bathroom

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Tabs	Low Physical Effort	Centerset lavatory tabs	Lever operated tabs
Faucets	Flexibility in Use	Manuel operated faucets	Sensor-activated faucets
Shower	Low Physical Effort	Difficult to use with a low-threshold and shower screen	Designing a floor-level shower unit with a light shower curtain
	Flexibility in Use	Wall-mounted shower	Adjustable and handheld shower
	Equitable Use	Unstable shower chair	Comfortable and stable shower bench
Toilet	Tolerance for Error	Difficult to use the toilet independently	Installing grab bars for toilet and shower
	Equitable Use	Not easy to use lower toilet seat	Installing wall-mounted toilet at a convenient level

b)Kitchen

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Counter	Size and Space for Approach and Use	Inaccessible counter for wheelchair	Redesigning / removing cabinets under the countertop
Cabinets	Size and Space for Approach and Use	Difficult to reach for storage	Designing at the appropriate level for easy use
	Tolerance for Error	Low vision within the storage space of cabinets	Installing under-cabinet lights for better vision and safety
Household appliances	Size and Space for Approach and Use	Difficult to access for using	Designing enough space in the kitchen, keeping most used appliances closer and accessible.
	Low Physical Effort	Difficult to use the doors of the closet opening to the main space	Installing sliding doors in order to operate with less effort in a larger space
Commode	Size and Space for Approach and Use	Minimizing the space and making access difficult by inappropriate position	Designing the commode with the appropriate size and position

c)Bedroom

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Bed	Low Physical Effort	Difficult to sit and raise	Raising bed for easy use, using a portable handrail
	Tolerance for Error	Poor vision in the bedroom, difficulty moving and acting in darkness	Wall-mounted lamps can be installed to be used when the user needs
Closet	Size and Space for Approach and Use	Difficult to reach shelves and clothes individually	Designing shelves and clothing rows easily accessible with the appropriate level.
	Low Physical Effort	Difficult to use the doors of the closet opening to the main space	Installing sliding doors in order to operate with less effort in a larger space
Commode	Size and Space for Approach and Use	Minimizing the space and making access difficult by inappropriate position	Designing the commode with the appropriate size and position

Table 4. Home design proposals for physiological/psychological items

a) Fatigue and Balance

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Handrail	Tolerance for Error	Using vacuum suction cups hand tool	Designing adjustable and decorative handrails
Circulation	Size and Space for Approach and Use	Difficult to use the wheelchair in corridors and rooms	Designing corridors and rooms with clear dimensions for wheelchair use
Mirrors and pictures	Tolerance for Error	Poorly and inappropriate installation on walls	Fixing all mirrors, pictures, and paints properly on walls in order not to be fallen or become hazardous
Floors	Low Physical Effort	Difficult to move on the floor covering materials	Installing easily walkable and drivable floor coverings

b) Vision and Lighting

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Glazing	Tolerance for Error	Undesired glazing on the floor and wall coverings	Designing with unshiny and non-reflective surfaces and materials
Colours	Tolerance for Error	Less perceivable similar colours in the house	Designing with colour contrasts between walls, floors, and doors for easy perception
Furniture	Equitable Use	Feeling uncomfortable and unhappy with the furniture	Using plain textures, and light-coloured textiles avoiding patterns, stripes, checks, and complexity. Designing with less furniture according to need and space.
Curtain systems	Low Physical Effort	Manuel operating	Remote control, Voice assistant
Lighting armatures	Equitable Use	Direct lighting	Indirect lighting
Switches & sockets	Low Physical Effort	Difficult to operate light switches	Remote control, motion / light sensor switches, using smartphone applications

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Remotes	Equitable Use	Difficult to use electrical sockets	Raising electrical sockets for easy access
	Perceptible information	Difficult to operate and perceive	Using remotes with clearly marked buttons

c) Climatization

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Temperature	Flexibility in Use	Disturbed by hot weather and humidity	Installing an auto-controlled climatization system
Colouring	Equitable Use	Affected uncomfortably by warm and dark colours in the house	Designing surfaces and furniture with cool colours for the perception of low temperature

d) Noise sensitivity

Design item	Universal Design Principle	Current situation (Case Study)	Design proposal
Walls	Equitable Use	Disturbed by the noise of neighbors	Designing with soundproofed wall systems
Outside noise	Equitable Use	High volume of noise coming from outside	Installing noise-insulated glass and sound-insulated window products, changing the most silence-requiring rooms with others to reduce the impact of outside noise

Findings and Discussion

Home design proposals listed in Table 2, Table 3, and Table 4 are formed by analyzing the sample resident of the user with MS but can be adaptable to the living environments of other people having similar symptoms and difficulties. The proposals are listed on the tables under the headings of accessibility items, basic rooms, and physiological/psychological items.

In Table 2, there are accessibility items including building entrance, building entrance door, corridors, inner doors, thresholds, and floor covering. Design proposals are associated with the appropriate Universal Design principle for each item. For the entrance of the building "equitable use" is the common request. An entrance has to be accessed easily by everyone (Maisel, Smith & Steinfeld, 2008). The building entrance door is closely related to simple and intuitive use. It should be both easily accessible and perceivable.

Inner corridors and doors of the house should be compatible with the Universal Design principle of "size and space for approach and use" (Roessler et al., 2013). The corridor width is under 1200mm in this case and it is difficult to use the wheelchair. Any furniture should be avoided in the corridors and any items on the walls such as paintings and mirrors should be stabled. The inner doors have to be designed with the appropriate clear opening width, especially for the use of the wheelchair. In the case study, the inner doors except the living room door have narrow clear widths for access. Thresholds are trouble-causing items in the house for a person with MS or other people having similar symptoms. The floor level should be the same for each space by covering it with the appropriate material. There should be "tolerance for error" as one of the Universal Design principals. Easily perceivable door threshold ramps can be used for safety (DLF, 2020). Floor coverings should be also related to the principles of "tolerance for error" and "low physical effort". Floor coverings should be designed to reduce falling and slipping. They should allow a person to walk or use a wheelchair easily. Low-pile carpets, non-glare, and anti-slip floor coverings should be preferred.

Home design proposals for the basic rooms are summarized in Table 3. Bathrooms, kitchens, and bedrooms usually need modifications for users with various disabilities. Tabs and showers should be designed to ensure "low physical effort" as a Universal Design principle. A floor-level shower unit can be used easily with a suitable shower curtain. Lever-operated tabs can be used with less effort. Sensor-activated faucets and an adjustable shower will help the user as they are related to the Universal Design principle of "flexibility in use". Grab bars can avoid the danger of falling and assist the user in bathroom activities enabling "tolerance for error". The user can use the toilet and the shower independently with the help of installed grab bars (Davies & Lopez, 2005). A raised toilet seat and a stable shower bench will be effective for the user with MS regarding "equitable use".

The kitchen should be easily accessible for the user (NDA, 2019c). "Size and space for approach and use" is one of the most important principles in this space. The counter is inaccessible for the wheelchair, so redesigning or moving the cabinets under the countertop will help the user to reach it. Cabinets also should be designed at the appropriate level for easy use. Most used household appliances should be reached easily by storing them closer on the counter. For "tolerance for error" it will be better to install under-cabinet lights for better vision and safety.

User with MS mostly spends high physical effort during bedroom activities. By enabling the "low physical effort" principle some design solutions can be activated. The bed can be raised to prevent difficulty to use it. Portable handrails can be used to assist the user. Installed wall-mounted lamps will help to reduce poor vision preventing mistakes and hazards related to the principle of "tolerance for error". The closet should be also easily accessible to reach shelves and clothes. Shelves and clothing rows can be designed at an appropriate level to reach. The commode should be positioned properly to enable easy access. It can be minimized in size considering the inefficient size of the bedroom.

Physiological and psychological items in home design proposals are considered in relation to the Universal Design principles (Table 4). Some proposals are suggested for the "equitable use" of the design items (Bishop, Roessler, Rumrill, Sheppard-Jones, Frain, Waletich, & Umeasiegbu, 2013). This principle is about making privacy, safety, and security issues equal for all users and providing the same means of use for all users (Null, 2014). The user with MS is unpleased with the current furniture. The user prefers less furniture in their residence. Light-coloured textiles without patterns, stripes, checks, and complexity, and plain textures will help the user with MS to feel calm and comfortable. Indirect lighting in the house will improve safety by reducing glare and make the user with MS feel peaceful. Surfaces and furniture can be designed with cool colours for the perception of low temperatures. Electrical sockets can be raised for easy access making them suitable for other users as well.

The noise of the neighbours and the high volume of voice coming from outside usually disturb the user with MS. Soundproofed wall systems, noise-insulated glass installations, and sound-insulated windows will help to reduce such problems. The most silence-requiring rooms should be designed far away from noise sources (Urban Land Institute, 2015).

