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Level-Up! Comparing accessibility features based on gameplay performance.

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Abstract: This study examined the impact of accessibility cues on hearing and non-hearing players' performance in a 3D, third-person shooter video game. The intent was to resolve the debate about whether accessibility features unfairly lessen the difficulty of video games for hearing players. In this study, players completed the video game with three accessibility cue conditions (visual, haptic, both) and were assigned to one of two audio conditions (audio, no audio). Hard-of-Hearing (HOH) participants played the video game under all three cue conditions. Performance data indicated that accessibility cues helped players without audio without affording an unfair advantage to those with audio. Qualitative data indicated that participants' beliefs about the cues aligned with the popular—but inaccurate—belief that accessibility cues afforded them an advantage. This research is a first step in examining accessibility cues in the context of video games. The results can be applied to video game design as well as to other fields that use cues to convey information—such as human perception—and as a method for designing cues for training people in the medical, aerospace, and education fields.

Keywords: videogames, accessibility, haptics.

1. Introduction

The experience of watching movies in the theatre has become a modern cultural norm that provides both entertainment and meaningful social interaction. However, a film with important dialogue but no audio or captioning would not be well-received. This scenario illustrates the experiences of Deaf and Hard-of-Hearing (HOH) people any time they visit a public theatre. People probably would not pay for this kind of experience.

Hearing loss greater than 40 decibels (i.e., difficulty understanding speech) is experienced by at least 466 million people around the world. Although hearing loss is disproportionately present among individuals 65 and older (WHO, 2020) it can happen to anyone, regardless of age. People who are Deaf and HOH want to share the same experiences as everyone else, but this can be difficult when human-made environments fail to follow the principles of universal design. Universal design allows most people to use or experience a product without adaptation, no matter their age or abilities (Story et al., 1998; Story, 2001). Ideally, accessibility features are so well-integrated into the design of a product that they are seen as "normal" and inconspicuous

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(Story, 2001). While universal designs are legally required for physical spaces, modern communications, and digital media (ADA, 1990; DOJ, 2010; FCC, 2010), no such requirements exist for non-speech accessibility features (e.g., sound effects, audio cues) in video games.

Some video game companies incorporate and share details about accessibility features through pre-release announcements. For example, Ubisoft (2019) tweeted a list of all the accessibility features included in Ghost Recon Breakpoint, including controller remapping, secondary audio and haptic cues, and user-adjusted visual contrast. Details on video game accessibility features are also spread independently through the gaming community in the form of accessibility-specific reviews (e.g., https://caniplaythat.com). Despite these efforts, many developers fail to implement accessibility features. In some instances, the failure to provide accessibility features has been taken up by members of the gaming community who produce game modifications (Bierre et al., 2005). These efforts require significant time and skill, placing undue burden on volunteers.

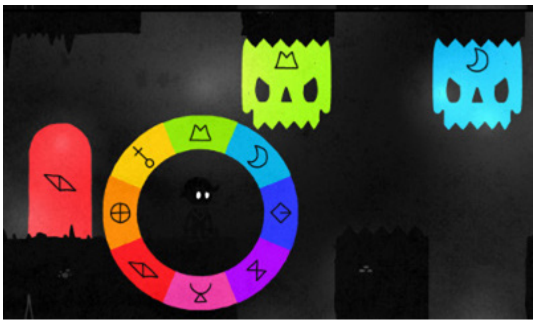
While advocates push for additional accessibility features in video games (Porter, 2014; Bierre et al., 2005), others resist due to concerns that accessibility features would lessen the difficulty of video games and reduce players' enjoyment (e.g., Metro UK, 2021). This paper reviews empirical evidence that supports the competing claims of each perspective: namely, whether accessibility features unduly help or hinder the players who choose to use them. We then report the results from an empirical study that was designed to test these hypotheses using a custom-designed video game that incorporated accessibility cues for Deaf and HOH players.

1.1. Accessibility in video games

Video games can be difficult for Deaf and HOH people to play because they often use auditory cues to convey important information. For example, a game may use footsteps to indicate an approaching enemy character or gunfire to signal an enemy's attack. These cues are easily missed by people who cannot hear the sounds or who are playing with the volume off. When auditory cues are the only means by which a display conveys important information, it significantly impacts some players' experience. Previous research has shown that removing sound associated with even a simple action—confirming a selection—increases players' reaction times and decreases their presence within the game world (Jørgensen, 2008). Developers who plan accessibility features from the start of the game create better products and can market their products to a broader audience (Powers, 2015).

Figure 1-left. Screen captures of Hue with visual accessibility features.

Figure 1-right. Screen captures of Hue without visual accessibility features.



Accessible video games ensure essential information is conveyed with a multi-cue display that spans two or more sensory modalities (Ng, Nesbitt, 2013; Barlet, Spohn, 2012; Ellis et al., 2020). For example, the game Hue has an option to add symbols that correlate with each colour (see

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Figure 1), providing important pattern information to those who cannot easily discriminate colours. Visual and haptic cues can also be used in this manner, such as when a player taking damage hears an audio groan alongside decrements in an on-screen health bar and a controller rumble (see Figure 2).

Figure 2. Screen capture from The Legend of Zelda: Breath of the Wild. Here, an auditory grunt and haptic rumble indicate that an enemy has been hit. Additional details about the intensity of the attack are available in a visual health bar (icons added to original screenshot).

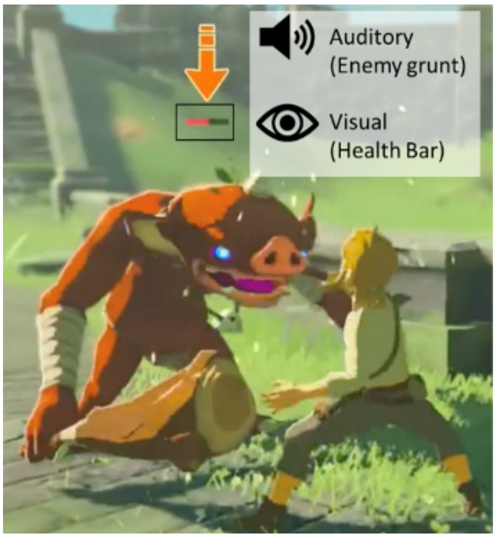
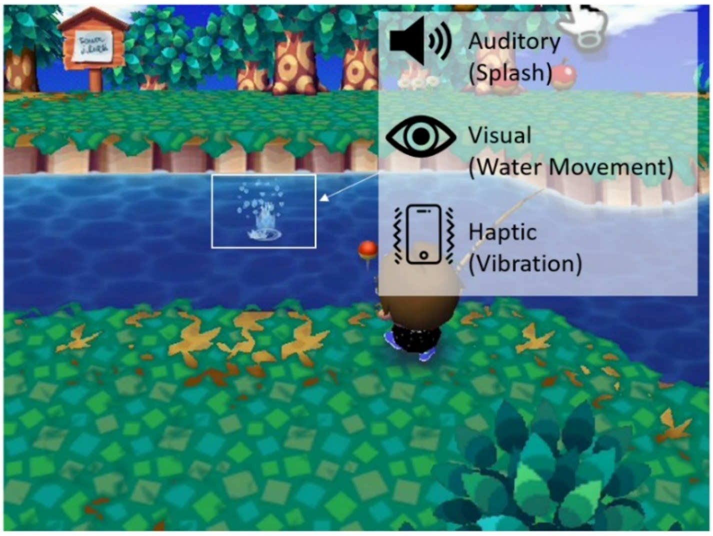


Figure 3. Screen capture of a fishing task in Animal Crossing. Here, an auditory splash, visual water movement, and a haptic pulse all indicate that the fish has bitten the line (icons added to original screenshot).



1.2. Multi-cue displays

There are three types of multi-cue display mappings: complementary, redundant, and conflicting displays (Ng, Nesbitt, 2013; Pao, Lawrence, 1998). Accessibility cues typically present as complimentary displays or redundant displays. Complementary displays use different sensory modalities to convey information with varying levels of detail (Ng, Nesbitt, 2013). For example, a game developer may use an auditory grunt and controller rumble to indicate that an enemy

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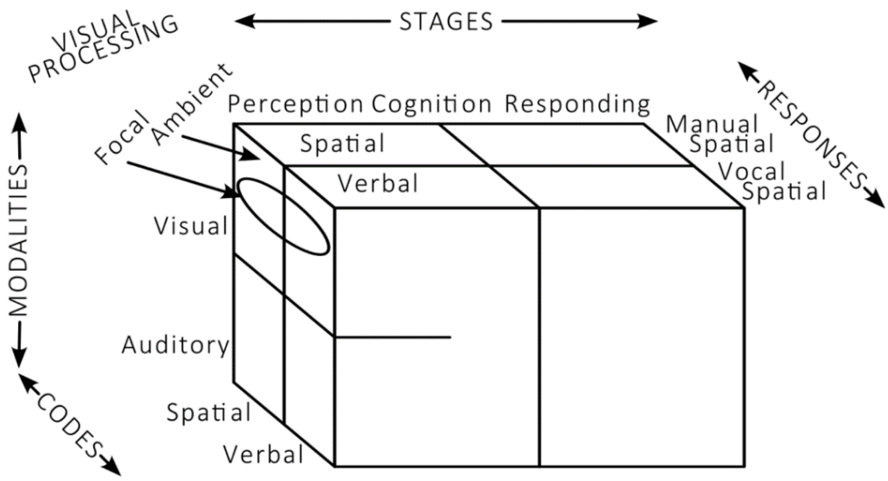
character is taking damage. Additional information about the extent of damage is indicated by a visual decrement in the enemy's health bar (see Figure 2). Redundant displays use different sensory modalities to convey information at similar levels of detail. For example, in a fishing game, a visual splash, a splashing sound, and a controller vibration all tell the player that a fish bit the line (see Figure 3). Intuitively, complimentary and redundant displays should increase task performance, increase users' confidence, and decrease their perceived workload (Ng, Nesbitt, 2013).

1.3. Multiple resource theory

While multi-cue displays provide a player with additional opportunities to identify relevant cues, they also create information-rich environments where people may struggle to attend to relevant information (Rosenholtz et. al., 2007). Wickens' (1980, 1991) multiple resource theory (see Figure 4) provides a useful framework for understanding the circumstances under which multi-cue displays can negatively impact performance. Multiple resource theory assumes that players' cognitive and perceptual abilities are limited by the amount and type of information they attend to, as well as when and how they attend to that information.

Figure 4. A graphical depiction of points of overlap in aspects of peoples' cognitive and perceptual resources (Wickens, 2008).



A person playing a video game must see (perception), think about (cognition), and respond to information. These stages of processing involve separate pools of resources and can be performed at the same time. For example, a player might notice a controller rumble (perception) while actively controlling their character (response) and planning their next move (cognition). Selective attention (Broadbent, 1958) allows a player to determine which information is perceived and considered for subsequent cognition and responding. It is informed by a player's experience: inexperienced players take a bottom-up approach by which attention is drawn to notable characteristics of the stimuli (e.g., motion; Navalpakkam, Itti, 2006), whereas experienced players can use a top-down strategy to constrain their attention to areas of importance that are identified based on previous knowledge (Navalpakkam, Itti, 2006; Soto et al., 2006). Therefore, players have varying degrees of control over when and how they attend to the different cues that are presented during gameplay.

Problems arise when multiple pieces of selected information occupy the same stage of processing. This is especially true when this information involves the same modality. For example, an auditory ping allows players to easily track the collection of items during a visually stimulating fight. A visual-only inventory, in contrast, would substantially impair gameplay by requiring a player to scan for acquired items while also attempting to track enemy locations. The superiority of auditory cues in visual environments has been demonstrated across a variety of contexts (e.g., Wickens, Sandry-Garza, Viulich, 1983). Similarly, studies suggest that haptic cues are equally or more beneficial in conveying information during visual tasks (Van Erp, Van Veen, 2001; Medeiros-Ward et al., 2010; Bovard et al., 2018; Sklar, Sarter, 1999). In addition, haptic cues have many benefits that make them a viable option for interfaces: they are transient, can capture attention with minimum intrusion, are omnidirectional, and can be presented in many locations on the body (Lu et al., 2011; Sklar, Sarter, 1999). Therefore, it is recommended that auditory or haptic cues be used to convey information in highly visual environments (for a review see Lu et al., 2011).

1.4. Multiple resource theory as a computational model

Wickens (2002) provides a computational model for predicting the degree to which additional information conflicts with a task's required cognitive or perceptual resources. In this model, overlapping resources are noted in a conflict matrix that represents the relative degree to which the resources cannot be shared. The resource demand of each task is modelled by a demand vector, which can be aggregated with the conflict matrix to yield a single total task interference value. This interference value can then be compared with other task interference values from other task configurations to make a relative judgement on which configurations have the highest resource conflict (and thereby, the lowest performance).

Third person shooter videogames require players to visually track and respond to many on-screen events. Players using sound (e.g., background music) must also listen for information about enemy locations (e.g., footprints) and successful attacks (e.g., groans). Players without access to sound cannot attend to auditory information of any kind, placing them at a distinct disadvantage. Therefore, videogames are highly visually demanding for both hearing and non-hearing players, and are moderately aurally demanding for players using sound.

Table 1. Resource conflicts predicted by Multiple Resource Theory (Wickens, 2002).

Additional Accessibility Cues	Total Conflict	HOH	Hearing
No cues	0.33	x	
Attending to visual cues	0.91	x	
Attending to haptic cues	1.03	x	
Attending to auditory cues	1.09		x
Attending to visual and haptic cues	1.43	x	
Attending to auditory and haptic cues	1.61		x
Attending to auditory and visual cues	1.49		x
Attending to auditory, visual, and haptic cues	2.02		x

Wickens' (2002) computational model offers clear predictions regarding the resource demands placed on players who need accessibility cues (e.g., HOH individuals) and those who can use but do not require them (i.e., hearing individuals). Contrary to intuition (e.g., Metro UK, 2021) and best practice (e.g., Ng, Nesbitt, 2013), Multiple Resource Theory suggests that hearing players who use accessibility cues act to their detriment by increasing their total cognitive load (see Table 1). The negative consequences of this cognitive load should be particularly pronounced under high workload conditions (i.e., when the videogame is especially hard; Wickens, 2002 Stanton et al., 1997).

1.5. Current study

The purpose of this study was to test the impact of accessibility cues on performance and to determine players' accessible cue preferences. We addressed these research questions within the context of a video game that used visual, auditory, and haptic directional cues to indicate the relative direction of a new oncoming enemy relative to the player. This game was primarily a visual experience that included some sound effects, such as firing weapons and groans following damage to the enemies or the player.

Multiple Resource Theory and the literature on redundant displays offered competing hypotheses regarding participant performance:

- H1A (Redundant Displays): Additional cues will act as a redundant display and improve or have no effect on performance.
- H1B (Multiple Resource Theory): Accessibility cues will improve the performance of players without audio; additional cues will act as a conflicting display and impair performance.

Table 2. Information about participants' gameplay habits.

Additional Accessibility Cues	Hearing	HOH
M (SD) hours weekly gameplay	15.6 (12.9)	9.2 (15.0)
N considering self "gamer"	28	2
Gaming platforms used		
None	4	1
PC	29	0
Console	26	0
Mobile phone	19	3
VR	7	0
Other	2	0

2. Methodology

2.1. Participants

Thirty-nine hearing participants (16 females; Mage = 25.5) and 4 HOH participants (1 female; Mage = 33.5) were recruited from the Wichita State University campus community. Recruitment was conducted using the SONA experiment management system, recruitment flyers in newsletters, and word-of-mouth. Hearing participants received research credits, while HOH participants received a lab-themed mug. Information about participants' gameplay habits is presented in Table 2; gameplay information was unavailable from one hearing participant due to researcher error. This research complied with the American Psychological Association's code of ethics and was approved by the institutional review board at Wichita State University.