The user with MS does not feel comfortable because of the hot weather and humidity (Halper, 2005). Installation of an auto-controlled climatization system will be related to the Universal Design principle of "flexibility in use" providing choice in methods of use. It is difficult to operate and perceive remotes by the user with MS. The "perceptible information" principle is related to providing compatibility with a variety of techniques and devices used by people with sensory limitations. Clearly marked buttons will help the user with MS in perceiving remotes (LaRocca & Kalb, 2005).

The "tolerance for error" principle is related to arranging elements to minimize hazards and errors. Design proposals in competence with this principle can be listed as; designing adjustable and decorative handrails, fixing all mirrors, pictures, and paints properly on walls in order not to be fallen or become hazardous, designing with unshiny and non-reflective surfaces and materials, designing with colour contrasts between walls, floors, and doors for easy perception. Minimizing physical effort and repetitive actions, and using reasonable operating forces will be related to the Universal Design principle of "low physical effort" in design proposals (Shammas, Zentek, Haaren, Schlesinger, Hey & Rashid, 2014; Story, 1998). Installing easily walkable and drivable floor coverings, remote control or voice assistant curtain systems, remote control or motion/light sensor switches, using smartphone applications for lighting, and voice-controlled intelligent personal assistants will help the user with MS in physical energy efficiency and fatigue (Pradhan, Mehta & Findlater, 2018).

Reaching all components comfortably by either a seated or standing user, and providing adequate space for the use of assistive devices and personal assistance will be included in the "size and space for approach and use" principle (Steinfield, Zimmerman & Tomasic, 2019). The user with MS has difficulty using the wheelchair in the residence. Designing corridors and rooms with clear dimensions for the wheelchair will be appropriate for the user.

Conclusion

Challenges specific to users with MS make their daily life difficult to cope with. They should be provided with equal and fair access to urban life, transportation, health, education, social life, and recreation. Architects and designers may contribute to the well-being of society with the Universal Design approach. Solutions and design ideas should all emerge from the idea that living standards should be distributed fairly and equally to all humans with disabilities and health problems that may come from birth or be encountered later in life. In this study, the daily life of a volunteer user with MS at home has been analyzed, and recommendations have been made to overcome the challenges through the Universal Design approach. All individuals, regardless of their abilities and physical features will be able to utilize products and spaces designed conforming to the principles of the Universal Design approach without any difficulty. The approach aims to ensure easy access to all available products, services, and environments for every individual. The Universal Design approach should be considered from the very beginning of the design process and reflected in the project. Any intervention and revision after the design process turns out to be less effective, more costly; and requires additional time and labour. Design criteria reflecting all kinds of difficulties, physiological and psychological changes, personal abilities, and the differences that may be encountered in life will provide important support for a safer and healthier life in society. Universal Design is the key to promoting useful and accessible suggestions and solutions for all different abilities. The Universal Design approach will be important for providing easy and reliable access to all kinds of designs in life in terms of increasing the frequency of users with MS in societies.

The Universal Design concept utilized in all physical environments will make a great contribution to eliminate or minimize the effects of physiological and psychological changes that individuals experience with MS. The adoption and implementation of the concept from the design process will minimize the modification or adaptation of existing buildings.

The accessibility of the house is essential for the person with MS to socialize with others. In cases where safe and comfortable outdoor access is not available, the individual may move away from social life and enter a depressive mood. Persons with MS can lead an active social life without being isolated when provided with access to buildings, the convenience of movement spaces, and an adequate physical environment inside the house. They are the most natural needs and rights of the users to adapt to their changing conditions with MS without having to change their residences or leave their social lives. Buildings designed with the Universal Design approach will prove to be more cost-effective and user-friendly in the long term without needing further adaptations that may arise in the future. As the accessibility of existing buildings and residences increases, the size of the adaptations that may be needed will decrease considerably. Spreading design criteria determined with the Universal Design approach both in relevant sectors and the society will allow more accessible and usable products and services. Transforming these criteria into standards will contribute to creating healthier, more equitable, accessible spaces and environments. Design suggestions considered in the example case in this study can also be used for people with symptoms similar to the user with MS. Since the main idea of Universal Design is designing for everyone, all living environments and houses have to be built in accordance with Universal Design principles in order to provide fair, safe and comfortable living conditions.

It is crucial that the physical environments of the users with MS should be arranged within the framework of the Universal Design approach in accordance with the unique findings of MS and the changes in the individuals' living conditions. Various design proposals have been suggested in this study to facilitate the life of users with MS and it is aimed to reduce gaps in the related literature and highlight that users with MS can carry out their own activities more comfortably, live in a safe environment, and socialize better when they have adequate living environment. This research revealed that the Universal Design approach has an inclusive role in order to realize optimal physical environmental conditions of the users with MS. The findings and proposals may contribute to further research on the physical environments of users having similar symptoms to MS. The study will support future research on spatial design ideas for a wide variety of users, including new technologies, inventions, and policies.

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LEFT-HANDEDNESS AND MUSCULOSKELETAL DISCOMFORT IN STUDENTS

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Abstract: School furniture design is based on the right-handed population since left-handedness is uncommon. In the classroom, left-handed students are forced to use the chair that was designed for the right-handed. The awkward posture caused by the improper chair may contribute to musculoskeletal discomfort. This study aimed to evaluate the benefit of using an ambidextrous chair to accommodate left-handed students. Nordic Musculoskeletal Questionnaire was given to 14 subjects to identify their health problems related to the chair in the classroom. The NMQ showed that students often perform awkward postures and experience pain afterwards. To validate the ambidextrous chair, the subjects were asked to perform writing while sitting on both the existing and modified chairs. Then, the angles of lateral flexion of their neck and lower back from upright sitting posture were compared. Paired t-test evaluation showed that the ambidextrous chair reduced lateral flexion. Developing proper school furniture based on user-centred design can increase the comfort of the students. However, it may be costly and too specific for general use.

Keywords: design, left-handed, Nordic musculoskeletal questionnaire, musculoskeletal discomfort, ambidextrous chair.

Introduction

Musculoskeletal discomfort (MSD) is a common health problem in modern society (Albers & Estill, 2007). Symptoms of MSD include pain, aching, discomfort, numbness, tingling, and swelling that usually occur in the back, shoulders, neck, legs, wrists, fingers, elbows, and arms. Previous studies suggested that prolonged static sitting is associated with an increased risk of developing MSD in the back, neck, shoulders, arms, and legs (Naqvi, 1994; Winkel & Jorgensen, 1986).

Students spend much time in the classroom and sit in a static posture (Murphy et al., 2003; Dianat et al., 2013). Therefore, they are at risk of various factors associated with a long-term sedentary position and poor and static postures (Dianat et al., 2013). Prolonged sitting might cause MSD in the buttock and low back regions (Sondergaard et al., 2010). The discomfort from prolonged sitting is attributed to muscle fatigue from sustained contraction of back muscles during sitting (Hosea et al., 1986). Awkward postures during prolonged sitting increase the prevalence of MSD in students (Allegri et al., 2016). Previous studies found that neck and low back pain are common problems for students in the classroom (Whittfield et al., 2001; Trevelyan & Legg, 2003). In addition to physical discomfort, awkward body posture may cause students to lose interest in participating in the classroom regardless of how interesting the teaching material is (Hira, 1980).

The most significant cause that contributes to MSD in left-handed students is the usage of improper school furniture that is designed for right-handed students (Flatt, 1999). The chair in the classroom may be designed poorly, that in the end, would cause low back pain. Postures with prolonged flexion will cause the soft tissue to aggravate the backbones which will lead to low back pain (Allegri et al., 2016). Regardless of the handedness, bad posture will cause low back pain. Since the chairs in the classroom are designed for right-handed students, the impact of bad posture will be even more significant for left-handed students. Thus, the left-handed students have to adjust their body posture to write on the table, which may cause discomfort in the neck and back. The common chair forces left-handed students to adjust their posture to reach the table when they try to write. It may lead to MSD because they spend most of their time in the classroom sitting with static and unchanged postures (Murphy et al., 2003).

Given the above, we have developed an ambidextrous chair suitable for both right-handed and left-handed students. This study aimed to evaluate the impact of using an ambidextrous chair for left-handed students. With this chair, left-handed students do not need to adjust their sitting posture in the classroom. Herein, we report the MSD evaluation on left-handed students, details of the chair design, evaluation of the proposed chair compared to the typical chair in the classroom, and students' feedback regarding their experience using the chair. The ambidextrous chair could be an alternative for schools to enhance left-handed students' learning activities by helping them minimise musculoskeletal discomfort due to improper school furniture.

Methodology

Participants

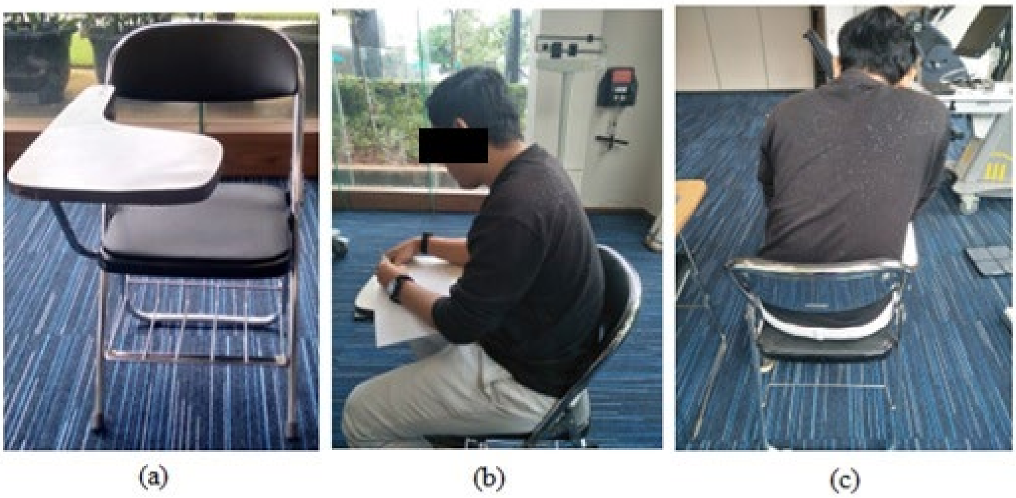
A total of 14 left-handed Indonesian students (21.64 ± 1.67 years) with a height of 163.7 ± 4.85 centimetres and a weight of 63.98 ± 11.3 kilograms were recruited in this study. The subjects were free of neurological disorders based on self-report, and informed consent forms were signed before participation. The subjects were asked to fill out the Nordic Musculoskeletal Questionnaire (NMQ) for a screening of MSD symptoms (Dickinson et al., 1992). We wanted to examine whether left-handed students experienced any MSD symptoms. In addition, the subjects were asked to fill out personal information such as the class duration, sitting habits in the classroom, rest duration, and exercise duration per week. The purpose of this set of questions was to evaluate the factors affecting left-handed students' discomforts.

Chair Design

The design of school furniture is most likely made to accommodate the majority of the students. Thus, left-handed students, as the minority, may become frustrated and have difficulties in doing simple tasks such as sitting and writing in the classroom. User-centred design is a term used to describe a wide range of design methods where end-users are involved in the process of creating a design (Abras et al., 2004). There are several methods to involve users in the development of a product: interviews/questionnaires, focus group discussion, direct observation, role-playing/simulations, and usability testing (Preece et al., 2002). The involvement of users in the design ensures that the product will be suitable for its intended use, and thus, the product will be safer, more effective, and more efficient. In this study, we started the design process by conducting interviews, questionnaires, and direct observation of the left-handed students while using the existing chair designed for the right-handed. There were 7 left-handed students (20±2.16 years) who participated in the preliminary study. The results of the preliminary study showed that left-handed students need to lean their bodies to the right with their neck and lower back deviated more than 40 degrees from the upright sitting posture. In addition, 6 out of 7 students experienced musculoskeletal pains in the last 7 days from the data collection date. From these findings, we devised an idea to modify the existing chair to reduce the neck and lower back deviations while writing.

The ambidextrous chair was designed based on the current chair in the classroom. As can be seen in Figure 1, the left-handed student has to adjust their body to reach the table to write. This awkward body posture might contribute to the MSD symptoms considering the duration students spend in the classroom. To overcome the discomfort of left-handed students caused by the current chair, we modified the chair to accommodate both right and left-handed students (Figure 2). For the modified chair model, an ordinary chair commonly used by Indonesian universities was selected. The chair was made adjustable due to left-handedness is not common in Indonesia. Thus, the chair can be used as usual if the student is right-handed. We did not specifically consider the chair dimensions, such as width, seat, and back angles because our purpose was to create an economical design to accommodate left-handed students. Therefore, we modified a chair already being used in the classroom. As can be seen in Figure 2, the proposed chair was designed with 3 table parts made of plywood. The table parts are connected using 2 hinges in each part with removable linkage to stabilise the table. The purpose of this design was to make sure that the table looks exactly similar when positioned on either side of the chair. In order to evaluate the design, the subjects were asked to perform writing tasks for 2 minutes in both the current and proposed chairs.

Figure 1. Current chair in the classroom: (a) current chair, (b) side view, (c) back view of a left-handed student sitting



Results

Table 1 shows the significant correlation between NMQ items and subjects' personal information ($p<0.05$). From this data, it can be seen that the subjects have signs of MSD due to their habit inside and outside of the classroom. Subjects with heavier weights reported having bad sitting posture ($p=0.032$) and pain in the neck ($p=0.035$) and knees ($p=0.036$). Interestingly, the subjects with longer exercise and rest duration admitted having better sitting posture ($p=0.027$). Additionally, enough rest could reduce the problem in the neck ($p=0.013$) and pain in the wrists ($p=0.038$). Subjects with long class duration experienced pain in the neck ($p=0.01$), wrists ($p=0.026$), and lower back ($p=0.021$). Similarly, bad sitting posture caused pain in the neck ($p=0.022$). However, prolonged sitting reduced the pain in the knees. The correlation analysis also showed the relationships among the items in the NMQ questionnaire, such as the pain in the neck is related to the pain in the wrists ($p=0.015$) and the shoulder ($p=0.13$).

Figure 2. Proposed chair: (a) for right-handed students, (b) for left-handed students, (c) top view for left-handed students, (d) front view of a left-handed student sitting, (e) side view of a left-handed student sitting, (f) back view of a left-handed student sitting

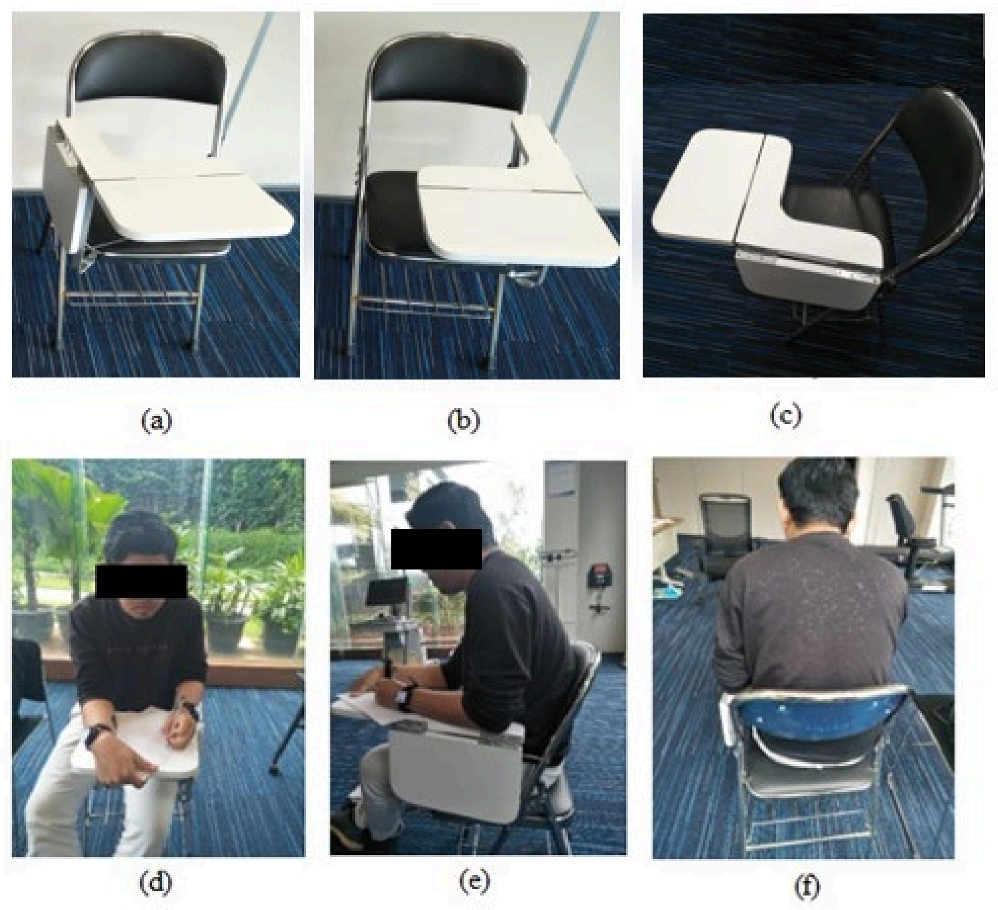


Table 1. Pairwise Pearson correlation of NMQ questionnaire

Category 1	Category 2	Correlation	p-value
Bad sitting posture	Weight	0.575	0.032
Pain in last 7 days_Neck	Weight	0.565	0.035
Pain in last 12 months_Knees	Weight	0.563	0.036
Bad sitting posture	Exercise duration	-0.589	0.027
Bad sitting posture	Enough rest	-0.603	0.022
Class duration	Enough rest	-0.591	0.026
Problem in doing activities_Neck	Enough rest	-0.645	0.013