2.2. Third-person shooter videogame

Participants played a 3D, third-person shooter (TPS) videogame developed with the Unity game engine (Unity, 2019; source code is available through GitHub (https://github.com/ChaMP-Lab/SurvivalShooter.git). Players controlled a character trapped in a nightmare with stuffed animal zombies. The stuffed animals moved towards and attempted to harm the players' character. The players, in turn, evaded and eliminated the stuffed animals using a toy gun. Each experimental session lasted 60–80 minutes, which provided enough time for the players to meet their goal of completing a short tutorial and passing 20, two-minute levels of the game.

Each level started without any stuffed animals; new stuffed animals appeared randomly at pre-determined locations every three seconds until the game space contained 30 enemies. At this point, new stuffed animals would only appear as existing ones were eliminated. Players were incentivized to eliminate enemy characters through game elements: a visual score counter tracked kills, enemies groaned upon receiving damage and displayed a death animation when killed, and damage received by the player hindered their progress and increased the amount of time that they had to spend in the research session.

Figure 5. Participants' view of the play screen. The visual accessibility cue alerts the player to the direction of oncoming enemies.

Directional cues signalled approaching stuffed animals. These cues were deployed the first time each enemy crossed a predetermined threshold (see Figure 5) and were determined based on each stuffed animal's location relative to the player's character. Specifically, haptic cues vibrated the appropriate side of the controller; visual cues depicted directional arrows; and audio cues (a monster groan) were played to the appropriate side of the headphones. When enemies crossed the threshold at the same time, the cues were given one after the other. The same threshold that triggered a new-enemy-cue also served as a barrier to restrict the player's movement to the lower area of the world, affording them more horizontal than vertical freedom.

Players started each level with 100 hit points of health. Each time a stuffed animal touched the character, the attack dealt 10 hit points of damage. The character also shouted "ouch," the screen flashed red, and a health bar in the lower left corner was reduced by 10% of its initial size. When the player's health was fully depleted, the character lost one of three total lives. When a player lost a life, the level timer paused, and they waited on a 30-second loading screen. Once the game resumed, the health bar was restored to full size, but players had one fewer life icon next to the health bar. If the player lost all three lives, they proceeded to the next trial. The player's health and lives were restored at the start of each level.

Players used an Xbox One controller to interact with the game. The left analog joystick moved the character around the screen. The right analog joystick aimed the weapon, which could be fired with the right trigger button at the top of the controller. All other controls were disabled for this application. This controller configuration was selected for its prevalence in TPS videogames.

2.2.1. Difficulty manipulation

The difficulty of the videogame was manipulated at the start of each level by changing the enemy characters' hit points (enemies with more hit points are harder to eliminate). A Halton sequence (Halton, Smith, 1964) was used to select values evenly from a range of 20 to 400 hit points. This range was determined through a previous study (Vangsness, 2019). Selected values were randomized for each participant using the Fisher-Yates reshuffling algorithm (Black, 2005). Each participant had a different set of random difficulties, but those difficulties were presented in the same order for each cue-block.

2.2.2. Accessibility cue manipulation

Players' experience with accessibility cues was determined by two manipulations. Firstly, half of the hearing players and all the HOH players were required to complete the videogame with headphones but without any sound (the no audio condition) to simulate the most extreme experiences of Deaf/HOH players. Secondly, the presence of visual and haptic cues was manipulated within-subjects by changing the type of directional cues provided to participants every five levels. Presentation order was counterbalanced using a William's Latin Square design (Fisher, 1992). Together, these manipulations produced 8 conditions in a fractional factorial design (Fisher, 1992; see Table 1). On-screen instructions described the cues to players each time they changed.

2.2.3. Tutorial level

After listening to and reading game instructions, participants completed an eight-minute tutorial at the lowest difficulty setting. During the tutorial, participants gained two minutes of practice with each within-subject cue condition. These cue conditions were presented in the same counterbalanced order as was used in the primary levels.

2.2.4. Post-task survey

After the experimental task was completed, the participants completed a demographic questionnaire and an opinion survey about their experiences with the different cues. In this opinion survey, participants rated the perceived efficacy of each accessibility cue condition on a scale from 1 (not at all effective) to 5 (extremely effective). Copies of these surveys are available on the project's Open Science Framework page (https://osf.io/axub6/).

3. Results

A multi-level censored gamma regression was conducted using the brms package in R (Bürkner, 2019). Posterior distributions were estimated by drawing 20,000 samples over four chains. The first 10,000 samples served as the burn-in period and were discarded. Parameters were estimated using uninformed priors. The model's fixed effect structure included the main effects of participants' between-subject audio condition, within-subject cue condition, and within-subject workload (i.e., enemy HP). The fixed effect structure also included all two- and three-way interaction terms, as well as hours of videogames played per week to control for player experience. The random effect structure allowed the model intercept to vary by participant to control for unmeasured individual differences that might affect players' average performance. All variables were effect-coded and means-centred to reduce multicollinearity within the model and to allow the intercept to represent participants' average video game performance. Complete output from the model is available on the project's OSF page.

3.1. Hypothesis tests

3.1.1. Audio cues improved performance

A planned comparison indicated that on average, players who received an auditory cue performed better than those who did not (Bdiff = 1.33, 95% credible interval = 0.42, 2.23]). Similarly, participants without audio cues were more strongly affected by changes in difficulty (Bdiff = 0.73, 95% credible interval = 0.35, 1.11]). This suggests that audio cues helped participants play the game better, and allowed them to better respond to changes in game difficulty.

3.1.2. Accessibility cues helped those without audio

Planned comparisons also indicated that players without audio were assisted by accessibility cues. Haptic cues reduced the amount of damage players took by an average of 32 points/second (Bdiff = -1.44, 95% credible interval = -1.10, -1.77]) and visual cues reduced the amount of damage players took by an average of 27 points/second (Bdiff = -1.03, 95% credible interval = -1.03, -1.37]). Visual and haptic cues together reduced the amount of damage players took about as much as visual cues did alone (an average of 25 points/second, Bdiff = -0.91, 95% credible interval = -1.24, -0.57; see right panel of Figure 6).

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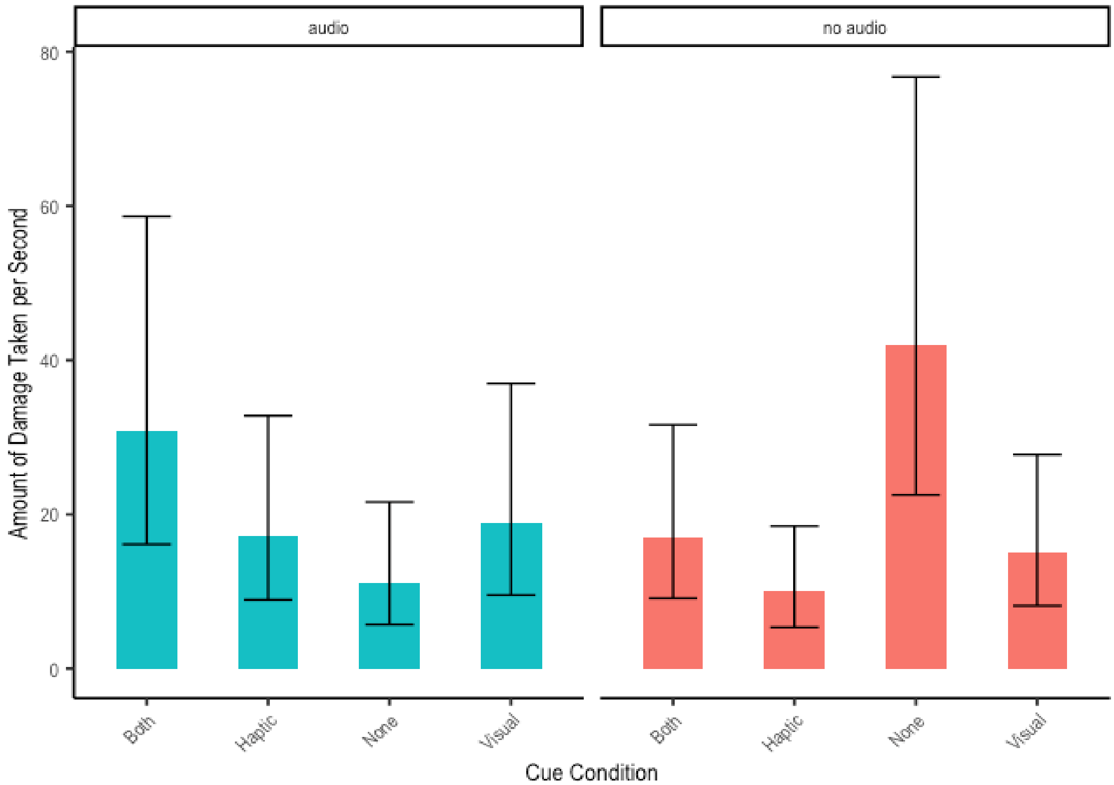
Figure 6. Accessibility cues' impact on performance depends on whether players have access to audio cues. Error bars represent 95% credible intervals.



3.1.3. Accessibility cues did not benefit those with audio

A different pattern was found among players who used the game's audio. These participants performed best when there were no additional cues. Adding haptic or visual cues did not substantially affect the amount of damage players took; however, adding haptic and visual cues together strongly impaired participants' performance – the amount of damage players took was increased by around 20 points/second under these circumstances (Bdiff = 1.02, 95% credible interval = 0.54, 1.51]; see left panel of Figure 6).

3.2. Exploratory analysis

3.2.1. Participants' perceptions did not align with reality

A multi-level linear regression was used to determine whether participants' beliefs about cue efficacy aligned with their performance in the game. The model included the main effects of log-transformed average rate of damage taken under each cue condition (performance), cue condition, and audio condition, as well as their higher-order interactions. Average rate of damage was log-transformed to accommodate the non-linear relationship between the average amount of damage players took and cue preference (additional detail are provided in the supplemental materials). The random effect structure allowed the intercept to vary across participants to control for other individual differences that affect judgment. These variables were regressed against perceived efficacy.

Players rated accessibility cues as equally effective, regardless of whether they received audio or not. Haptic cues were an exception, with participants in the audio condition rating them as much more effective than participants in the no audio condition (Bdiff = 2.46, SE = 0.32, t = -7.72, p < .001; see Figure 7).

Figure 7. Players' cue efficacy ratings did not align with their actual performance. Error bars represent 95% credible intervals.

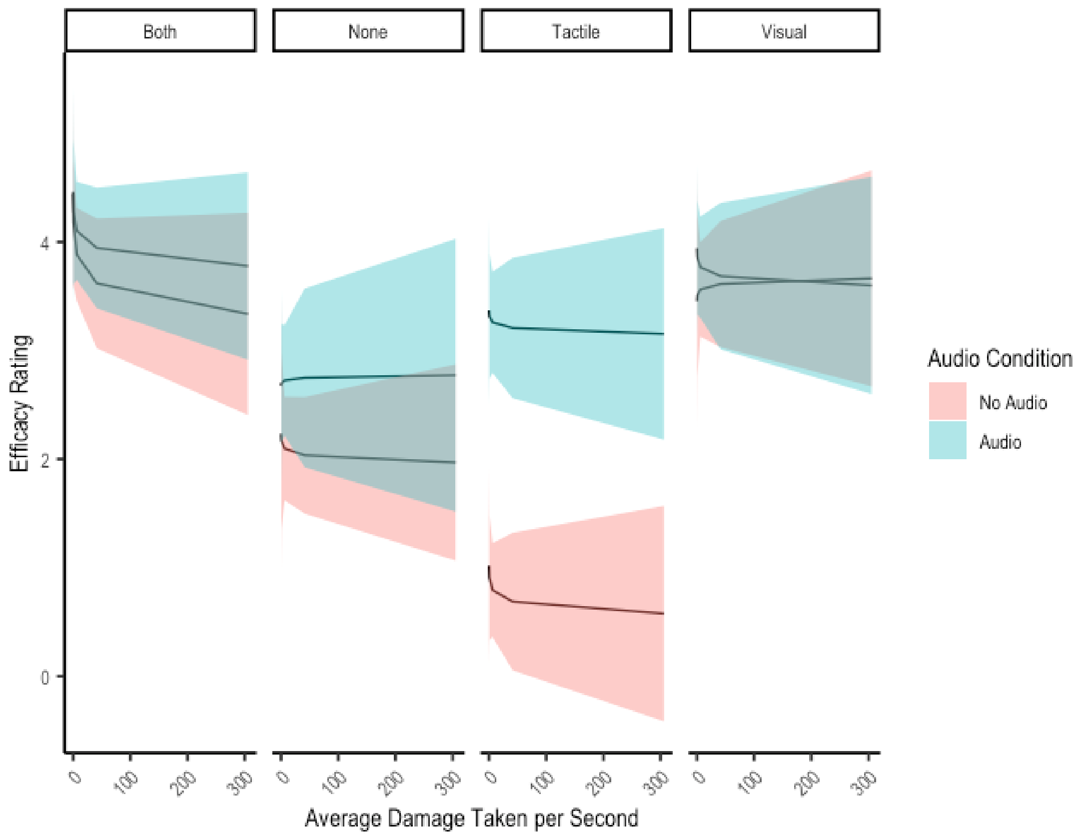


Table 3. Themes from the Thematic Analysis.

Cue	Theme	Count
Haptic	provided information that enemies were entering area	9
	difficulty distinguishing the right from the left cues	9
	provided directional information of the enemy's location	4
	did not provide enough information to be useful	4
Audio	provided information that enemies were entering area	7
	provided directional information of the enemy's location	4
Visual	provided directional information of the enemy's location	17
	binary nature of cue made it less helpful	9
None	did not provide enough information to be useful	13
Combined Cues	cues made up for what the other lack	2

3.3. Thematic analysis

A thematic analysis was conducted on responses to the free-response question about why participants preferred their selected cue condition. The thematic analysis identified four themes for haptic cues, two themes for audio cues, two themes for visual cues, one theme for no cues, and one theme for combined cues (See Table 3). Participants reported that haptic and audio cues provided information about when an enemy was entering the area, but fewer participants said these cues gave them directional information about the enemy character's location. It was strongly reported that visual cues provided the most directional information about the enemy character's location. Many participants reported that the no cue condition did not provide enough directional information. A few participants reported that having the cues together allowed the cues to make up for each other where one may lack.

3.4. Discussion

The results revealed that additional cues helped players without audio and provided no performance benefits to those with audio, supporting H1A. The results also indicated that players held strong beliefs about cue efficacy that did not align with the reality. Together, these results provide empirical support for players' anecdotal beliefs about cues while also illustrating that these beliefs are not grounded in reality. Accessibility cues do not provide an unfair advantage to hearing players; they fairly help those who cannot use a game's audio.

This study was a first step in looking at accessibility cues in the context of a video game; therefore, the video game was very simple. Accessibility cues provided only minimal information (i.e., left/right) about approaching enemies and were not essential to gameplay—players could see oncoming enemies without needing to attend to the accessibility cues. Nevertheless, our performance data indicated that players were clearly affected by the presence of accessibility cues. Still, efforts must be made to determine the generalizability of these results to more complex accessibility cues, as well as to other types of video games (e.g., puzzle games, first-person shooters). Additionally, this study included only a small sample of HOH players. Although HOH players' data aligned with that of hearing participants in the no-audio condition, future studies should seek to replicate these results with a larger sample of Deaf/HOH players.