Category 1	Category 2	Correlation	p-value
Pain in last 12 months_Wrists	Enough rest	-0.559	0.038
Pain in last 7 days_Knees	Prolonged sitting	-0.679	0.008
Pain in last 7 days_Neck	Bad sitting posture	0.603	0.022
Problem in doing activities_Neck	Class duration	0.664	0.01
Pain in last 12 months_Wrists	Class duration	0.592	0.026
Pain in last 12 months_Lower Back	Class duration	0.609	0.021
Pain in last 7 days_Wrists	Pain in last 12 months_Neck	0.632	0.015
Pain in last 7 days_Shoulder	Pain in last 7 days_Neck	0.645	0.013
Pain in last 12 months_Elbows	Problem in doing activities_Shoulder	0.548	0.043
Problem in doing activities_Elbows	Problem in doing activities_Shoulder	0.65	0.012
Problem in doing activities_Hips	Problem in doing activities_Shoulder	0.645	0.013
Problem in doing activities_Hips	Seeing doctor in last 12 months_Shoulder	0.679	0.008
Pain in last 7 days_Ankles	Pain in last 7 days_Shoulder	0.548	0.043
Pain in last 7 days_Lower Back	Pain in last 12 months_Upper Back	0.559	0.038
Pain in last 12 months_Wrists	Pain in last 12 months_Elbows	0.559	0.038

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Category 1	Category 2	Correlation	p-value
Pain in last 12 months_Knees	Pain in last 12 months_Elbows	0.548	0.043
Problem in doing activities_Hips	Pain in last 7 days_Elbows	0.782	0.001
Pain in last 7 days_Hips	Pain in last 7 days_Elbows	0.782	0.001
Pain in last 12 months_Ankles	Pain in last 7 days_Elbows	0.576	0.031
Pain in last 7 days_Wrists	Problem in doing activities_Wrists	0.632	0.015
Problem in doing activities_Hips	Problem in doing activities_Wrists	0.645	0.013
Problem in doing activities_Hips	Seeing doctor in last 12 months_Wrists	0.679	0.008
Problem in doing activities_Hips	Seeing doctor in last 12 months_Lower Back	0.679	0.008
Pain in last 7 days_Knees	Pain in last 12 months_Knees	0.645	0.013
Pain in last 7 days_Knees	Problem in doing activities_Knees	0.679	0.008

Based on the correlation analysis, the left-handed students showed signs of MSD due to improper sitting posture in the classroom. The modification of the existing chair was done to help students in minimizing this problem. To evaluate the experience of left-handed students in using the proposed chair, the degree of the neck and lower back deviation from the upright sitting posture was measured. The purpose of this measurement was to see the sitting posture improvement when the subject sits on the proposed chair. Table 2 shows the comparison between the current and proposed chair in terms of the neck and lower back degree deviation from the upright sitting posture. The proposed chair reduced the deviation significantly in both the neck ($p<0.001$) and lower back deviation ($p<0.001$).

Table 2. Neck and lower back degree deviation from the upright sitting

Parameter	Current chair	Proposed chair	p-value
Neck deviation	28.52±10.71	3.42±3.42	p<0.001
Lower back deviation	38.55±8.91	5.95±3.94	p<0.001

Discussion

MSD in left-handed students

Life is never easy for left-handers in Indonesia since everything is designed to be used for the right-handed population. Thus, they need to work harder to comprehend and remain in the classroom. One of the struggles of left-handed students is using the writing armchair designed for right-handers. In order to write, they need to adjust their bodies to reach the table on the right side of the chair. Left-handed students need to maintain this awkward body posture constantly during writing activities in the classroom. This awkward body posture in the classroom may lead to spine deformities such as thoracic hyperkyphosis (Nissinen et al., 1995) and scoliosis (Milenkovic et al., 2004).

In addition to the higher risk of spine deformities, left-handed students also are at greater risk of MSD (Murphy et al., 2003). The screening of MSD symptoms using the NMQ showed that left-handed students experienced pain in the neck, shoulder, wrists, lower back, hips, knees, and ankles in the last 7 days. These discomforts may be caused by their bad sitting posture in the classroom. As shown in Table 1, that bad sitting posture is correlated with neck pain (p=0.022). Whereas neck pain is linked to pains in the shoulder (p=0.013) and wrists (p=0.05). Neck, upper back, and lower back pains are common in students (Azuan et al., 2010). However, left-handed students may experience more musculoskeletal discomforts because they need to lean to the right in order to write due to the position of the table being on the right side of the chair. This condition forces their bodies, especially the neck, shoulder, and lower back, to be in an awkward position. The average lateral flexion of the neck and lower back of the left-handed students while using the existing chair were 28.52±10.71 degrees and 38.55±8.91 degrees, respectively. Past studies reported that lateral flexion of the lower back of more than 25 degrees will cause pain in the spine (Todd & Vaccaro, 2016). In addition, lower back pain is associated with upper back, neck, shoulder (Daraiseh et al., 2010), hip, and knee pains (Urits et al., 2019).

The students also reported having pain in their wrists and lower back in the last 12 months, and the Pairwise Pearson correlation analysis showed these issues were linked to the class duration. When writing on the table, left-handed students not only need to flex their bodies laterally but also need to curl their wrists. This non-neutral posture, when performed frequently, will cause discomfort. A past study found that non-neutral postures and prolonged sitting can lead to the development of MSD symptoms (O'Sullivan et al., 2012). Since the students need to be in the classroom for several hours almost every day, the sustained awkward posture of the left-handed students further enhanced the symptoms (Lis et al., 2007). In left-handed students, preventive interventions such as improving writing techniques, body posture while writing, and specially created school supplies such as school furniture might reduce spine deformities and MSD symptoms (Paul, 1994).

Modified chair

The consideration of modifying the current chair was because left-handers are the minority in Indonesia. Using the modified chair, the right-handed students are still able to use the chair. The modified chair was designed to make it possible for the writing armchair to be put on either side of the chair. We modified the chair that is frequently used at universities in Indonesia. This modification is considered more economical than preparing a special chair for left-handed students.

Figure 3. Details of proposed chair: (a) isometric view, (b) left-side view, (c) right-side view, (d) top view, (e) isometric-bottom view, (f) bottom view