The results of this study are consequential for the future progress of accessibility in games and make valuable theoretical contributions to the field by supporting the predictions of Multiple Resource Theory. Although players believe that redundant cues can provide an unfair advantage to hearing players by "dumbing down" a game, the results of this study clearly illustrate that this is not the case. Therefore, the best route for video game developers to take is to provide accessibility options for the players because not including these options limits the potential audience for their video games.

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Experimental study about 3D printed tactile symbols for tactile maps and blind users.

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Abstract: The aim of this paper is to determine whether certain volumetric tactile symbols (3D) have a level of tactile recognition similar to those of low relief (2D). This study evaluates a sample of 3D volumetric symbols produced by means of 3D printing for use in tactile maps. An experimental test was conducted on a group of 26 totally blind users with different levels of experience in tactile exploration. Part of the experiment involved analysing the percentage of correct answers as a dependent variable and the volume in the shape of the tactile symbols (3D vs. 2D) as the experimental stimulus. The results obtained indicate that volumetric symbols have a high level of tactile recognition. In addition, the study shows some of the possibilities that are emerging in the design of tactile maps and models with the development of new techniques such as 3D Printing (3DP). The inclusion of 3DP within the field of tactile map design is leading to a reassessment of some of the basic principles of tangible graphic design, such as using only two-dimensional graphic elements to produce tangible graphics. Other categories of design elements such as volumetric design elements (3D) can now be included. This opens up a range of possibilities in the field of tactile maps, providing the designer and/or the Mobility Instructor with a wider range of variations in shape from which to design or select a set of symbols for use in tactile maps.

Keywords: visual impairment, blind, inclusive design, 3D printing, tactile map.

1. Introduction

This section describes the objective and the research question, and the background considered in the study. Specifically, the background deals with the design and use of tactile maps, some studies on tactile symbols on relief maps, the importance of tactile experience in the use of this type of maps and some works that have discussed the production of tactile maps or tactile scale models using 3D printing.

1.1. Objective and research question

The objective of this work is to determine whether certain volumetric tactile symbols (3D) have a level of tactile recognition similar to that of low relief ones (2D), these latter being the most commonly employed in the design and use of inclusive tactile maps.

The research question is: Do volumetric symbols extend the range of the current set of tactile symbols?

1.2. Background

Tactile maps, as tangible graphic resources, are a group of devices that rely on relief to convey graphic information. Tactile symbols are usually used within this sort of product and are normally employed with their corresponding legends. These devices help the visually impaired understand features of the environment around them using the sense of touch.

The morphological design elements used when designing tactile maps and symbols for visually impaired users are points, lines, and areas (Amick, Corcoran, Hering, Nousanen, 2002; Bentzen, Marston, 2010; Edman, 1992). As a result of using these design elements, typical of 2D graphics, the tactile symbols that are utilized today in tangible graphics have a low relief, normally translated from an original 2D format.

However, since 3D design came into being, a fourth group of elements, volumetric elements (Wong, 1993) such as basic prisms, could be added. These are commonly used in product design and architecture (Ching, 2007) but are not normally used in the design process of tactile maps, partly due to difficulties stemming from the traditional production systems, i.e., microencapsulation and thermoforming (Rowel, Ungar, 2003).

1.2.1. Design and use of tactile maps

Ergonomics, which is also centred on the study of human interaction with displays, among other things, shows how it is possible to use volumetric shapes to reach good results in terms of tactile discrimination (Sanders, 1993). Anthropometry shows us data for designing this sort of element in harmony with human interaction (Pleasant, Haslegrave, 2006). This is the case, for example, of the controls of an airplane, which should be easily distinguishable and discriminable, among other factors, by touch in order to avoid human errors while pilots are using them (Sanders, 1993; Self, Van Erp, Eriksson, Elliot, 2008).

In the field of tactile maps, it is important to point out some previous studies closely linked to this one, such as that conducted by Sandra Jehoel, Paul T. Sowden, Simon Ungar and Annette Sterr on elevation in tactile maps (Jehoel, Sowden, Ungar, Sterr, 2009). According to the results of this study, the minimum range of elevation for identifying a tactile symbol using the sense of touch is 0.04-0.08 mm. However, the use of tactile contrast, for example height or texture contrasts, is one of the most important recommendations when designing an efficient tactile map (Nolan, Morris, 1971), regardless of the cost involved.

Regarding use, the main beneficiaries of this type of maps are the blind and visually impaired, although with a correct design which includes relief elements, colour contrast, braille code, large text, etc., a tactile symbol or map can generally be understood by almost all users.

Some of the most important factors to be considered when designing this sort of product for the blind are:

Firstly, always adopt simple solutions in the design process (Amick et al., 2002; Edman, 1992), since touch is less sensitive than sight (Schiff, Foulke, 1982).

Secondly, user familiarity with tactile graphics, i.e., previous tactile experience (See Section 1.3.3), because reading a tactile map requires certain skills and knowledge of exploration strategies (Lillo-Jover, 2008; Rowell, Ungar, 2003).

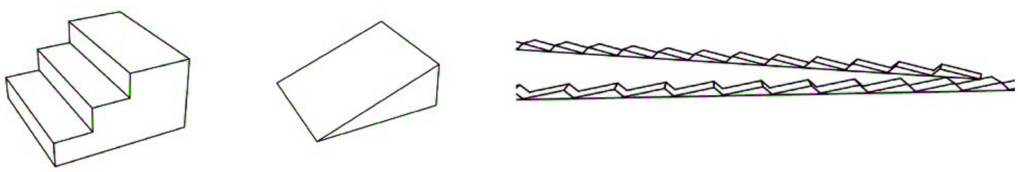
Finally, it is important to mention the role played by haptic memory in totally blind users when it comes to exploring tangible graphics (Millar, Al-Attar, 2003). This sort of memory works sequentially and requires the use of design elements that are easy to recognize and memorize through touch. In contrast, visual memory is simultaneous.

1.2.2. Tactile symbols on relief maps

The symbology of tactile maps has been widely studied from disciplines such as Cartography (Perkins, 2002; Rener, 1993; Rowell, Ungar, 2003). The factors of recognition, legibility, memorizing and discrimination of symbols have also been examined in a number of studies in order to verify the usability of these types of products and their efficient use for maps (Berlá, 1982; Gill, James, 1972; Gual, Puyuelo, Lloveras, 2014; Lambert, Lederman, 1989). One of the criteria for accepting a symbol as efficient for tactile recognition is that no symbol with an error rate of more than 5% should be recommended for use on tactile maps (Amick et al., 2002).

Volumetric symbology has not received much attention in the literature, although the work of Don McCallum, Simon Ungar and Sandra Jehoel should be mentioned. In this work, the authors analysed different kinds of directional symbols with a certain amount of relief. The results in this case were ambiguous, since the use of some 3D shapes yielded a modest increase in the level of agreement of 'up' for symbols intended to show stairs (McCallun, Ungar, Jehoel, 2006). This last study was the starting point for the current one. In addition to the stairs symbol, represented as a miniature stairway with three steps, this study also included a group of volumetric symbols with a variation in height or cross-sectional profile, such as ramps or lines with a saw-tooth surface profile (Figure 1), which allows users to perceive a feeling of roughness or smoothness depending on the direction of the line traced by the finger. In this study this direction was detected quite clearly, although there was no consistent interpretation by all participants. However, users could be trained or instructed to interpret the directional information in a specific way (McCallun et al., 2006).

Figure 1. Images of some of the tactile symbols tested in the study by McCallum, Ungar and Jehoel. From left to right, the miniature stair symbol, the ramp, and the saw-tooth line profile.



In addition, standardization of tactile symbols is a goal sought by all those involved, although this is proving to be a complicated issue given the difficulty in reaching efficient agreements.

Notable efforts have been made, however, such as those proposed at the International Conference on Mobility Maps in Nottingham in 1972 (Perkins, 2002; James, 1982).

Nowadays the selection of the symbol and its relationship with the content of a tactile map depends on the criteria of the designers, who have access to a wide variety of design recommendations supported by empirical evidence (ADON, 1986; Edman, 1992; Gill, James, 1972; Goodrick, 1987; Hinton, 1996; Rener, 1993). Thus, the designer's role is to select the appropriate symbols, which are easily recognizable and distinguishable to the touch, in order to represent specific meanings.

1.2.3. Tactile experience

As it was mentioned above, it is important to mention the previous tactile experience of each user for reading efficiently a tactile phenomenon, this familiarity depends fundamentally on the training received by the people using the map (Lillo-Jover, 2008; Rowell, Ungar 2003). For example, using two hands to explore a tactile map allows blind users to recognize the information offered by a tactile product more accurately and effectively than using only one, as shown by Perkins and Gardiner in their study (Perkins, Gardiner, 2003).

1.2.4. 3D Printing (3DP) to produce tactile maps and models

Traditionally, studies of symbols have focused on the possibilities of microencapsulated manufacturing systems and/or thermoforming (Rowell, Ungar, 2003), while the new Additive Manufacturing (also known as 3D Printing) techniques offer a wide range of possibilities to address this phenomenon (Kordon, 2002). These last techniques allow us to design and produce a new type of tactile symbol by using CAD tools and the geometric possibilities offered by them. Nevertheless, we consider this aspect to be poorly developed due to the technical limitations of the traditional manufacturing processes of thermoforming and microencapsulation, which are not able to reproduce some of the more complex geometries.

The novelty of this work lies in the use of an empirical study to test the feasibility of integrating a new category of symbols, namely volumetric tactile symbols (3D), into the current ones, whose shape is associated with three main design elements – points, lines, and areas – and are therefore characterized by a low relief format.

3D printing (3DP) is used to manufacture volumetric symbols, since it can produce more complex geometries, provide more edge resolution in the shapes than can be achieved with traditional methods (Chua, Leong, Lim, 2003) and can also include colour in the final model. This technique is not yet fully integrated as a tool for the production of evaluation models, prototypes, or even as a final product in the field of tactile map design, although some studies support an increasingly common use of the technique in the design of maps and its possibilities for tactile models. For example, researchers at Palacky University in Olomouc (Czech Republic) have analysed the use of 3DP technology for producing tactile maps with Geographic Information System (GIS) to improve the understanding of spatial orientation and movement of blind persons (Voženílek, Kozáková, Šťávová, Ludíková, Růžičková, Finková, 2009). In addition, the study by Gual was focused on improving urban orientation for the blind, using tactile maps based on 3DP to improve the understanding of some urban landmarks (Gual, Puyuelo, Lloveras, 2011).

Moreover, the production of tactile scale-models through this system of manufacturing seems to be an appropriate way to manufacture this sort of device for the sense of touch. Celani and Milan, from the State University of Campinas in Brazil, obtained good results in their experiments with tactile scale-models and blind users. The scale-models were very helpful for spatial orientation, but also highlighted the importance of other variables in improving human interaction with these products. These factors were the type of blindness, previous knowledge of the space, and previous experience with tactile maps and scale-models (Celani, Milan, 2007). Finally, it is worth noting the study by Voigt and Martens, from Vienna University of Technology in Austria, who worked with 3D printing techniques to produce architectural scale-models to help blind users to recognize environmental features more efficiently. Among other aspects the models improved the cognitive maps for blind and partially sighted people of the architectural phenomena in terms of better recognize spatial elements and their relationships, subspaces, and possible spatial sequences (Voigt, Martens, 2006).

2. Methodology

The following is a description of the methodology of the study, mainly the main characteristics of the sample used in this study, the tactile symbols selected, the material and its design and production characteristics, and the tasks and protocol of the experimental part of the work. The methodology used was experimental and the data obtained were quantitative and it was analysed from an inferential statistical perspective.

2.1. Subjects

The experimental test was conducted on a group of 26 totally blind users (13 congenitally blind and 13 adventitiously blind) with ages ranging between 26 and 80 (Table 1). The subjects participated voluntarily in the experiment and provided written informed consent.

Table 1: Segmented profiles of the subjects in the sample used in the experiment.

Totally blind	Mean age	Expert users	Some experienced users	No experienced users
26	51.19 (SD 12.56)	13	7	6

Regarding the tactile experience factor (see Section 1.2.3), that is, the degree of knowledge of techniques or strategies of haptic reading of any type of tangible graphic and braille code, the sample contained:

- 13 expert users; these were users who regularly used tactile graphics and braille code in their daily life or job, an example of which are those who had received special training in the past to learn how to explore a tangible graphic effectively. They were subjects such as educators of blind children who need to explain, for example, graphical concepts in subjects like maths or geography to their blind students in their classes, as well as passionate lovers of the adapted cultural exhibitions who were used to exploring relief materials when they visit these cultural events.

- 7 users with some experience (usually of reading braille, but only occasionally tactile graphics).
- 6 users with no experience of tactile devices, that is, users whose first experience with tactile devices was in the above-mentioned experiment, and they did not know or use braille code.

Figure 2. Image of the four target symbols. From left to right: a. Circumference "O" 2D stimulus; b. Arrowhead 2D stimulus; c. Pyramid 3D stimulus; d. Ring 3D stimulus.

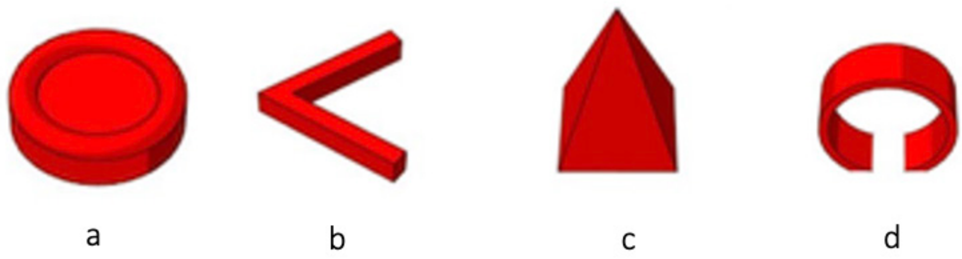


Table 2. Dimensions of the four target symbols.

Symbol	Circumference "O" 2D stimulus	Arrowhead 2D stimulus	Pyramid 3D stimulus	Ring 3D stimulus
Exterior diameter	7.0 mm	-	-	6.5 mm
Interior diameter	5.0 mm	-	-	5.6 mm
Height	2.0 mm	1.2 mm	7.5 mm	6.0 mm
Inner height	1.0 mm	-	-	-
Angle	-	70º	-	-
Length of outer lines	-	7.0 mm	-	-
Line thickness	-	2.0 mm	-	-
Square base	-	-	5.5 x 5.5 mm	-
Ring 3D stimulus	-	-	-	-
Depth	-	-	-	2.5 mm

2.2. Target symbols

Four "target" symbols were studied and evaluated, two of them with a two-dimensional attribute relief (2D), like extruded surfaces, and the other two volumetric (3D), hereafter referred to as circumference "O" (2D), arrowhead "V" (2D), pyramid (3D) and ring (3D) (Figure 2, Table 2). These symbols could be used, for example, as specific points or even directional symbols on a tactile map. The reason for selecting these symbols was, on the

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one hand, that the symbols chosen in 2D (circumference "O" and arrowhead "V") were two of the most commonly used on tactile maps and mentioned in several studies (Bentzen, Marston, 2010; Edman, 1992; Goodrick, 1987; Jehoel, McCallum, Rowell, Ungar, 2005; Lockwood, 1995; Meihoefer, 1969; NMCA, 1985; Nolan, Morris, 1971; Rener, 1993), generally with good results. On the other hand, the volumetric symbols (3D: pyramid and ring) were selected on the basis of previous studies. In these pilot studies, the subjects in an experiment were stimulated with volumetric (3D) and 2D shapes and had to recognize a set of 80 tactile symbols. The results of this experiment showed that the pyramid and ring tactile symbols obtained a high level of tactile recognition (Gual, Puyuelo, Lloveras, 2012), which created good expectations for further studies.

2.3. Material

The main material used in this study was a set of eight test cards distributed with other tactile symbols arranged in a table of 4 columns by 5 rows (Figures 3, 4).

All material used was produced using polychrome 3DP equipment (Z-Corb 510, CMYK and 24 bits colour).

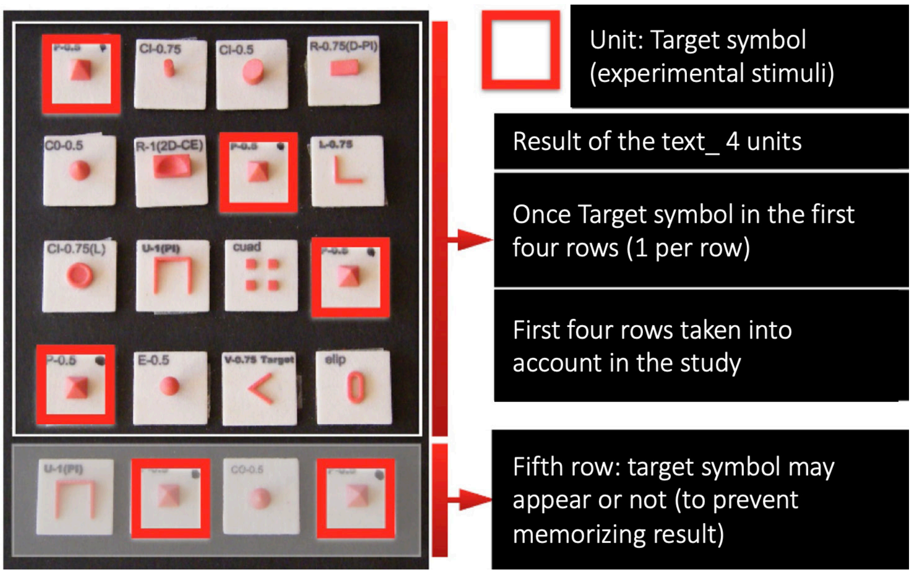
Prior to the experiment, an introductory test card was carried out in order to teach the tasks to each user.

On each test card there are different types of symbols (Figure 4), including the target symbols (experimental stimuli) that are the object of this study.

These are randomly distributed, but always appear once in the first four rows, so that there are always four target symbols in the first four rows. In the fifth and last row more target symbols may or may not be shown randomly, following a similar method to that used by Sandra Jehoel, Simon Ungar, Don McCallum and Jonathan Rowell for the evaluation of substrates of tactile maps (Jehoel et al., 2005). In this way, the fifth row prevents participants from memorizing the number of symbols per test, i.e. four. Thus, for this study, only the results of the first four rows were considered (Figure 4).

Figure 3. Subject from the experiment doing a task while using one of the eight cards of the study.

Figure 4. Sample of one of the eight test cards used in the study.



Other symbols with different characteristics such as ellipses, squares, "U-shapes", cones, cylinders, etc. (Figure 5) were used on the test card¸ randomly distributed along with the target symbols. Some of these symbols have been designed taking into account 3D attributes in the shape and others were selected according to a clear representation of 2D attributes.

Figure 5: Image of some of the symbols used along with target symbols on the test card. The symbols at the top follow the shape of basic prisms (3D attributes) such as a cylinder or cone, while the symbols below are two extruded surfaces that follow 2D shapes with relief. Those in the first group have a greater height contrast than the ones in the second.

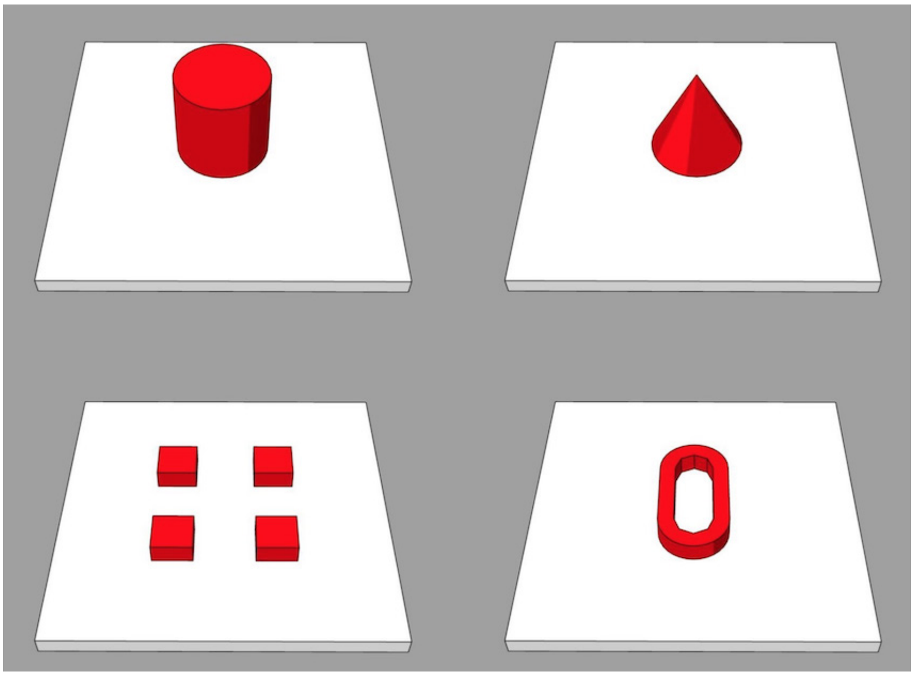
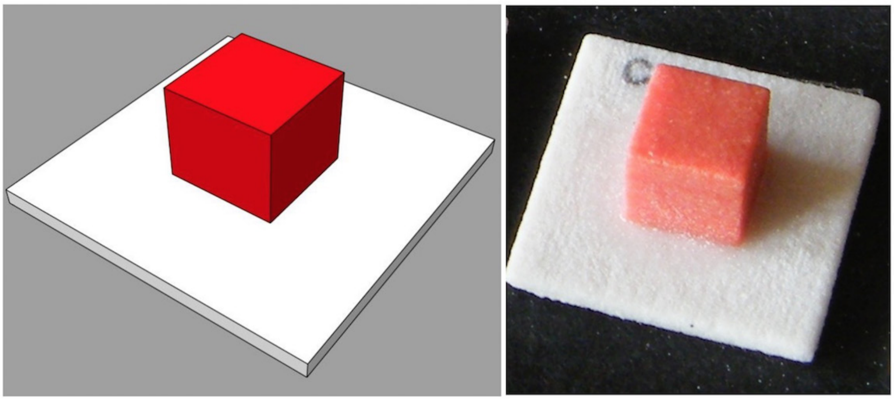


Figure 6: Image of the geometry of a cube designed by means of CAD techniques (left) and the same cube printed by means of 3DP (right). This simple shape could be a good design element to be recognized by touch if given the correct size because, among other reasons, it is simple.



2.4. Design and production of the symbols evaluated

To produce these types of symbols, basically two steps have to be followed. The first is to be able to use CAD software, which helps the designer to conceptualize the virtual-digital shape (geometry) in 3D in the form of a closed polysurface (solid). Conceptual design programs such as Blender, Sketch up, Rhinoceros, AutoCAD or Inspire Studio could be used to model the 3D shapes and, for experts, advanced CAD software like Catia or Solidworks can also be used. These applications always have a specific command for building basic prisms. Once the geometry has been modelled in any CAD file format, it must be exported (within the CAD program) to the STL file format in order to obtain a new file with the same type of solid but now polygonised (i.e. having a closed polysurface). In this stage, the CAD program normally prompts the user as to the different options available with which to adjust the final geometry; this may involve, for example, specifying the number of polygons, but usually the default options are sufficient. In any case, STL is a very common file format supported by several CAD programs and 3D printers, and most of these CAD programs and 3D printers are quite intuitive to use.

The second step is the physical production of the 3D virtual geometry. It is necessary to use some of the multiple 3D Printing techniques for this, including Fused Deposition Modelling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS) and 3D Printing (3DP-Binder Jetting). In the case of this project, the researchers used 3DP-Binder Jetting, which produces physical models using fine dust combined with small droplets of glue to produce polychrome pieces. The reason for using this technique is due to the possibility of including in the final design a wide range of colours (CMYK colours), which makes possible the production of inclusive tactile maps for people with low vision. In addition, using this technique, some complex geometries, such as the ring in Table 2 used in this study, do not require support material to be removed in a subsequent post-processing stage, which facilitates their production. Finally, the excess material can be reused again, reducing waste, and thus extending its life cycle.

In any event, using this method allows 3D shapes to be produced almost without limitation, and it can be applied to several areas such as this case, i.e., to propose different ways to manufacture tactile symbols, maps, or tangible graphs. As mentioned earlier, the 3D symbols selected in this experiment are only a proposal of the researchers based on previous studies (Gual, et al., 2011; Gual et al., 2012; Gual et al., 2014), but the use of CAD software and 3DP equipment makes it possible to design any geometry capable of being recognized by the sense of touch (Figure 6).

2.5. Tasks, procedure and description of the variables and experimental stimulus

In this study, the different cards containing the different tests (a total of eight test cards) were shown one by one, randomly, and sequentially to each participant until the eight test cards had been completed. The task to be conducted consisted in the recognition of a target symbol through the sense of touch, its memorization and subsequent localization on the relevant test card. Users were asked to count the number of target symbols recognized through the sense of touch on each of the test cards and to feel the symbols row by row using their fingers, going from left to right and from top to bottom, as if they were reading Braille. Before beginning the experiment with the eight test cards, the researcher used a draft sample, not employed during the experiment, so the participants could practise. Once the participants understood the tasks to be conducted, the complete experiment of eight test cards was carried out. So, participants had to identify the target symbols and explain them orally to the researchers when they found them; the experimenters recorded the correct or wrong answers (see Section 2.3. for further information about the structure of the test cards employed during the experiment; Figure 4). The experiment was recorded using digital video and the statistics were analysed using statistics data software (IBM SPSS Statistics 21 and G*Power 3.1.2).

The dependent variable to be measured was the correct answer rate, the units chosen to do this being the percentage of correct answers given by the subjects during the experiment. In addition, it was measured the average number of errors committed per participant, according to his previous tactile experience.

The types of error that can occur in recognizing tactile symbols are:

- Error in reading: it was not recognized although it was touched.
- False hits: it was confused with other symbols, because of a similar shape or other causes.

The experimental stimulus taken into account was the volume (3D vs. 2D) of the shape of the tactile symbols. Thus, in this article the results are shown as follows:

- First, the percentage of correct answers for target symbols: low relief ("V" (2D) or "O" (2D)) and volumetric symbols in 3D (ring and pyramid; see Section 3.1, Table 3). Also, it was measured the type of errors per user (See Section 2.5).
- Second, the differences between the use of the symbols depending on the previous experience of participants with tactile maps and haptic reading strategies (see Section 3.2, Table 4).

3. Results

The following section shows the results obtained in the experiment carried out from basically two points of view, i.e., on the one hand, from the data collected from the dependent variable (2D vs. 3D volume) and, on the other hand, from the previous experience of the participating subjects.

These are original data from this work, some of which have a certain statistical significance.

3.1. Depending on the experimental stimulus: volume (3D vs. 2D) of the shape of the tactile symbol

As can be seen in Table 3, data indicate that, in the dependent variable, the highest percentage of correct answers was for a volumetric symbol (pyramid, 99,03 %), one with 3D attributes, while the symbol with the lowest percentage of correct answers was the "V" or arrowhead (2D, 93,26%).

The first point to note, in this analysis, is that all symbols were read fairly well, that is, with a high level of correct answers (more than 90%). However, under a criterion such as that put forward by Nancy S. Amick, Jane M. Corcoran, Sally Hering, Diane Nousanen (Amick et al., 2002), which assumes that if the symbols are correctly perceived in 95% of cases, they can be used in the design of a tactile map, only two of the symbols analysed, the pyramid (3D, 99,03%) and the "O" (2D, 96,15%), can be guaranteed to function properly on a tactile map. The Friedman test shows that these data are statistically significant ($N = 208$; p value $= 0.017$; $\alpha = 0.05$).

On performing an in-depth exploration of the data obtained in the study, it is possible to appreciate a high level of tactile recognition for the pyramid symbol: this new volumetric symbol obtained a rate of almost 100% of correct answers in the experiment.

Table 3. Percentage of correct answers depending on the symbol analysed.

Name of symbol	Type of stimulus	N*	Frequency of correct answers	Percentage
V	2D	208	194	93.26%
O	2D	208	200	96.15%
PYRAMID	3D	208	206	99.03%
RING	3D	208	195	93.80%

**N = 26 participants x 4 symbols/card x 2 cards/symbol=208.*

Finally, if the dependent variables are analysed based on the type of errors per user (see Section 2.5), i.e., errors in reading and false hits, comparing 2D vs. 3D stimuli:

- The average number of errors in reading tactile symbols in 3D was 0.73 (SD 0.96), while in 2D the average was 0.81 (SD 0.98).
- The average number of false hits for tactile symbols in 3D was 0.11 (SD 0.32), while in 2D the average was 0.38 (SD 0.80).

Although both differences between groups of symbols show better results in tactile recognition for 3D symbols, these differences are not statistically significant. So, the ratios of errors indicate a similar pattern between different types of volumes (3D vs. 2D) of the shape of the tactile symbols (experimental stimulus).

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Table 4. Number of correct answers, total errors and percentage of correct answers depending on the type of symbols and the level of experience of the participants.

Type of symbol	Type of stimulus	No experience	Some experience	Experienced
V Correct Answers	2D	29	65	100
V Errors	2D	3	7	4
V, Percentage of correct answers	2D	89.65%	89.23%	96.00%
O Correct Answers	2D	32	68	100
O Errors	2D	0	4	4
O, Percentage of correct answers	2D	100%	94.12%	96.00%
Pyramid Correct Answers	3D	30	72	104
Pyramid Errors	3D	2	0	0
Pyramid, Percentage of correct answers	3D	93.33%	100%	100%
Ring Correct Answers	3D	29	70	96
Ring Errors	3D	3	2	8
Ring, Percentage of correct answers	3D	89.65%	98.57%	91.66%

3.2. Depending on the participants' previous experience

The data collected according to the type of symbol and the previous experience of the users (Table 4) show that experienced and some experienced participants, surprisingly, made no mistakes during the experiment when they performed the tasks with the Pyramid symbol. In addition, experienced participants perceived the "O" and "V" symbol with a 96 % of correct answers and less than 95% when they tested the Ring symbol (91,66%).

On the other hand, the seven subjects with only some experience using tactile maps obtained a 98,57% of correct answers when they performed the tasks with the Ring symbol, and they obtained a percentage of correct answers of 89,23% for "V" symbol and 94,12% for "O" symbol.

Additionally, the participants of the experiment with no experience made no mistakes using the "O" symbol, while the rest of the symbols ("V", Pyramid and Ring) were perceived with a range of correct answers below 95%.