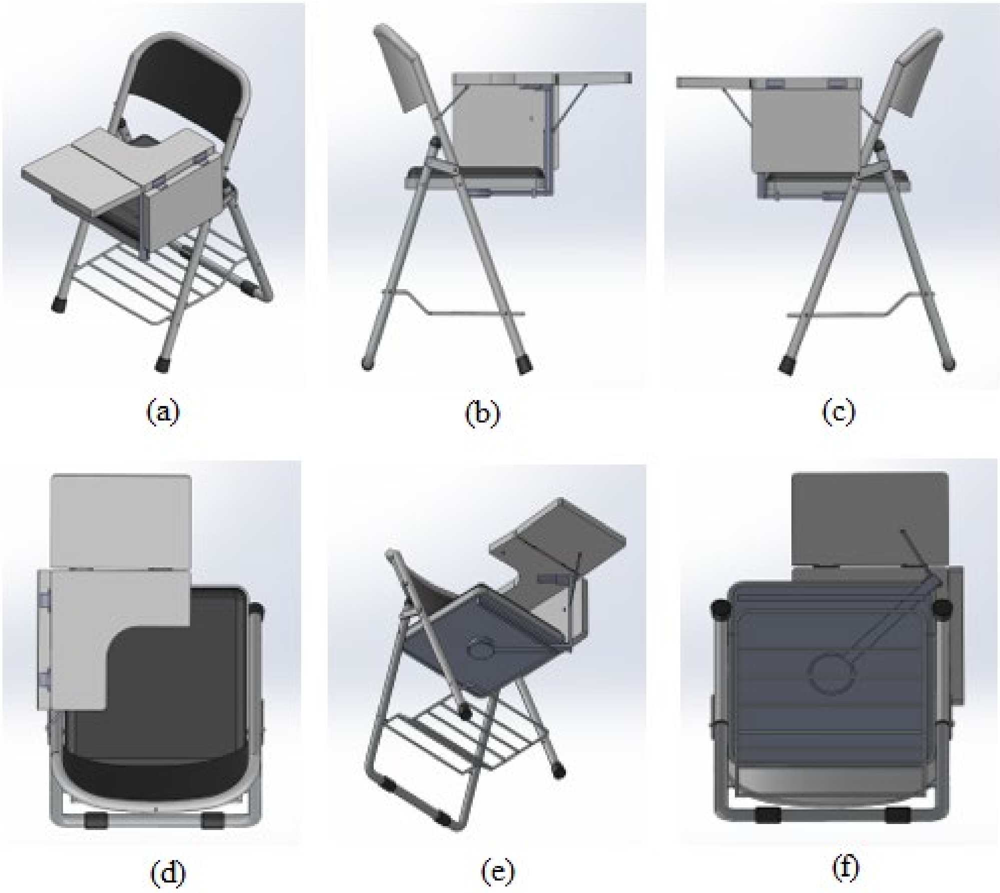

Figure 3 shows the detailed design of the chair. The table was made of high-pressure laminated plywood. It consists of 3 parts (2 parts are rectangular, and 1 part has a slope). The part with slope is the main table, while the rectangular parts are the additional tables to make writing possible. The main table and each of the additional tables are connected by 2 hinges to ensure the writing armchair will exactly look the same regardless of which side of the chair the writing armchair will be put. Depending on the user, a swivel is put under the chair to turn the table right and left. When the right-handed student uses the chair, the main table should be moved to the right side, and the rectangular part on the right side will be used. Similarly, when the left-handed student uses the chair, the main table should be positioned on the left side, and the rectangular part on the left side shall be used. To support the table, there is a linkage made of a steel bar on each side of the chair to mimic the

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function of the window stopper. When the chair is used for left-handed students, then the linkage on the left side should be used.

Based on the comparison analysis between the current and modified chairs, the results showed that the modified chair significantly reduced the deviation degree of both the neck and lower back from the upright sitting position. Furthermore, the subjects admitted that the modified chair was more convenient. They do not need to adjust their bodies to reach the writing armchair. However, some students with larger bodies felt the chair would be better with a wider seat. In order to develop an ergonomic chair for students, it is essential to measure the anthropometric data of the students, such as elbow height, buttock to popliteal length, popliteal height, and knee height (Tunay & Melemez, 2008). The development of a chair based on students' anthropometric data might be more convenient for students, but it will be more costly for the school. Furthermore, the school furniture may need to be frequently adjusted after the previous cohort of students graduated and the new cohort of students enrolled. We modified the existing chair based on our direct observation of the posture of left-handed students during the writing task. We aimed to reduce the students' lateral flexion of the neck and lower back to minimise the MSD symptoms in left-handed students. This study did not consider the anthropometric data for the chair design, considering that changing the whole design of the chair would be too costly for the school. Future studies developing the chair design using anthropometric data will be beneficial to give a better understanding of the impact of the improper chair on MSD in students. Especially if the school is willing to invest in school furniture to minimise the potential of MSD in students.User-centred design is beneficial to create safer school furniture for students, however, it is costly and takes more time to develop. In addition, the furniture could be too specific for general use. Therefore, it may not be readily transferable to the next cohort of students.

Conclusion

We modified the existing school chair widely used by the universities in Indonesia to reduce the lateral flexion of the neck and lower back of left-handed students during writing tasks. The modification was done based on the evaluation in the preliminary study. Our modified chair has shown that it could be used to help left-handed students in maintaining better body posture during the writing activity in the classroom. This modified chair was expected to reduce musculoskeletal discomfort (MSD) in left-handed students due to improper furniture in the classroom. In this study, we did not evaluate the spine deformities of the subjects. Only the MSD symptoms were evaluated. From the comparison between the existing and the modified chairs, our modified chair significantly reduced the lateral flexion of the neck and lower back of the left-handed students. However, the modified chair was developed by only considering the sitting posture of the students during observation. We did not consider students' anthropometric data in this study. Future studies developing ergonomic chairs for left-handed students with appropriate anthropometric measurements will be beneficial if cost is not an issue. The development of a user-centred design chair would greatly increase the comfort of the students, regardless of their hand preference. However, it would be very costly since the too specific design may not be able to be used for general students.

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LEGIBILITY OF JAPANESE CHARACTERS IN GRAPHIC FLOOR SIGNS FOR ELDERLY PEOPLE

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***Abstract*:** For low-vision people and elderly people with decreased vision and cognitive function, the legibility of signs (character size, position, etc.) is an important issue. Graphic floor signs are considered more effective for low-vision people and elderly people than typical hanging signs because they are closer to pedestrians and can be larger in size. There is a growing number of improved graphic floor signs, but there are no guidelines for character sizes, colour scheme, and layout. Therefore, this study considers the character size ofgraphic floor signs that are legible for elderly people. In this study, we aimed to verify the legibility of characters installed on the floor. The test was conducted on 30 non-elderly and 30 elderly people, about Japanese Industrial Standards (JIS) S 0032 “Guidelines for the elderly and people with disabilities - Visual signs and displays -Estimation of minimum legible size for a Japanese single character”. Experiments on minimum legible sizes of characters and experiments on readability were conducted in that order. In the experiment on the minimum legible sizes of characters, we found that the minimum legible sizes of characters written on the vertical surface can be converted to the minimum size of legible characters written on the floor surface by multiplying with the coefficient of minimum legible characters on the floor surface by 2 to 3 times. In the experiment on readability, we found that the optimum character sizes are about 90 mm and 80 mm in height at a minimum for vertical and horizontal characters, respectively. These results showed that the optimum size of characters on graphic floor signs is about 90 mm.

Keywords: Graphic floor signs, Legible font size, Elderly people, Sign system

Introduction

In Japan, the Traffic Barrier-Free Transportation Act came into effect in 2000, and barrier-free public transportation facilities and buildings are being promoted. For the sign system, which is a visual display facility for leading guidance, the Act provides guidelines for information contents, expression style (including display system, lighting system, shape, and layout), and spatial location (Eco-Mo Foundation, 2020). For hanging type signs, this guideline describes the display height, layout position, layout interval, etc., so that the signs can be visually identified from a distance while moving.

On the other hand, for visually impaired and elderly people with decreased visual acuity, it is difficult to use these signs in some cases because they cannot get close enough to these signs to read them. In response to this problem, the authors have been developing pavement guidance signs mainly to support pedestrian movement around railway stations. Kitagawa (2012) examined the size, shape, and contents of pavement guidance signs based on the evaluation by five low-vision persons, installed prototype signs around two railway stations, and conducted a questionnaire survey of station users. Results showed that the graphic floor signs were easy to find and understand in railway stations where there were relatively few passengers. Omori, Yanagihara, Kitagawa and Ikeda (2014, 2016) conducted a walking experiment on low-vision persons, elderly persons, and sighted persons as subjects using prototype pavement guidance signs made experimentally by Kitagawa, finding that graphic floor signs were more legible than hanging signs. It was found that the range of visibility of graphic floor signs was completely different depending on the non-elderly, elderly, and low-vision people, and that a guide to determining the size of legible characters is necessary.

Therefore, in this study, we aimed to verify the legibility of characters installed on the floor. The test was conducted on 30 non-elderly and 30 elderly people, about Japanese Industrial Standards (JIS) S 0032 “Guidelines for the elderly and people with disabilities - Visual signs and displays -Estimation of minimum legible size for a Japanese single character”. This standard provides a method for estimating the minimum legible size for a Japanese single character of Hiragana, Katakana, Arabic numerals, and Kanji under various environments for observers of any age from young to elderly people. This standard assumes that the subjects face directly to the characters and that they are not required to read the characters written on the floor. Therefore, in this study, we estimate the minimum sizes of legible characters while changing the size and direction of the characters placed on the floor. In addition, the size of easy-to-read characters for graphic floor signs is examined.

Among the past research on station guide signs, Zheng et al. (2008a, 2008b), conducted surveys on station guide signs and search behaviour at above-ground and underground stations, describing that long-distance movement at above-ground stations require detailed information such as maps and that several information signs must be provided especially at intersections. Ikeda, Yoshida and Hirate (2017) conducted web questionnaires to evaluate the temporary signs installed additionally by station staff and reported about the installation height, concluding that these signs are often installed at eye level. However, these studies make no mention of graphic floor signs. Yusue et al.(2018a, 2019b), conducted web questionnaires of users to evaluate positive or negative elements of temporary signs installed additionally by station staff, stating that graphic floor signs fall into an intermediate category. However, the viewability of graphic floor signs is not described. Harada (2017) conducted a legibility experiment of the route maps and fare charts installed at station ticket gates, and showed that legibility is affected by the visual distance, character size, and luminance. Taso et al.(2020) evaluate the sign from the perspective of universal design and propose a new sign system based on UD. Rousek and Hallbeck (2011) evaluate the effects of colour contrasts of healthcare pictograms for participants with both non-impaired and impaired vision. High-contrast signage with consistent pictograms involving human figures (not too detailed or too abstract) is most identifiable. Kusumarini et al. (2012), examine the user's experience in shopping malls to get information and guidance about direction from the applied signage system. The experiences discussed in terms of universal design. Shi et al. (2020) studied a wayfinding sign in metro stations with two colour combinations of signs regarding the legibility. Achromatic colour combinations were more legible than chromatic colour combination.