The difference of correct answers within the group of 3D stimuli is statistically significant (p value = 0.04) and there were no significant differences between Errors in Reading and False Hits attending the profile of users.

Summarizing the best results of the experiment under the point of view of each symbols V, O and Pyramid symbols were well distinguished for experienced users (96%, 96% and 100%

of corrects answers), Pyramid and Ring symbols were easily distinguished when users had some experience (100% and 98,57 % of correct answers), and "O" symbol was perfectly perceived by no experienced subjects (100% of correct answers).

4. Discussion and Implications

In the following, the data are discussed from an analytical and critical perspective, trying to link the aspects addressed in the introduction, mainly with the literature mentioned in this section.

Finally, some considerations regarding the production of this type of tactile symbols are also described and discussed in this section.

4.1. Experiment

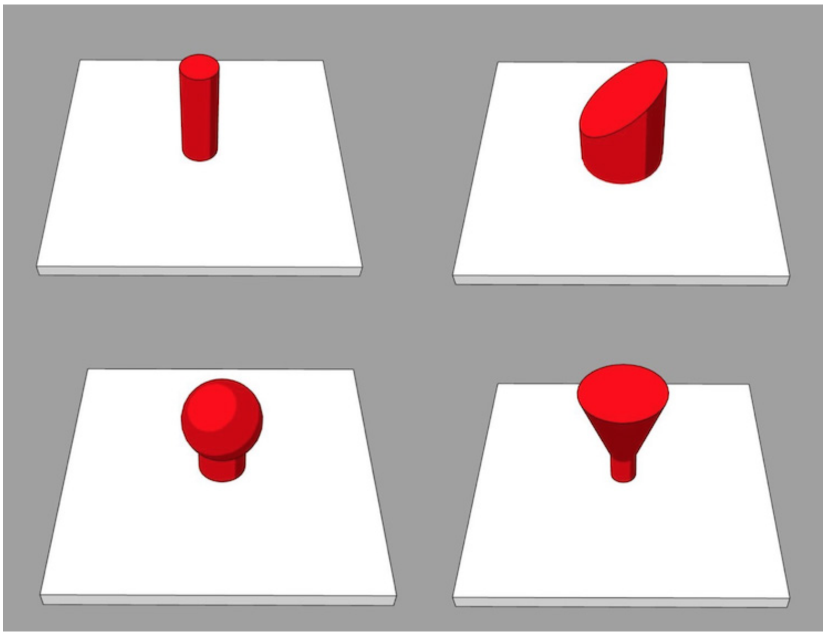
In general, taking into account the percentage of correct answers (dependent variable) for symbols in 3D compared with those in 2D, we can state that volumetric tactile symbols (3D), and more specifically the ones studied here (pyramid and ring), seem good elements to extend the range of the current set of tactile symbols, specifically Pyramid symbol. This last type of symbol considers only two-dimensional design elements. In contrast, those proposed here in 3D consider volumetric design elements (Ching, 2007; Wong, 1993).

Of the 4 symbols evaluated, the pyramid (3D) and "O" (2D) display a very high rate of success in reading, which shows that they could be used on tactile maps following the criteria proposed by Amick and colleagues (Amick et al. 2002). In addition, following the results of the group of 3D symbols, it seems reasonable to trust in this sort of elements to design a tactile map or simply a tactile device, because the rate of correct answers in this experiment was higher than that obtained in the group of 2D symbols which have been mentioned or used with good results in several studies (Bentzen, Marston, 2010; Edman, 1992; Goodrick, 1987; Jehoel et al., 2005; Lockwood, 1995; NMCA, 1985; Nolan, Morris, 1971; Rener, 1993) and there was a similar pattern of tactile recognition during the experiment between the different stimuli.

On the other hand, following the results of this experiment, the group of blind users with some experience regarding tactile exploration could benefit from the inclusion, in tactile graphics, of this type of volumetric shapes because they obtained good results when they explored the Pyramid and Ring symbols. Under the perspective of experienced users, in this experiment, they obtained a good range of results testing the tactile cards except for the Ring symbol, which it was perceived with a lower percentage of correct answers than the rest of the analysed symbols.

Probably, users with some experience have a minimum level of haptic exploration to learn or memorize (haptic memory) quickly, by the sense of touch, a different type of tactile elements that requires new tactile techniques to be recognized by fingers because they present 3D attributes. Meanwhile, experts' users, in our opinion, are influenced by their previous learned strategies to read a common tactile map in relief (2D - 2,5D). For users non experts, the process of learning any of the two types of stimuli, 3D or 2D, should not present difference at first, although they obtained no mistakes when they explored the "O" symbol, which is very simple and suitable for the sense of touch.

Figure 7. Some volumetric symbols for possible use as symbols in tactile maps. They are configured from the use of basic prisms (3D).



The novelty of this study lies in the positive results for the pyramid and ring symbols (3D), which were surprisingly at the same level as a symbol as simple and consolidated as "O" (Lockwood, 1995; Meihoefer, 1969). At this point it is especially important to highlight the good results obtained using the pyramid symbol. Therefore, it is worthwhile continuing this line of research – already initiated by Don McCallum and his colleagues – with the analysis of some symbols with volumetric attributes (James, 1992) (Figure 1). This opens the door to the study of other 3D symbol shapes (Figures 6 and 7), such as spheres, cones, or regular prisms in order to discern, among other factors, the degree of recognition, tactile discrimination, texture and size to be used on tactile maps.

The selection of a group of symbols that are recognizable to the touch and distinguishable from each other is one of the critical points in the design of tactile maps. Including 3D symbols in the production of tactile maps or any tangible graphic could improve the usability of these devices, thus benefiting Orientation and Mobility Instructors, educators, rehabilitation professionals and others in the field, because they would be able to combine graphic design elements (2D elements) with volumetric elements to design tangible graphics. The results of the experiment presented here open up the possibility of using distinguishable 3D elements for the sense of touch for any conceivable use, such as employing volumetric symbols (with the greatest elevation) to indicate specific elements on the maps that require quick and easy localization and positioning using a significant abstract shape. Example uses include the case of some of the information items that designers tend to employ in the conceptualization of tactile maps to be understood by end users: information desk, “you are here” or lifts on plans of the inside of buildings; traffic lights or telephone booths on urban maps; capitals of countries, cities and villages in geographic and themed maps; and vertex, centre points or cross points in tactile graphics for teaching maths or any other tactile graphic information for blind students.

In accordance with the results of this study, 3D symbols such as the pyramid or ring can be introduced as tactile representation elements because they are clearly recognizable and are seldom confused with symbols in low relief (2D), thus slightly improving the usability of these devices.

4.2. The 3D printing (3DP) considerations and implications

Producing a 3D symbol is not really a problem with production systems such as 3DP, and even certain symbols like the pyramid, among others, could also be reproduced in thermoforming (Figure 8). To make a 3D printed pyramid like the one employed in this experiment (Figure 9), firstly its geometry was modelled using Rhinoceros CAD software (height=7.5 mm; sides of the square base=5.5 mm) and NURBS (Non-Uniform Rational B-Splines) surfaces. This program, like most similar applications, has a specific command in its Solid menu to (digitally) make pyramids or any other basic prism easily. Once the pyramid had been modelled it was exported to the STL file format and sent directly to the 3D Printer (see also Section 2.3.), which finally produced the model in a few minutes. The precision of this technique is greater than competing systems, and once the model has been designed its flexibility allows mapmakers to quickly introduce changes into the geometry in order to reprint a new version, which is very interesting in the evaluation stages.

Figure 8. A draft of pyramid symbols (3D) produced with thermoforming.

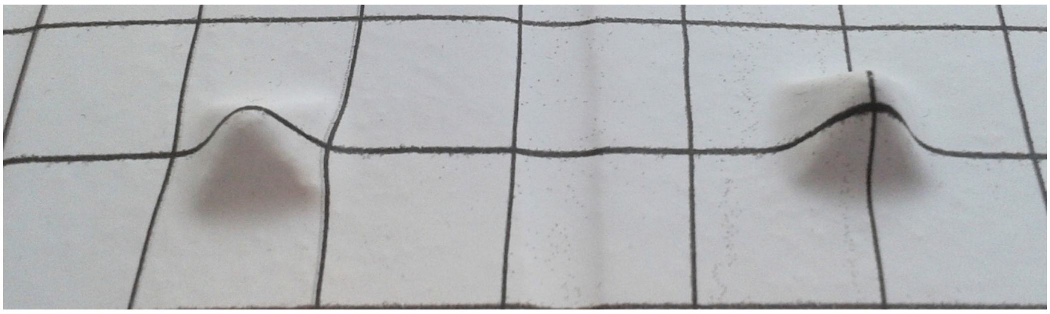
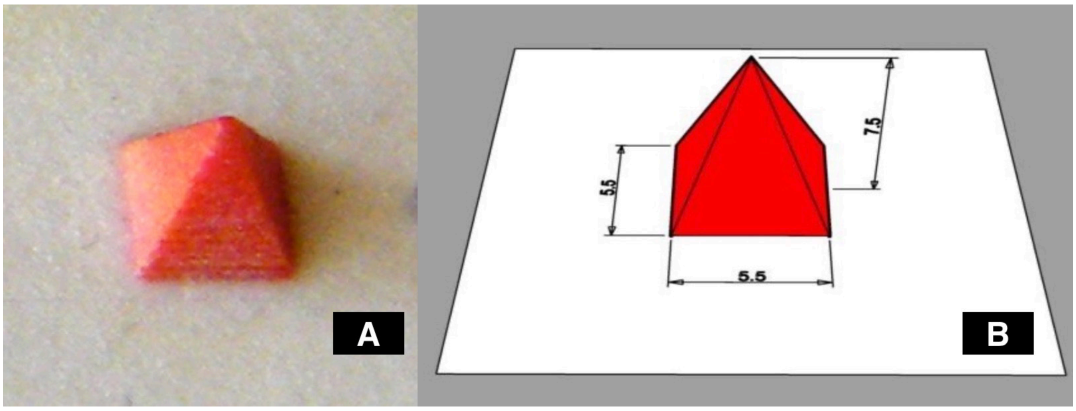


Figure 9. The pyramid symbol used in the experiment. The edges between surfaces show greater precision in the geometry of the shape than the thermoforming sample shown in the previous figure (A). Measurements of the pyramid tactile symbol (B).



Thus, 3D Printing has been used in several contexts with successful results, such as in the area of tactile maps and scale-models for the blind (Voženílek et al., 2009). This fact should encourage researchers to follow this thread of investigation because the use of 3DP makes it possible to design tactile maps that were previously unthinkable with other systems of production such as thermoform or microencapsulation (Rowell, Ungar, 2003). Examples of such maps include tactile maps with volumetric attributes that are easy to recognize by touch, thereby improving their usability. In any case, further research for evaluating 3D tactile symbols should be done, following a similar methodology, but with a bigger sample of subjects to increase data quality.

5. Conclusions

In view of the results and the analysis of the data obtained in this experiment, on one hand, 3D symbols could be incorporated into the set of symbols in 2D because they have, at least, similar results in terms of tactile recognition and discrimination, and some symbols such as the pyramid even seem to obtain better ratios than the 2D ones used today.

On the other hand, the inclusion of 3D tactile symbols in tactile maps seems that can benefit those blind users who have little experience and they do not have a strong influence from the common strategies of tactile exploration as experts' users who have mechanical gestures learned to explore a typical tactile map.

Thus, the researchers consider that 3D symbols could be good elements of design for extending the range of the current set of symbols, in this way answering the research question proposed in this work. This may make it necessary to reconsider the theoretical framework so as to think in both volumetric and two-dimensional terms when designing elements for tactile maps.

The idea of evaluating this type of symbols arises in parallel with the incorporation into the state of the art of new manufacturing process capable to produce three dimensional shapes quickly and easily. This work shows a first approach to how to take advantage of the tactile attributes of three-dimensional shapes to use them in tactile maps. Although some research has been conducted in this idea (McCallum et al., 2006), the nature of the volumetric attributes for the tactile sense, and for designing tactile symbols for improving the use of tactile maps, has not been studied sufficiently.

In any case, using 3DP for tactile maps seems a good choice given the possibilities for reproducing, among other things, colour for low-vision users and accurate complex geometries suitable for tactile perception. Although it must be recognized that the rapid prototyping techniques Fused Deposition Modeling (FDM) or the equivalent of Fused Filament Fabrication (FFM) are currently more popular, and they have lower cost than the one used in this study.

The possibilities of 3D Printing techniques applied to tactile maps for blind users should be more exploited by the community of researchers, and experiments like the one presented here are only a first step to show how we can improve these devices through the new production techniques of Additive Manufacturing. Some studies using 3D symbols applied to real tactile maps (3D printed) support this thesis with encouraging results and implications (Gual et al., 2015).

Finally, this study opens a door to the design of and research into new volumetric symbols with a size, texture and form suited to the sense of touch for use on tactile maps.

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Disabilities and User Experience.
An exploratory case study of survey and website accessibility.

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Abstract: There is a lack of research regarding the challenges experienced by people with disabilities when taking surveys or participating in usability testing. Websites, digital health applications, and electronic books are products users are recruited to evaluate through surveys and usability tests. However, these products and the instruments used to evaluate them aren't necessarily developed with the intended users being people with disabilities. Although some products use accessibility and usability practices when designing products, they vary in quality and quantity. Before a product—the website or electronic book—can move to production, it needs to be tested by a sample of people who are potential users but there is a lack of research on accessible instrument design that would make the user testing population and practices more inclusive. The purpose of this case study is to address this lack of research; and understand the experiences, challenges, and preferences of diverse users when participating in research studies through three forms of data collection: an interview, observation, and document analysis. The interview explores the experiences and observations encountered by a disability services professional at a public research institution. This data is triangulated with content analysis from a relevant document that describes 12 disability personas and an observation about accessible web design for people with cognitive disabilities. Two main themes emerged in the findings: Challenges and frustrations for people with disabilities and advice or guidance for information design. The triangulated analysis brings forth accessible design considerations for future research, practical advice for survey and usability testing with the disability community, and new questions for future research on inclusive instrument design.

Keywords: disabilities, user experience, survey design, usability testing, accessibility, usability.

1. Introduction

Websites, smartphone applications, and electronic books are products people use daily to access information. However, these products aren't necessarily developed with the intended users being people with disabilities. Although some products use accessibility and usability practices when designing products, they vary in quality and quantity. In some instances, accessibility and usability are not used at all or merely afterthoughts rather than being an intentional focus of design from the beginning of a product concept and with prototyping and testing phases later. Before a product—the website or electronic book—can move to production, it needs to be tested by a sample of people who are potential users. This population includes people with disabilities, yet product and research surveys fail to make participation accessible.

1.1. Research problem

There is a lack of research regarding tools and strategies used to collect data from people with disabilities, and the challenges experienced by people with disabilities when taking surveys or participating in usability testing is also scarcely seen in scholarly literature. Though publications

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may discuss creating inclusive surveys, design considerations and guidance on accessible survey or usability testing design is difficult to locate (Nikivincze & Ancis, 2018). As a result, people with disabilities may struggle to complete or participate in surveys or usability testing; additionally, they may be offended by the process researchers use (Interviewee, personal communication, June 23, 2023). Therefore, this study will address this lack of research by investigating the experiences faced by people with disabilities and the recommended practices that can help increase positive and effective participation in web-based surveys and usability testing. This will increase successful participation, and the quality of the product being developed as more inclusive perspectives are being addressed and varied user testing applied in the iterative design phases.

1.2. Research purpose and research questions

This case study is part of a larger study that seeks to understand the experiences, challenges, and preferences of diverse users when participating in research studies (which involves taking surveys, being interviewed, or performing a usability test of a website or product). This study has two specific goals: One aim is to investigate survey design and usability testing recommended practices. The second aim is to learn how research studies can enable more inclusive ways and opportunities for people with disabilities to participate in earlier design and testing phases of web-based products. At this stage in the research, the experiences and observations of using web-based products (which includes online surveys) was examined through the perspective of a disability services professional at a public research institution. This professional not only works with people who have a variety of disability conditions, but is also the parent of a child with disabilities and has disabilities themself. This varied perspective informs the case study's direction for further research and is triangulated with relevant data from document and observation analysis while addressing the following research questions:

1. What are recommended practices for diverse users to participate in research studies from the perspective of a special education and disability services professional or a person with disabilities?
2. What are recommended practices for creating accessible websites that reduce barriers for people with cognitive disabilities?

1.3. Definitions and background

The world population is estimated to have 1.3 billion people who have a significant disability, which is about 16% of the population (WHO, 2023). Disability is defined as "an interaction between an individual with an impairment and the environment rather than as a deficit of an individual" (NCD, 1998). The World Health Organization (WHO, Ageing and health, 2024) states, "Disability is a part of being human" and almost everyone will temporarily or permanently experience disabilities at some point in their life. Accessibility is concerned with making products or services available to a range of people with a focus on specific accommodations to enable people with disabilities to have access to products and services (W3C, 2016). Usability is defined as something being usable (Hasnain, et al., 2014) with a focus on how effective, efficient, and satisfying the product is to use (W3C, 2016). User experience is a concept that covers a user's feelings, attitude, and behaviour while using a system, service, product, or space (Neusesser, 2023). This experience involves how a person interacts with a system or product and any positive or negative aspects encountered, including challenges and preferences.

For this paper, research studies are defined as studies that involve the creation of instruments by researchers to assess, evaluate, or further research a topic where instruments (surveys, interview protocols, usability test protocols, etc.) are used to collect data, analyse a theory or assumption, and/or make informed decisions, and for some, publication of products or research outcomes. Surveys are organized templates used to gather information by asking questions and are used in both scholarly and social inquiries (Nikivincze & Ancis, 2018).

Web Content Accessibility Guidelines (WCAG) are a set of technical and design guidelines for web content authors to minimize difficulties faced by people with disabilities (Hasnain, et al., 2014). These internationally recognized WCAG guidelines are established by the Web Accessibility Initiative (WAI) group within the World Wide Web Consortium (W3C) with endorsement from the U.S. government. There are 14 WCAG guidelines divided into compliance checkpoints and priority levels. All of the guidelines fall into one of four basic groups: information that is perceivable, operable, understandable, and robust. The latter group of robust requires content to be interpreted widely by various users and their agents such as assistive technologies (WCAG, n.d.). Section 508 of the Rehabilitation Act was created to ensure that federal employees (in the USA) and members of the public with disabilities have access to and use information in a manner that is comparable to others and ensures that all information communication technologies are accessible (Section508, 2018). Section 508 incorporates the WCAG guidelines to ensure a range of technologies and services are accessible. The WCAG guidelines are also tested against in a Voluntary Product Accessibility Template (VPAT) that some vendors use to document efforts towards accessibility compliance of web-based products (Willis & O'Reilly, 2020).

1.4. Literature review

Given the diversity of the population with disabilities—including types and severity, age, employment, education, and environmental supports—there are complexities in designing accessible and usable surveys (Mitchell, Ciemnecki, CyBulski, & Markesich, 2006). Literature shows surveys for participants with disabilities have used proxy respondents, assisted interviews, and incentives in order to overcome challenges with disability research (Kroll, 2011; Mitchell et al., 2006; Wilson et al., 2013). However, this is not enough, as existing practices still largely exclude people with disabilities from research studies (Hasnain et al., 2015; Kroll, 2011; Parsons et al., 2001). There are general reasons for the exclusion in national research initiatives: lack of alternative survey formats, inappropriate handling of proxy responses, lack of interviewer training, and under-sampling (Hasnain, et al., 2014). Given the range of types and severity levels of possible disabilities, it is nearly impossible to design a survey that addresses all disability categories (Hasnain et al., 2015; Mitchell et al., 2006).

However, there have been various recommended practices for designing inclusive surveys across disability types, which include use of simple language (Mitchell et al. 2006; Nikivincze & Ancis, 2018; Wilson et al., 2013), brief questions and shorter survey lengths (Mitchell et al. 2006; Nikivincze & Ancis, 2018), shorter recall periods (Mitchell et al., 2006), minimizing high frequency sounds (Mitchell et al., 2006), building in breaks or checks points for participant fatigue (Kroll, 2011; Mitchel et al., 2006), using multiple sessions if needed (Kroll, 2011; Mitchel et al., 2006), rewording questions as needed for comprehension (Kroll, 2011; Mitchell et al., 2006), offering alternative methods or formats (Kroll, 2011; Nikivincze & Ancis, 2018; Parsons et al., 2001), streamlining question types and scales (Nikivincze & Ancis, 2018; Wilson et al., 2013), and layout changes such as high contrast, large font sizes, and adjusting the presentation of selections, questions, and scales (Nikivincze & Ancis, 2018; Wilson et al., 2013). These recommended practices are mentioned in studies that discussed disabilities generally (Mitchell et al., 2006;

Parsons et al., 2001) and other studies that focused specifically on health-related impairments (Kroll, 2011), print disabilities (Nikivincze & Ancis, 2018), and intellectual, physical, and sensory disabilities (Wilson, et al., 2013).

Error handling is another common accessibility challenge, especially when required survey fields don't notify the participant through the use of screen readers or a sound alert which can explain the mistake or error. Nikivincze and Ancis (2018) also stress a focus on survey navigation, especially keyboard tabbing order, which is not always perceivable or turned on; and it is critical to test and get feedback from your target audience, including those with disabilities, before implementing a survey. To further remove barriers, interviewer training should not only happen but should include strategies for sensitizing interviewers to the needs of people with disabilities, including how to use assistive technologies (Mitchell et al., 2006; Parsons et al., 2011).

Until recently, online survey providers lacked experienced in accessibility practices though guidelines that exist with WCAG and Section 508. Two studies in particular have reviewed online survey platforms such as Survey Monkey and Qualtrics, among others, and found that only 1 out of 13 were compliant with WCAG accessibility guidelines and all 13 were deemed unusable by assistive technologies such as screen readers (Gottliebson et al., 2010; Nikivincze & Ancis, 2018). These studies found that most accessibility issues occur in the implementation phase by the researcher as they have limited knowledge of best practices and "rely on that [online survey] platform's implementation and compliance to web accessibility standards" (Nikivincze & Ancis (2018, 3). Hasnain et al. (2015) concluded that very few researchers and survey tool vendors follow the WCAG guidelines, even if they claim to and testing has demonstrated otherwise as seen in Gottliebson et al. (2010) and Nikivincze and Ancis (2018). According to Hasnain et al. (2015), "In most cases, noncompliance was due to complex layout and heavy reliance on JavaScript, a ubiquitous software that adds cosmetic flair to a website and applications." Additionally, web-based products broadly have seen a lack of WCAG or VPAT accessibility compliance as seen with health-related websites (Fernandes, Paramananthan, Cockburn, & Nganji, 2023), online databases (Willis & O'Reilly, 2020), and web products or services (DeLancey, 2015).

Some user experience researchers (Alahmadi & Drew, 2018; Lazar et al., 2007, 2017; David et al., 2023), have studied web accessibility challenges while other researchers have studied survey design challenges (Gottliebson, Layton, & Wilson, 2010). Societal assumptions of some disabilities impact web accessibility and design. For example, most Deaf people use a national sign language as their first language; moreover, up to 80% of Deaf people have limited reading comprehension (David, Morado Vázquez, & Casalegno, 2023). Thus, text-heavy instruments or surveys may not be readily accessible to the Deaf population. Ribera et al. (2015) studies the difficulties people with motor impairments have when interacting with webpages and found that web forms and Flash elements were critical accessibility barriers. Similarly, there are unique challenges for people with a sensory disability and it's vital for designers to understand the characteristics of people with visual impairments to address accessibility barriers with web-based systems or products (Alahmadi & Drew, 2018). For example, visually impaired users may interact with online images, animations, video, voice, and text where this content requires descriptive text for such media to be transferred to a screen reader, Braille code, or other assistive technology. Descriptive text for these non-textual elements (e.g., images and video) are accessibility standards put forth by WCAG, Section 508, and others.

Universal design is a key principle to increasing survey accessibility and usability (Nikivincze & Ancis, 2018). This design approach is the responsibility of the researchers and survey designers, which includes not only engaging people with disabilities but also understanding human diversity (Gottliebson, Layton, & Wilson, 2010). Further, the researcher must make accommodations in the survey and interview designs (Wilson, et al., 2013). Both researchers and web designers must be educated on the needs of the disability community and survey designs must comply with the necessary code to make them accessible to diverse users (Hasnain et al., 2015; Wilson et al., 2013).

1.5. Research gap and research goals

Although some studies have examined and modified surveys distributed to people with disabilities (Hasnain et al., 2015; Mitchell et al., 2006), few studies have focused on the survey design with an intentional focus on the design parameters directly from these participants. Most studies only focus on accessibility (Wilson, et al., 2013), rather than both accessibility and usability of surveys. Additionally, survey usability and tasks analysis (a structured, scenario-based usability test) are largely underrepresented in the literature. Instead, the attempt of a usability test is an unstructured "catch any problems you can" task given to a person with disabilities (without guidance or instruction). This alone is a weak way to test for usability. Further, many of the studies examined come from the researcher perspective, with only some feedback from the survey participants, and most studies don't provide the actual instruments or examples of question-wording to demonstrate their findings. Moreover, although some online survey tools have undergone evaluation (Gottliebson et al., 2010; Nikivincze & Ancis, 2018), studies evaluating Springshare's LibWizard and Google survey tool products are lacking.

Studies conducted to date seem to evaluate online survey tools that are selected by the researcher, rather than those tools preferred by people with disabilities. This study sought to understand the user experience of people with disabilities who take surveys and accessible design recommendations that can help improve the experience. This study also sought direct feedback from a person with three vantage points—the perspective of a disability services provider, a parent of a child with a disability, and a person with a disability themself. This rare combination is unique when compared to existing research.

2. Methodology

2.1. Methodological approach and positionality

A case study approach was selected to provide an in-depth understanding of a case (Creswell & Poth, 2018). The case pertains to the experiences and perspective of the disability community when participating in research studies. User experience (UX) and human-computer interaction (HCI) frameworks that guided this study include universal design and human-centred design (Dolph, 2021; Hasso, 2024; Lazar et al., 2017; Nikivincze and Ancis, 2018) as well as participatory design (Henry, Gallagher, Stringfellow, Hooven, & Himmelstein, 2007) which involves stakeholders and researchers working together to ensure the needs of the population are met. As typical with case study methodology and UX/HCI research, this study uses multiple methods of data collection such as interviews, document analysis, and observations (Alahmadi & Drew, 2018; Antona et al., 2009; Lazar et al., 2017; Yin, 2009). Given the varied aspects of disability types, instrument types, product (e.g., survey tools) features, the use of mixed methods is well matched for analysing accessibility and design considerations (Alahmadi & Drew, 2018; David et al., 2023) for research study participation.

The author, an experienced designer of web-based products, focuses on inclusive design methods as practice (positionality). This practice includes design thinking, validating user experiences, removing bias from design, and advocating for changes that effect edge cases. Given this experience, the author hopes to build on prior knowledge and learn how to create more accessible and usable information products such as websites or electronic books, by learning about the lived experiences of people with disabilities and their interactions and preferences of surveys and usability testing instruments and environments. The inclusive mindset is a philosophical framework brought to both the scholarship and practice of the UX field.

2.2. Methods and sampling strategy

A purposeful sampling strategy was used for this qualitative case study. Specifically, convenience sampling was selected due to the nature of the study's exploratory nature and criteria sampling was utilized where the participants had to meet certain criteria for quality assurance (Creswell & Poth, 2018). "Qualitative inquiry typically focuses in depth on relatively small samples, even single cases (n = 1), selected purposefully" (Patton, 2002, p.272-273) where there is power in purposefully selecting information-rich cases that can yield insights and an in-depth understanding of the case. Purposefully sampling was also used which helps when working with hard-to-reach or sensitive populations (Abrams, 2010).

2.2.1. Interview

Using these sampling strategies, a list of possible organizations (disability service providers) and potential people who work there (who met the criteria for the study) was drafted, culminating in a ranked list of potential interviewees. Ultimately, one participant was recruited for the study (interview phase) who met the age criteria of at least 18 years old, who worked within the disability services profession and within the higher education field, and also identified as having a disability. The academic nature was preferred as this population would be more prone to participating in research studies, such as taking surveys or performing usability testing. Once a potential participant was identified, they were contacted via email and invited to participate in the study. Due to prior professional rapport with the participant (convenience sampling), the recruitment was successful.

2.2.2. Observation

Typically, qualitative case studies also use non-probabilistic techniques (purposeful and convenience sampling) for units of analysis other than people, such as documents and observations (Hurst, 2023). Similar to interviewing, the procedures involved in collecting observation data began with identifying possible sites to be observed and gaining access. Several live webinars were considered based on the topic, presentation abstracts, presenter bio, and expertise. That list of potential observation sites (live webinar) narrowed to a disability focus of cognitive impairment and lived experiences (criterion sampling) while also being a source the author had access to as it was accessible online and free (convenience sampling). This webinar on cognitive disabilities and user experience (UX) was selected (for the observation analysis phase) because of the author's background in UX and their lack of experience with design for specific disabilities. This was an opportunity to learn about cognitive disabilities and accessibility on the web.

2.2.3. Document

Similarly, the document selected for analysis (Accessibility Dos and Don'ts Posters by Deque, 2023) had a disability focus but was broader by describing 12 different disability types through the use of personas (a tool used to create a representation of a person in order to build empathy and design for that person). The document selection also sought a complementary yet different approach with a design focus (method or tool approach used by a reputable organization) that can help create better web-based designs (criterion sampling) while also being accessible in the public domain (convenience sampling).

2.3. Data collection and analysis

Case study data analysis starts with the creation and organization of data files for the interview, document, and observation that will undergo analysis. The interview used a semi-structured protocol with eight pre-determined questions (see Appendix A) and several other non-scripted questions. The interview lasted approximately one-hour on Zoom.

This study used an inductive coding approach with open coding, where codes are developed based on topics in the data. This open coding used a combination of descriptive coding and values coding (Creswell & Poth, 2018) to capture both short phrases consistently used throughout the interviews and observations, and considered the participant's own values and attitudes towards the topic. This combination brings perspective to the initial coding process, further enabling the iterative and thematic coding to take shape. For example, "accessibility" and "tools" were later consolidated into one theme. The codebook example in Creswell and Poth (2018) was modified for this study and shows how the themes, code name, and code definition guided the development and boundaries for this study (see Appendix C). This coding helps to make sense of the collected information from interviews, observations, and documents by aggregating data into categories and using labels to identify the code placed on the theme (Creswell & Poth, 2018).

Inductive coding was also applied to the document analysis using the same iterative coding process used with the interview analysis. The document described twelve personas of people with disabilities, as discussed later in the Results section. The Document Content Analysis Matrix (Appendix D) was created to assist in the analysis and mirrored the format of the interview codebook mentioned earlier. The observation was a webinar on cognitive disabilities and user experience, and it was presented by a person with disabilities who wanted to share website creation best practices, as discussed in the Results section later. The observation analysis used a protocol template (see Appendix B) to document and reflect on the lessons of the observation.