As described above, few studies on guide signs have mentioned graphic floor signs, and there is no study on their legibility. Therefore, this study aimed to verify the legibility of the characters of graphic floor signs installed on the floor.

Figure 1. Examples of graphic floor signs(left: guide to elevators and platforms, right:guide to gates and bus stops)

Methodolgy

The experimental overview is shown in Table 1. Experiments on minimum legible sizes of characters (Experiment A) and experiments on readability (Experiment B) were conducted in that order. To adjust the eye level, the subject sat in a chair, and the height of the top of the head was 164 cm. The vertical viewing angle is about 18 degrees. For the visual acuity test, a hand-held Landolt ring was used. The experiment was carried out in a dark room with controlled illuminance. After explaining the contents of the experiment to the subjects, the experiment was carried out visual acuity test, experiment A, and experiment B. Subjects were given time for light adaptation in the experiment room. In addition, the investigator instructed the subject not to look into the experimental board.

The subjects were 30 young and 30 elderly people with no history of visual trouble. The young people were mainly university students, and the elderly people were recruited by temporary staffing companies.

Table 1. Experimental overview

Subjects	No medical disorders in the eyes. The older (65 or more): 30 people The younger (20s): 30 people
Experiment condition	Luminance level of blank space between letters on the board used in Experiment A in Figure-1：100 cd/m2 Average illuminance in a dark room: 500lx Viewing distance: 5 m

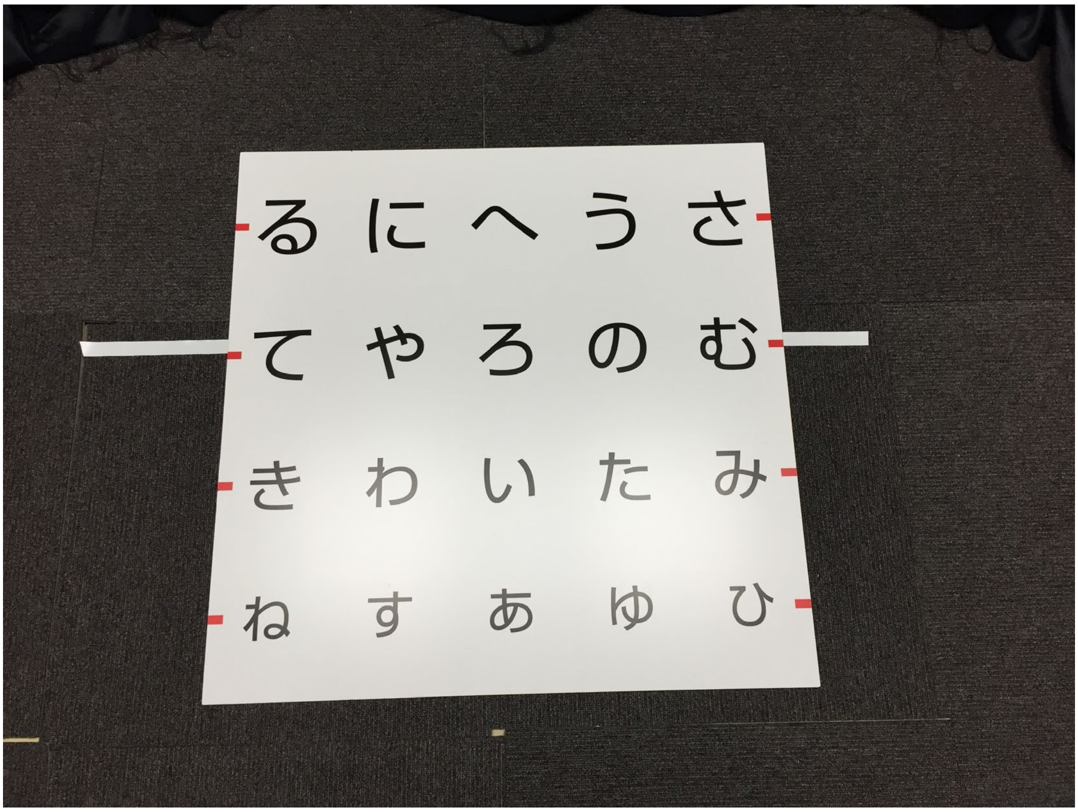
Experiments on minimum legible sizes of characters (Experiment A)

Experimental method of minimum legible sizes of characters in graphic floor signs

In Experiment A, the size of characters is changed using the board of Figure 2 to investigate the minimum legible sizes of characters on the floor surface for each subject. The minimum legible size of characters was the smallest character size in which one Japanese hiragana character can be read correctly 3 times or more out of 4 times. The character heights in Experiment A were 80, 70, 60, 50, 40, 35, 30, 25, and 20 (all dimensions in mm), and they were presented in descending order. The Japanese typefaces are mainly Mincho and Gothic. For guide signs, Gothic font is recommended in Barrier-free maintenance guidelines (Eco-Mo Foundation, 2020). The font size is commonly expressed in points, but in the guideline, the character size of the sign is expressed in mm as the character height.

The results of this survey are compared with the minimum legible characters calculated by the estimation formula of JISS0032 to obtain the coefficient of minimum legible characters on the floor surface (the average of minimum legible sizes of characters on the floor surface in Experiment A is calculated by the average of minimum legible sizes of characters calculated by the estimation formula of the minimum legible sizes of characters of JISS0032). By multiplying the minimum size of legible characters estimated from JISS0032 by this coefficient, the minimum size of legible characters can be corrected to the one written on the floor surface.

Image 2. Board for experiment A (Hiragana index of used for vision test)



How to calculate minimum legible sizes of characters

The minimum legible sizes of characters are estimated from the estimation formula of JISS0032. The visual acuity Vo at a luminance of 100 cd/m^2 is determined by the visual distance and age. Table 2 shows the visual acuities of subjects by age. Then, the visual acuity V in observation conditions is given by the expression V=kVo, into which Vo is substituted (luminance correction coefficient k=1). The size coefficient S can be determined by the following expression, S=D/V, where D represents the visual distance and is 5 m in this experiment. Finally, the equation for the minimum size of legible characters Pmin (all dimensions in pt) can be determined by the expression Pmin=aS+b from the JIS Standard, where a and b represent the coefficients of Gothic hiragana from the JIS Standard Appendix, and a=6.4, b=3.0. In this study, we change the character size as 1pt = 0.35 mm. The font type used in this study was Gothic, which is commonly used in Japanese guide signs.

Table 2. Visual acuity Vo of young and elderly people at a luminance of 100 cd/m²

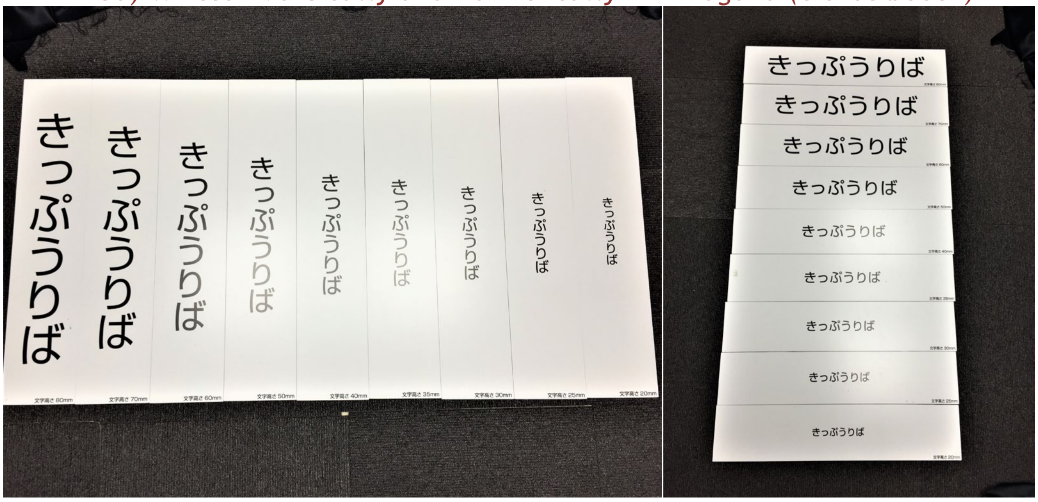
Subjects age	Acuity(Vo)
20	1.63
21	1.62
22	1.6
23	1.59
25	1.55
65	1.04
66	1.03
67	1.02
68	1.01
69	1
71	0.98

Experiments on readability (Experiment B)

In Experiment B, six types of boards written vertically and horizontally in Hiragana (ticket booth) of Figure 3, Katakana (elevator), and Kanji (general information centre) were presented to the subject in three directions: forward, sideward, and backward to evaluate the readability. The boards used in the experiment are shown in Figure 2. We used a total of 54 boards written both vertically and horizontally with 9 different character heights for experiment A and in 3 different characters - Hiragana, Katakana, and Kanji. The 54 boards were presented randomly to the subjects. The readability rating is as follows: 0. Unreadable, 1. Very hard to read, 2. Rather hard to read, 3. Neither, 4. Rather easy to read, and 5. Very easy to read. Based on these results, the average of the evaluation values of each subject is plotted to obtain an approximation expression. The optimum character size (character height of readability evaluation value 4.5) for the floor surface is estimated from the approximation expression.

Figure 3. Board written in Hiragana and in Katakana

3a) Written vertically and horizontally in Hiragana (ticket booth)



3b) Written vertically and horizontally in Katakana (elevator)

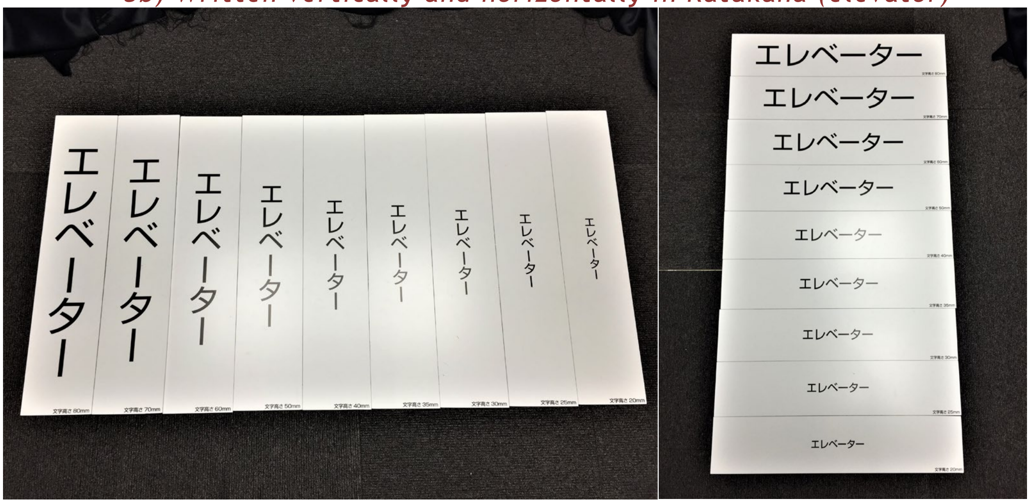
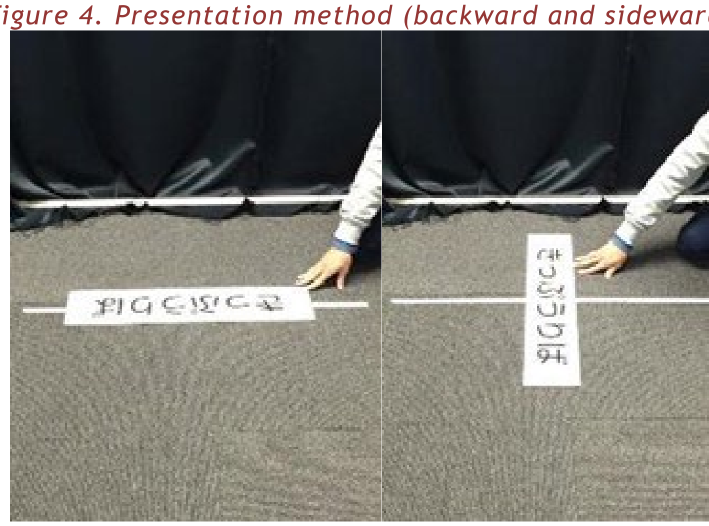


Figure 4. Presentation method (backward and sideward)



Results

Experiments on minimum legible sizes of characters (Experiment A)

In Experiment A, the average of the minimum legible sizes of characters on the floor surface was 21.33 mm for young people while the average for the elderly was 28.83 mm (Table 3).

Then, the minimum size of legible characters by JISS0032 of each subject is obtained. The results are shown in Table 4. The minimum readable character sizes for young and elderly people were 8.02 mm and 14.31 mm, respectively.

These results show that the characters are readable at a visual distance of 5 m for young people facing directly to the characters when the character height is 8.02 mm, but the height must be 21.33 mm as for the characters written on the floor. Similarly, the characters are readable for the elderly facing directly to the characters when the height is 14.31 mm, but the height must be 28.83 mm in the case of the characters written on the floor. These results showed that the coefficient of minimum legible characters on the floor surface was 2.66 (21.33/8.02) for young people and 2.02 (28.83/14.31) for the elderly, and that when installing a sign on the floor surface, the character size needs to be at least twice that for a normal sign.

However, since the minimum character size was 20 mm in this experiment, the size of minimum legible characters on the floor surface for young people can be even smaller. Thus, the coefficient of minimum legible characters on the floor surface is larger than that for the elderly.

Experiments on readability (Experiment B)

In Experiment B, we separated vertical characters from horizontal characters according to the calculation method in 2-2, and set the largest value of optimum character sizes including the young and elderly to the optimum character size required for each character type.

As a method for calculating an optimum character size, Fig. 1 shows an evaluation approximation line of a Japanese word for “ticket booth” written vertically in hiragana. The readability was evaluated by young people from the front. In JISS0032, the readability evaluation value of 4.5 is used in this approximation expression y=0.057x + 0.5094 as a legible evaluation value. Thus, the evaluation value of 4.5 was also obtained in this study. The result is obtained as an optimum character size. Therefore, in this case, the optimum character size is 70.01 mm. All calculated results are shown in Table 6.

For young people, the optimum character sizes of hiragana (ticket booth) written vertically were 70.11 mm, 69.75 mm, and 78.04 mm when read forward, sideward, and backward, respectively. As for the elderly, the optimum character sizes were 68.50 mm, 70.34 mm, and 76.56 mm, respectively. In the case of horizontal writing, the optimum character sizes for young people were 67.31 mm, 73.26 mm, and 72.18 mm when read forward, sideward, and backward, respectively. As for the elderly, the optimum sizes were 67.12 mm, 72.85 mm, and 72.01 mm, respectively. If the largest value of these optimum character sizes is the optimum character size required for each character type, the optimum character sizes of hiragana written vertically and horizontally are 78.04 mm and 73.26 mm, respectively. The calculation was conducted on Katakana and Kanji in the same way. The results showed that the largest value is 90.96 mm when reading horizontally-written Kanji backwards. Therefore, the required character height is about 90 mm to read information written on the floor from a distance of 5 m.

Table 3. Experimental results of minimum legible sizes of characters written on floor surfaces

The younger	Minimum legible font size（mm）	The older	Minimum legible font size（mm）
No.1	20	No.1	25
No.2	20	No.2	30
No.3	20	No.3	25
No.4	20	No.4	30
No.5	20	No.5	20

The younger	Minimum legible font size（mm）	The older	Minimum legible font size（mm）
No.6	25	No.6	30
No.7	25	No.7	30
No.8	20	No.8	30
No.9	20	No.9	30
No.10	20	No.10	30
No.11	20	No.11	30
No.12	20	No.12	20
No.13	20	No.13	25
No.14	20	No.14	25
No.15	30	No.15	30
No.16	20	No.16	30
No.17	20	No.17	50
No.18	20	No.18	25
No.19	20	No.19	25
No.20	20	No.20	20
No.21	25	No.21	35
No.22	25	No.22	20
No.23	25	No.23	25
No.24	25	No.24	60
No.25	20	No.25	25
No.26	20	No.26	20
No.27	20	No.27	25
No.28	20	No.28	40
No.29	20	No.29	30
No.30	20	No.30	25
Average	**21.3**	**Average**	**28.8**

Table 4. Minimum size of legible characters

The older	Age	V	S	Pmin(pt)	Character height (mm)	The younger	Age	V	S	Pmin(pt)	Character height (mm)
No.1	65	0.8	6.3	43.0	15.1	No.1	22	1.6	3.1	23.0	8.0
No.2	71	1.0	5.0	35.0	12.3	No.2	22	1.6	3.1	23.0	8.0
No.3	66	0.8	6.3	43.0	15.1	No.3	22	1.6	3.1	23.0	8.0
No.4	67	1.0	5.0	35.0	12.3	No.4	22	1.6	3.1	23.0	8.0
No.5	71	1.0	5.0	35.0	12.3	No.5	21	1.6	3.1	22.8	8.0
No.6	67	0.8	6.3	43.0	15.1	No.6	22	1.6	3.1	23.0	8.0
No.7	65	1.0	5.0	35.0	12.3	No.7	21	1.6	3.1	22.8	8.0
No.8	67	1.0	5.0	35.0	12.3	No.8	21	1.6	3.1	22.8	8.0
No.9	66	1.0	5.0	35.0	12.3	No.9	22	1.6	3.1	23.0	8.0
No.10	65	0.8	6.3	43.0	15.1	No.10	23	1.6	3.2	23.2	8.1
No.11	67	1.0	5.0	35.0	12.3	No.11	22	1.6	3.1	23.0	8.0