While reading through the text (the interview transcript, document, and observation protocol), notes were made in the margins which helped to inform the initial codes that were developed in the code names identified in Appendix C. This use of categorical aggregation helps to establish themes or patterns. Additionally, this study used direct interpretation and naturalistic generalizations of what was learned from the data (Creswell & Poth, 2018) by using quotes from the interview, document, and observation. Once coded, interpretation required abstracting out from the codes and themes to find a larger meaning within the data (Creswell & Poth, 2018).

2.4. Ethical considerations and validation strategies

This study received institutional review board (IRB) approval from the University of Missouri. Additionally, participant consent was obtained prior to the interview and the participant was informed of how the interview was being recorded and what would happen with the data. The participant's personal information was redacted prior to analysis. Validation strategies included having a colleague review the semi-structured interview questions prior to use for understandability, and an external audit was used as a form of peer review of the methodology (Creswell & Poth, 2018). The document was freely available in the public domain and placed on the document authors' website (an established organization). The observation required registration and a password-protected login to attend the live presentation. The observation's field notes intentionally redacted the presenter's information for privacy, but this may not have been necessary as the presentation recording and slides are now publicly available online. Triangulation was used to control bias and corroborate evidence across the three forms of data collection (interview, document, and observation), as recommended by Creswell and Poth (2018).

3. Results

From the three forms of data collection, themes were noticed that influence the nature and degree of difficulty a person with disabilities experiences with daily life or participation in research.

3.1. Data collection 1: Interview

3.1.1. Challenges

The most prevalent theme during the interview regarded various challenges faced by people with disabilities. This included challenges in daily life, school life, and specific to research studies (where people with disabilities are recruited to participate in research through a survey, interview, or product usability testing). These challenges include feelings of frustration or missed opportunities. For example, the lack of support at school or work, limited funding, and limited understanding from others are a constant challenge. The interviewee further emphasized a lack of understanding or willingness to accommodate work or school environments:

> *It's frustrating that [someone] could be so successful and so beneficial to the company if they [the company] would just be willing to work with [that person]" or that some teachers think that following a documented accommodation protocol for a person with a disability is a form of "babying them (Interviewee).*

According to the interview, teachers who don't follow accommodations enable troubles to continue in school settings for students with disabilities, which is frustrating as it is a fixable problem if the accommodation would have been supported.

Regarding participation in survey or usability testing, frustration or challenges also arise from people with disabilities. The interviewee put this into perspective when describing how constantly asking the same person for website usability feedback "takes away from their human experience because they are spending all their time testing" (Interviewee). This feeling of bombardment occurs when the same person feels they are always asked to represent a disability community. Other negative feelings in this theme included the dislike of long surveys. For a person with physical impairments, autism, or ADHD, long surveys cause frustration due to a lack of patience, attention, and hand cramps.

3.1.2. Positive

Rewarding or positive themes during the interview foreshadowed success, even small success, is a big deal. For example, the length of time in a job for an autistic person can be a cause for celebration. The interviewee highlights this by saying "seeing success is an amazing thing when everything is so hard and so we tend to celebrate smaller successes" (Interviewee). Giving a person with a disability an opportunity to share their experiences or opinions in research settings is also beneficial and can be a positive experience.

3.1.3. Reflective advice

The interview also heavily discussed guidance of solutions or fixes to known problems. Retrospectively, the interviewee described alternative or better approaches to consider in design or practice, both broadly and with surveys specifically. An example of a broad application is rather than trying to design for the disabled community with current methods, it is better to hear directly from people with disabilities. “I think the voices that need to be heard the most are from people with disabilities” (Interviewee). Pragmatically, there is room for greater improvement regarding accessibility, which can help people with disabilities. For example:

> *I think every company should have somebody who's an accessibility specialist, an adaptive technology specialist, whether they have a disability or not. They need to be an expert on all the different types of disabilities. What are the different issues that people are gonna have with this thing? And how do we fix it? And they need to test extensively, etc. I wish that was consistent at all companies, that they have…a person [like that] as part of the testing process (Interviewee).*

Guidance for survey design was also discussed, including how to ask demographic questions at the start of the survey. Advice on how to ask about disability types is challenging as there are so many different types of disabilities and categories within the types. Giving options for selecting various types of disabilities or gender options is considered inclusive for the demographic section of surveys. Other survey design guidance included breaking up long surveys into shorter segments, enabling a user to work on just one page at a time, and a progress bar.

> *I would think that those two things would be helpful for almost any disability. [For] somebody who is blind, who's using a screen reader, or a braille device, I can see it being the same for them as long as it's easy for them to navigate to the next page (Interviewee).*

Another critical survey design feature is that the more keyboard friendly a survey or website is, the better it is for everybody. The interviewee shared how frustrating a lack of keyboard accessibility can be to someone with a disability:

> *I get annoyed with things that I can't tab in or tab space to enter my answer. I have to physically drag my mouse over and push the thing, that's a lot of extra work. And I imagine, with a screen reader like JAWS, that it doesn't work right. I imagine others have trouble getting to the next page. If I can't do it with my keyboard, I bet they can't either, which is a problem. (Interviewee).*

When end users (in this case, people with disabilities) do a usability test, most times they are directed to a website and asked to test it without guidance. When this happens, asking the tester whether they did an in-depth or surface level review is advised. This context provides meaningful feedback. A person’s mood at the testing time or the quality of the review process may vary among testers, so it is wise to know about the level of the review conducted. Additionally, it gives testers a choice in survey or usability tests and lessens the time it takes to complete. If compensating people for their time is impossible, try other types of rewards.

> *I love the little things that if you play a game or you do a survey, you get points, and eventually you've done enough to get a $5 Amazon gift*

> *card…rewarded [time] is advertised a lot. Those might be good ways to get people (Interviewee)*

In addition to this type of points system as a reward, entering people into a drawing is another way to recruit people to complete surveys and improve their usability review quality.

3.1.4. Terms

Understanding terms or policies used in a discipline, industry, or within the disability community can help remove barriers. For example, it is important to know that "differently abled" and "handy capable" are labels not embraced by the disability community (but perhaps by some parents of disabled children) (Interviewee). In the education setting, the term "exceptional" is used, which is "a nice word because it covers anything that's outside the norm…both sides of the spectrum [disabled and intellectually gifted]" (Interviewee). Twice exceptional is a term for "kids that are both literally gifted in high IQ, etc. and have neurodiversity, autism, or ADHD, etc." (Interviewee) that are from the disability side of the spectrum.

Neurodiversity is another term currently used which applies to disabilities that involve how the brain works. This includes ADHD, autism, anxiety, and depression. The interviewee further explains that a neurodivergent person's brain behaves differently than other people's:

> *It is divergent of the neurotypical set up…neurodiversity is a person who is neuro divergent. A group is neuro diverse by having a variety of people with a variety of experiences. That is how those labels are applied. (Interviewee).*

3.1.5. Accessibility and tools

The theme of accessibility and tools describes considerations, practices, challenges, benefits, or resources within the discipline, industry, or disability community. Tools mentioned during the interview included JAWS (a read-aloud device), braille devices (a reading tool for blind people), and Amazon MTurk (a reward system for doing surveys).

According to the interviewee, there are discrepancies in what is considered accessible. In industry.

> *A lot of companies say that their website or app or service is accessible. It's only accessible at the very bare minimum. You know, they've done the least amount possible which doesn't necessarily make it accessible…in the real-world setting (Interviewee).*

One of the biggest accessibility requests (as a disability services professional) of the interviewee is for accessible books. Many of these requests require a book to be read out loud. Some digital book apps do this better than others, and specific ones are avoided entirely because,

> *Their app isn't great…you can't use JAWS [and] you can't use [it]…for somebody who has dyslexia or ADHD" or a disabled person's own tools can't be used within the app, which makes the app unusable, in addition, it has a bad built-in read aloud tool (Interviewee).*

When asked about online survey tools that are compatible with the JAWS tool, the interviewee did not know of any JAWS-friendly survey options. However, they use Google Forms because it is free and has fewer limitations than Survey Monkey. Though Google Forms does have its limitations, "my impression is that Google Forms is supposed to be completely accessible" (Interviewee). That's why survey design is important; regardless of what survey tool you use, consider how JAWS will read the survey, considering how JAWS reads everything on the page. Therefore, when the interviewee designs surveys, they try to limit what JAWS will read:

> *If I'm going to have different sections of a form, I'm not going to put the same instruction at the top of each section, because then they [people taking the survey] have to listen to it all over again (Interviewee).*

3.2. Data collection 2: Document content analysis

For triangulation analysis, the relevant document that underwent content analysis was the "Accessibility Dos and Don'ts Posters" by Deque (2023). This document has developed 12 personas to represent people with varying disabilities and the types of experiences and challenges they face daily. For each persona, a brief description is given about that person (complete with a name and image), and other aspects that describe them: demographics, personality, needs, frustrations, and things that a design should always do and should never do for someone with that specific disability.

The posters, or personas, cover a wide variety of disabilities, including blindness, mobility, deafness, dyslexia, colourblindness, autism, low vision, anxiety, vestibular disorders, ADHD, ageing, and photo-epileptic sensitivity. The interview codebook (Appendix C) was adapted to guide the document's content analysis matrix by listing 12 disabilities in the document and their aspects of accessibility considerations via tools used, challenges, advice, and quotes as seen in Appendix D. Tools were only listed for four of the 12 personas and therefore omitted from the matrix. The tools for these four disabilities included: screen reader, haptic feedback (blindness); voice dictation software (mobility); text to speech (deafness); and big screens, screen magnification software (low vision).

Each persona describes the user experience of a person with the specific disability of that persona. When looked at holistically, the Document Content Analysis Matrix (Appendix D) shows crossover, where one design consideration can help people with various disabilities who may have similar experiences or challenges with inaccessible web-based products. For example, a selection of the most frequently cross-referenced accessibility tips among the personas includes the following:

- 5 of the 12 disability types (deafness, dyslexia, autism, and aging), recommend to **always** "leverage plain language principles to make the content easier to read, process, and understand" (Deque, 2023).
- 5 of the 12 disability types (deafness, colour-blindness, low vision, and aging) recommend to **always** "support information on the pages with a combination of text, colours, and other visual cues" (Deque, 2023).
- 3 out of 12 disability types (blindness, mobility, and aging) recommend to **always** "ensure navigation or features throughout pages or screens can be fully achieved using just the keyboard."
- 3 of 12 disability types (autism, anxiety, and aging) recommend to **always** "provide clear instructions so people understand what to expect as they interact with the content (Deque, 2023) (Deque, 2023).
- 3 of 12 disability types (deafness, dyslexia, and ADHD) recommend to **never** "organize the content of the page into large, intimidating, hard to scan, and unappealing blocks of text" (Deque, 2023).

- 3 of the 12 disability types (blindness, mobility, and aging) recommend to **never** "design or implement features on pages that are only meant to work with the use of a mouse," **never** "impose complex finger gestures that make it impossible for some people to use the interface," and **never** "require painful wrist movements (Deque, 2023).
- 2 of 12 disability types (vestibular disorder and photo-epileptic sensitivity) recommend to **never** "rely on flashing, blinking, or other strobing effects as a way to draw people's attention on the screen" (Deque, 2023).

3.3. Data collection 3: Observation

The observation was a live webinar with a guest speaker on the topic of cognitive disabilities and user experience. An observation protocol (Appendix B) was used to document descriptive and reflective notes during the observation. This one-hour-long presentation was guided by a slide presentation and a speaker who gave a background on their experience with disabilities and their professional experience in creating accessible experiences for people with cognitive disabilities. Attending this webinar live allowed the author to see the moderator interact with the speaker and participants and ask questions at the close of the presentation. The speaker began with factual statements including that 25% of people in the U.S. have a disability.

Additionally, 80% of those people have an invisible disability (e.g., trouble reading, colour-blindness, etc.). Next, the speaker presented a cognitive disabilities overview by defining which disabilities are considered cognitive: dyslexia, autism, ADHD, and learning (intellectual challenges, trouble solving problems). Additionally, of all disability types (e.g., motor, vision, hearing, learning, etc.), cognitive disabilities have a higher percentage of the U.S. population across all age group (18-65+). This background segment was followed by a brief demonstration of how to refer to a disabled person according to the speaker, preferably with an identity-first approach (a blind person, a person with disabilities, etc.).

The next topic was challenges or barriers for people with cognitive disabilities, which include complex layouts, long paragraphs/texts, unusual words, and media you can't stop or turn off (ASERL, 2023). Advice or ways to assist people with cognitive disabilities include keeping user interfaces (UI) clean and simple, providing alternative formats, and making it easy to get help. To illustrate this point, the speaker showed an example of a frequently asked questions (FAQ) webpage that has a massive number of links and asked the audience "Are these really helpful FAQs when there are so many?" Similarly, the "Browse by topic" navigation feature had over 90 topics to select from, where the audience was asked, "Is this really a browsable list at 90 topics?" Although both questions posed to the audience were rhetorical, the speaker's point was understood without question. This exercise demonstrated the user experience of interacting with a website for someone with cognitive disabilities.

The advice given falls under basic UX principles: affordance; keep things simple; provide signposts and clues; and provide people with the information they need. Other examples given that can help improve content on websites (and in related products such as books or surveys) include:

- Readability: word choice; avoid abbreviation.
- Headings: use large font size; avoid underlining and italics; and avoid all caps.
- Space: around items.
- Layout: left justify text; use bullets, 60-70 characters per link; avoid sentences starting at end of the line.

- Writing Style: avoid long sentences; be concise.
- Contrast: use colour combinations strategically.
- Links: avoid “click here”, “read more”.
- Icons: if using icons, also have words with icons or use words as links.
- Underline: only underline links; use italics or bold for emphasis instead of underlining.

All of these considerations can help with cognitive load. Creating accessible content makes things easier to use for everyone, including people with and without disabilities. The lack of content that is easy to use is the digital divide for people with cognitive disabilities [note: the digital divide is the lack of internet access]. The speaker’s concluding thought was that “if people think a website is accessible, they will have a more positive experience with the content” (ASERL, 2023).

3.4. Triangulation of findings across the 3 forms of data collection

The interview, document analysis, and observation revealed crossover of codes and content. The two most frequent occurrences were the themes of challenges and advice.

3.4.1. Challenges and frustrations for people with disabilities

The interviewee’s examples around society’s lack of understanding of people with disabilities highlight the challenges encountered at work and school when other people lack the knowledge and empathy for people different from themselves. This lack of understanding of human diversity was also mentioned in the literature (Gottliebson et al., 2010).) The interview and literature also discussed web-based products (DeLancey, 2015; Fernandez et al., 2023; Willis & O’Reilly, 2020) and survey tools (Gottliebson et al., 2010; Nikivincze & Ancis, 2018) available, most lacking in accessibility compliance even when products or companies claim to be accessible (through VPATs or their own testing).

Data from the interview, document analysis, and observation all mention challenges or frustrations with long pages or long surveys. For many people, with and without disabilities, long pages, or surveys cause frustration due to lack of patience, attention, time, and physical pain (such as excessive scrolling which causes hand cramps for those with mobility challenges).

Challenges or barriers for people with cognitive disabilities include complex layouts, long paragraphs or texts, unusual words, and media you can’t stop or turn off, which was represented across all three forms of data collection. The data presented in the observation correlate to the data found in the literature regarding disability populations and cognitive disabilities being one of the largest categories. Given its girth, information design should consider following more of the design advice for people with cognitive disabilities.