The older	Age	V	S	Pmin(pt)	Character height (mm)	The younger	Age	V	S	Pmin(pt)	Character height (mm)
No.12	65	1.0	5.0	35.0	12.3	No.12	21	1.6	3.1	22.8	8.0
No.13	67	0.6	7.9	53.8	18.8	No.13	21	1.6	3.1	22.8	8.0
No.14	66	1.0	5.0	35.0	12.3	No.14	23	1.6	3.2	23.2	8.1
No.15	66	1.0	5.0	35.0	12.3	No.15	22	1.6	3.1	23.0	8.0
No.16	67	0.8	6.3	43.0	15.1	No.16	22	1.6	3.1	23.0	8.0
No.17	67	0.6	7.9	53.8	18.8	No.17	20	1.6	3.1	22.6	7.9
No.18	66	1.0	5.0	35.0	12.3	No.18	25	1.6	3.2	23.6	8.3
No.19	65	1.0	5.0	35.0	12.3	No.19	21	1.6	3.1	22.8	8.0
No.20	65	1.0	5.0	35.0	12.3	No.20	21	1.6	3.1	22.8	8.0
No.21	65	0.8	6.3	43.0	15.1	No.21	22	1.6	3.1	23.0	8.0
No.22	65	1.0	5.0	35.0	12.3	No.22	22	1.6	3.1	23.0	8.0
No.23	67	0.8	6.3	43.0	15.1	No.23	21	1.6	3.1	22.8	8.0

The older	Age	V	S	Pmin(pt)	Character height (mm)	The younger	Age	V	S	Pmin(pt)	Character height (mm)
No.24	68	0.4	12.5	83.0	29.1	No.24	21	1.6	3.1	22.8	8.0
No.25	65	1.0	5.0	35.0	12.3	No.25	22	1.6	3.1	23.0	8.0
No.26	66	1.0	5.0	35.0	12.3	No.26	22	1.6	3.1	23.0	8.0
No.27	65	1.0	5.0	35.0	12.3	No.27	22	1.6	3.1	23.0	8.0
No.28	67	0.6	7.9	53.8	18.8	No.28	21	1.6	3.1	22.8	8.0
No.29	69	0.8	6.3	43.0	15.1	No.29	21	1.6	3.1	22.8	8.0
No.30	68	0.8	6.3	43.0	15.1	No.30	21	1.6	3.1	22.8	8.0
				Average	**14.3**					**Average**	**8.0**

Figure 1. Example of approximation expression in Experiment B

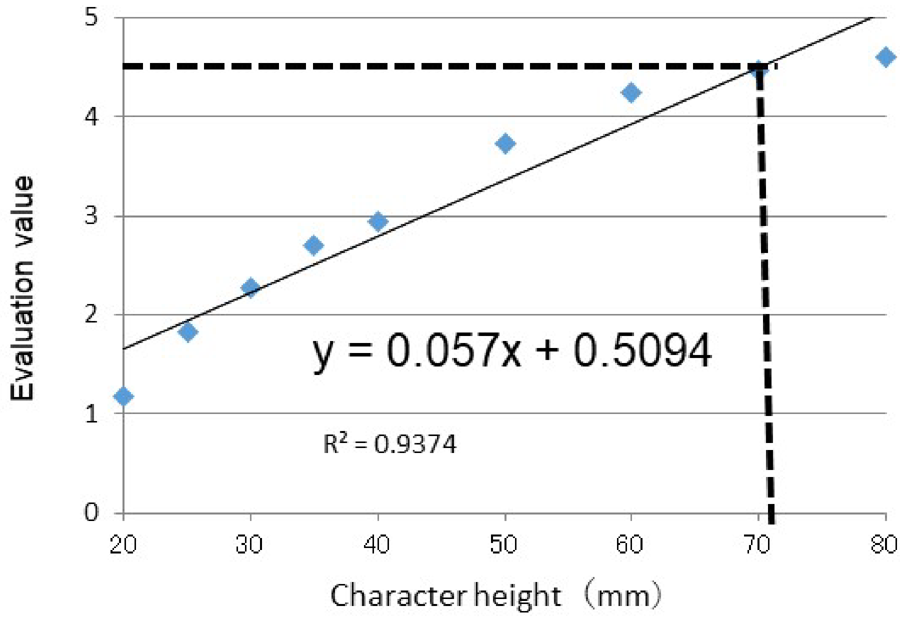


Table 5. Optimum character size for each character type

Character type	Younger subjects Forward	Younger subjects Sideward	Younger subjects Backward	Older subjects Forward	Older subjects Sideward	Older subjects Backward	The good level of legible font size
Vertical writing Hiragana	70.0	69.8	78.0	68.5	70.3	76.6	78.0
Horizontal writing Hiragana	67.3	73.3	72.2	67.1	72.9	72.0	73.3
Vertical writing Katakana	68.4	72.0	73.3	67.2	65.3	68.1	73.3
Horizontal writing Katakana	67.6	73.2	72.5	66.2	68.3	69.3	73.2
Vertical writing Kanji	75.6	77.9	91.0	73.4	72.6	82.6	91.0
Horizontal writing Kanji	70.1	78.9	77.0	68.4	74.7	74.0	78.9

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Discussion

The Barrier-free maintenance guidelines (Eco-Mo Foundation, 2020) stipulates that the character height is 20 mm or more at a visual distance of 4 to 5 m as an index of the size of characters used in guide signs. In the experiment on readability (Experiment B), we found that the optimum character sizes are about 90 mm and 80 mm in height at a minimum when written vertically and horizontally, respectively. These results showed that the characters in graphic floor signs should be much larger than those in normal guide signs. However, since the visual distance is 5 m in this study, an easy-to-see distance is not necessarily ensured (with a visual angle of about 18 degrees). In the future, by clarifying an easy-to-see distance of graphic floor signs, it is possible to review the optimum character sizes from an easy-to-see distance.

The optimum character sizes evaluated by young people and elderly people showed that the optimum character sizes for young people are larger than those for elderly people. The young subjects consisted of students while the older subjects were paid and hired, so the older subjects may have tried their best to see the characters. However, although there are differences in character height, the results of t-test showed that there is no significant difference in the slope of the approximation expression of each graph. This suggests that the evaluation values of young people and the elderly have the same tendency, and that it is appropriate to estimate legible character sizes from the approximate curve obtained in this study (Table 6).

Sagawa and Katakura(2013) report that the Mincho is harder to read than the Gothic. It also reports that Kanji is harder to read than Hiragana and Katakana. In Japan, Kanji, Hiragana, and Katakana are commonly used. In recent years, Chinese, Korean, and Roman characters have been used as guidance signs. Gold et al.(2009), compared the legibility of two fonts (Tiresias Signfont and FF Transit Front Neg Normal). Tiresias was recommended to the transit company for new signage.

Colour combination influences legibility (M.V.Mclean,1965). The test materials used in the experiments were letter and word boards that displayed only black letters on white background. We used the colour scheme used in visual acuity tests.

Since various characters and colour combinations are used in the guide sign, it is necessary to consider different languages, font types and colour combinations.

Table 6. Slope of approximation expression

Character type	Younger subjects Forward	Younger subjects Sideward	Younger subjects Backward	Older subjects Forward	Older subjects Sideward	Older subjects Backward
Vertical writing Hiragana	0.057	0.057	0.059	0.061	0.061	0.063
Horizontal writing Hiragana	0.052	0.058	0.053	0.051	0.059	0.052
Vertical writing Katakana	0.052	0.050	0.057	0.049	0.055	0.062
Horizontal writing Katakana	0.050	0.055	0.054	0.050	0.056	0.046
Vertical writing Kanji	0.062	0.057	0.056	0.069	0.068	0.065
Horizontal writing Kanji	0.056	0.063	0.062	0.062	0.074	0.064

Conclusion

In this study, we estimated the minimum legible sizes of characters and the optimum characters written on the floor surface for sighted persons in reference to the JIS Standard. In the experiment on the minimum legible sizes of characters (Experiment A), we found that the minimum legible sizes of characters written on the standing surface can be corrected to the minimum size of legible characters written on the floor surface by multiplying with the coefficient of minimum legible characters on the floor surface by 2 to 3 times. In the experiment on readability (Experiment B), we found that the optimum character sizes are about 90 mm and 80 mm in height at a minimum for vertical and horizontal characters, respectively. These results showed that the optimum size of characters on graphic floor signs is about 90 mm.

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