3.4.2. Advice or guidance for improving information design

The document analysis looked at accessibility dos and don’ts through the use of personas, a design tool used to create a representation of a person in order to build empathy and design for that person. Challenges and advice within those 12 personas were reminiscent of challenges and advice also mentioned during the interview and observation. For example, using simple language, clear instructions, and having multiple ways to distinguish information (colour, text, visual clues, etc.) were all advice given across the forms of data collection. The persona tools were impressively designed. Finding, using, and creating personas is important in design work, and having personas specifically address accessibility is unique and certainly lacking in the literature.

For example, for Cindy (a persona with a mobility disability), the accessibility dos and don'ts state to never design features on pages that are only meant to work with the use of a mouse (so you should have it designed to also work with a keyboard) and to provide experiences that are fully optimized for voice dictation and other assistive technologies. These points were also made during the interview, further corroborating this critical design need.

Regarding terms and labels, it is important to seek advice from the disability community or the person directly. As the interview revealed, terms and labels change over time, and there are debates within communities on their preferred use. The observation and interview referenced the 'identity-first' approach when talking with and about people with disabilities, though there are other approaches that can be explored in future studies.

Although the accessible design considerations previously described are advice that can be applied to the information design of websites and surveys, there is also advice on how to recruit people to help with research studies specifically. For example, the interview discussed the use of a reward system for participation in research studies when direct compensation is not possible, a concept lacking in the literature. Using rewards (a positive experience) to compensate people for their time in surveys and usability testing can help recruit users and it appropriately compensates them for their time. This could be done with money or gift cards, though this is not always possible. However, an alternative could include a points system that adds up over time as a game-like experience that attracts and retains participants for research studies.

4. Discussion

The case study aimed to understand the experiences, challenges, and preferences of diverse users when participating in research studies. Through three forms of data collection (an interview and content analysis of a relevant document and observation), the following research questions were addressed:

1. What are recommended practices for diverse users to participate in research studies from the perspective of a special education and disability services professional or a person with disabilities?
2. What are recommended practices for creating accessible websites that reduce barriers for people with cognitive disabilities?

Both perspectives of question one and question two were addressed with just the interview. However, the document and observation analysis also echoed what was discovered during the interview. Question two was addressed in the interview, document, and observation, which are summarized in the Themes and Findings section. Several recommendations are helpful for more than one type of disability, which was heavily evidenced in the interview and document analysis. The observation focused exclusively on cognitive disabilities, and though there are several subcategories, it was slightly less holistic (across all disabilities) compared to the interview and document analysis. However, cognitive disabilities can impact people broadly, compared to other disability types such as sensory (vision, hearing) or motor/physical. For example, cognitive disabilities can decline with age, which is part of being human (WHO, 2024).

4.1. Themes and findings

This study revealed two themes central to improving the user experience of diverse users in research settings: *Challenges and Frustrations for People with Disabilities* and *Advice or Guidance for Improving Information Design*. The challenges and advice themes had the most frequent

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occurrences across all three forms of data collection and have additional crossover in the literature regarding some specific design considerations (Mitchell et al., 2006; Nikivincze & Ancis, 2018). This study found that by reducing the number of challenges and applying the advice shared in this study, people with disabilities may have a more inclusive opportunity to participate in research studies.

The study's findings confirm that in today's information environment, accessible website design is more prevalent than accessible survey design. The interview and observation data note this lack of accessible survey and usability testing design. Although accessible website design is more prevalent in the literature and this study's findings, it is inadequate for survey or usability testing design. More research is needed to fill this gap in the literature.

This study brought out challenges of research study designs. For example, although the literature discussed the need for accessible survey design, none of the studies provided their survey instruments or described the accessibility designs of the survey instruments. It felt like a contradiction to not include those instruments in a study that used such instruments to improve information designs for people with disabilities. Additionally, with the variety of disability types, it is nearly impossible to design a survey or website that mitigates all challenges for all people. However, looking at the criticality of the challenges and addressing those on the higher count end of the spectrum, can alleviate a lot of issues for a lot of people. This is a lesson learned that will be applied to future survey and usability testing designs. This goes with the inclusive mindset that UX designers strive to maintain as their job is to empathize with their end users to design usable interfaces.

From the interview phase (which addresses RQ 1 and RQ2), recommendations include avoidance of long surveys, assuming a person with a disability represents all people with a disability and overtaxing any one person with research study requests (and by extension, survey, and usability testing requests). Rewarding people for their research study or usability testing participation is recommended even if it's just being entered into a drawing or being awarded points that can accumulate over time (for a gift card or prize). Survey tool and digital books may claim to be accessible (as discussed in the literature and interviewee phase) yet that is not always the case. From personal survey taking experience, the interviewee finds Google Forms is more accessible than SurveyMonkey, though all online surveys have limitations, and offered some solutions. For example, to circumvent survey design challenges that impact people who use screen readers when taking surveys, it is recommended to not repeat the same survey instructions at the top of each page which helps lessen the amount of text read by the assistive technology.

Breaking up surveys into shorter segments, utilizing a progress bar, and prioritizing keyboard accessibility are recommendations in the interview, document analysis, and observation (and addressed RQ2). Research question two is also answered with recommendations from the document and observation analysis. From the document analysis, specific web accessibility design considerations are based on 12 disability personas. As a tool, these personas are a static way to demonstrate the user experience for a person with a specific disability who uses technology or the web. These recommendations by disability type are applicable to online survey design and there is considerable crossover of advice among the various disabilities represented in the document. For example, the use of plain language will help people with deafness, dyslexia, autism, and aging. From the observation phase, findings mirror the advice from the interview and document analysis, however the observation prioritizes a simple user interface and designing for people with cognitive disabilities as it will help the most users (with and without disabilities). The personas are a static way to demonstrate the user experience for a person with a specific disability who uses technology or the web. Clearly, the quality work put into its creation held to the standards expected for this organization (known for its accessibility work). The variety, similarities, and contrasts among disability types were a reason for the document selection and why it will be consulted in the future. Challenges or barriers for people with cognitive disabilities include complex layouts, long paragraphs or texts, unusual words, and media you can't stop or turn off, and thus, simplicity and readability are critical design tenets.

Web-based product creators have a responsibility to design products that are usable by everyone and should follow internationally accepted accessibility standards (Section508, WCAG, etc.). Though web-based product vendors may attempt to apply web accessibility standards, those practices are not universally applied. According to the literature and this study's findings, there are still issues with current web accessibility practices and a lack of scholarly literature that highlight inclusive practices for survey and usability testing designs. A summarized list of these findings is below:

- A vendor-supplied accessibility compliance statements (e.g., VPAT) does not mean the product (e.g., a website or online survey tool) is usable by people with disabilities.
- Some Web-based products still lack WCAG compliance.
- People with disabilities are often over tested or taxed with usability and user testing requests for research studies.
- Usability and user testing protocols often lack inclusivity in design, where people with disabilities are asked to catch any errors possible rather follow a structured set of tasks or objectives and lack flexibility in adapting protocols to meet accommodation needs.
- Some surveys fail to give people with disabilities inclusive ways to provide meaningful feedback and are not compatible with assistive technology use.
- Although some studies report people are compensated for their time when participating in surveys or usability tests, this is not always the case and alternative ways to reward user testers is recommended when cash compensation is not possible.
- Accessible website design is more prevalent (than survey design) in the literature, it is inadequate for survey or usability testing design. More research is needed to fill this gap in the literature.

4.2. Limitations

Although this study increases the understanding of the user experience for people with varied disabilities, the research was limited by conducting one interview rather than four or five interviews where a greater degree of triangulation could provide a deeper understanding. Additionally, these subsequent interviews could include people with disabilities other than Autism, ADHD, and mobility difficulties in order to have a more diverse pool of disability types (which will be done for a later phase of this research). The observation focused on cognitive disabilities, and the study could benefit from subsequent observations that covered other disability types. With more time and funding, future studies could also develop survey and usability testing prototypes to use during the interviews to get participants' feedback on specific techniques or features within those designs to iterate improvements.

5. Conclusion

Findings from this study provide a deeper perspective of the positive and negative aspects that affect the daily life of a person with disabilities. Reducing the challenges and applying the advice in this study facilitates universal and human-centred design frameworks that may help increase online survey accessibility for people with disabilities who participate in survey and usability testing. Disability-focused and universal designs also have broader implications as many of the design considerations can increase access and satisfaction more broadly.

This enriched understanding will assist researchers and designers in approaching diverse users during survey and usability testing of web-based products such as websites or electronic books. Although this study highlights accessibility challenges and guidance on improving web-based experiences for the disability community, more research is needed. Beyond accessible websites, research on designing accessible surveys and usability tests is needed, as well as more survey tools that are compliant with accessibility standards. The combined analysis of this study brings forth preliminary design considerations, practical advice for survey and usability testing with the disability community, and new questions for future research on inclusive instrument design.

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Appendix A: Semi-structured interview questions

1. How should we talk about disabilities?
2. What is the general attitude of a person with disabilities in taking surveys or doing a usability test of website?
3. How should survey questions be framed for people with disabilities? (Especially the demographic questions when they are being asked if they have a disability and which one(s)?)
4. What are experiences for a person with disabilities when taking a survey?
5. What are experiences for a person with disabilities when undergoing usability testing?
6. How can researchers best interact with people with disabilities in order to more effectively design products or services?

7. What would you consider are the professional practices that can help survey and usability study designers to assist people with disabilities to overcome obstacles when participating in studies?
8. Do you have recommendations on where to recruit for survey or usability testing? (Groups or associations to send surveys or interview requests?
9. Do you have any questions for me?

Appendix B: Observation protocol template of live webinar on disabilities and web accessibility

7.1. Part 1

7.1.1. Descriptive notes

LOCATION: Online via WebEx platform

Webinar title: Cognitive Disabilities and UX

Note the number of attendees, the date, and start time of the webinar.

7.1.2. Reflective notes

Describe any reflective notes during part 1.

7.2. Part 2

7.2.1. Descriptive notes

Introduction of Webinar (include moderator and speaker); Describe the tone, number of participants viewing, etc.; Describe content presented, order, etc.

7.2.2. Reflective notes

Describe speaker's tone, manner, etc.

7.3. Part 3

7.3.1. Descriptive notes

Webinar ending description: describe conclusion, future, etc; Describe Q & A session.

7.3.2. Reflective notes

Describe tone, rapport with audience (and their questions); Describe any wrap up comments from moderator or speaker; Record end time.

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Appendix C: Interview codebook

Table 1: Interview Codebook

Theme	Code Name [Short]	Definition	When to use	Example of a segment of text
Feelings or attitudes	Frustration or challenges, missed opportunity [Challenges]	Any negative feeling or action	Use when describing how participants felt or use of their own expression	Constantly asking the same person for feedback: “that takes away from their human experience because they are spending all their time testing” (line 356)
Feelings or attitudes	Positive experiences, benefits, or rewards [Positive]	Any positive feeling or action	Use when describing how participants felt or use of their own expression	“Seeing success is an amazing thing when everything is so hard, and so we tend to celebrate smaller successes” (lines 123-124)
Retrospective opinions	Advice	Descriptions or guidance of solutions or fixes to known problems	Use when describing alternative or better approaches to consider in design or practice	“I think it's important to hear from people with disabilities. So, I do think surveys are good” (line 325)
Discipline, industry, or Community at-large aspects	Process, technique, or standards [Process]	Describes the way something is done previously or currently and any evidence or basis for that way of doing	Use when describing systematic and known methods or processes	Graphic organizer
Discipline, Industry or Community at-large aspects	Terms, Policies [Terms]	Describes new or important terms or policies that shape the discipline or community	Use to gain an understanding and background information	“It is divergent of the neurotypical set up…neurodiversity is a person who is neuro divergent. A group is neuro diverse by having a variety of people with a variety of experiences. That is how those labels are applied.” (line 277)

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Theme	Code Name [Short]	Definition	When to use	Example of a segment of text
Discipline, Industry or Community at-large aspects	Accessibility	Describes accessibility considerations, practices, challenges, and benefits	Use when the topic is exclusively about accessibility practices	"A lot of companies who say that their website or app or service is accessible. It's only accessible at the very bare minimum. You know, they've done the least amount possible which doesn't necessarily make it accessible for real in the real-world setting" (line 328)

Appendix D: Document content analysis matrix

Table 2: Document Content Analysis Matrix

Disability	Challenges	Advice	Quote
Blindness	Websites and apps that are incompatible with a screen reader and content that depends on sight; Can't use a mouse	Use meaningful heading structures, semantic values in source code, programmatic form associations	"I need full support for assistive technologies, so the information can be reliably conveyed back to me" (Deque, 2023, Malik persona)
Mobility	Can't use a mouse, partial use of keyboard; Features and interactions that are only designed to work with the use of a mouse	Features that are fully operable using keyboard or voice commands only	"I need full keyboard and voice support, as features or interactions that only work with the mouse are totally useless to me" (Deque, 2023, Cindy persona).
Deafness	Most multimedia content creates significant barriers, but so does written content (inability to hear the language); Walls of text with little whitespace, multimedia content that is not captioned or transcribed	Captions and transcripts for audio and video, sign language interpretation, CART, plain language	"I need support with multimedia files online, but I also enjoy pages and screens that are both easy to scan and read" (Deque, 2023, Brian persona)
Dyslexia	Struggles with most forms of written content; Content complexity, text density, uneven spacing between words, insufficient sparing between paragraphs; Big	Line readers, text-to-speech, multi-sensory learning	"I need support with differentiated learning opportunities and do better when pages are

Disability	Challenges	Advice	Quote
	walls of words with little whitespace, fully justified text, and small, hard to read fonts	opportunities and dyslexic-friendly fonts	supported by visuals and have legible fonts. (Deque, 2023, Lenny persona)
Colorblindness	Struggles when it comes to perceiving information conveyed through color alone or poor contrast; Complex graphs and charts driven by colors, contrasts that are too weak or too subtle	Sufficient color contrasts, information based on more than just colors and other visual cues	"I need support with strong color combination, so I can perceive contrasts and not miss any critical information" (Deque, 2023, Matt persona)
Autism	Thinks in images rather than words (perceived info differently than most people); Inconsistent navigation patterns, lack of while space, and fixed layouts	Consistent layouts, larger font sizes, plain language, minimal clutter and distractions	"I need flexibility in the way I am allowed to use the interface, as I like to do things in very specific ways" (Deque, 2023, Nicky persona)
Low vision	Vision loss with age has affected his ability to read; Depends on big screens, screen magnification software; PDF documents that won't reflow properly, small-sized text and mobile sites without pinch to zoom	Truly responsive web interfaces and applications, CSS based layouts, adaptive fonts, contrasts	"I need support with flexible layouts and legible fonts, so I can resize the text to a size that works well for me" (Deque, 2023, Rakesh persona)
Anxiety	Hard time dealing with stressful situations and easily finds herself feeling defeated when things don't go the way she expected (affects the quality of her online experiences); Dark, anti-patterns that create false senses of urgency and feed into her anxiety are difficult	Not feeling rushed into tasks or interactions, and being provided with clear instructions to succeed	"I need support with clearly defined expectations on sites and apps, as I can get easily anxious or give up." (Deque, 2023, Ying persona)
Vestibular disorders	Permanently damages nerve system affecting overall sense of balance; Sensitive to animations, scrolling effects, and can get dizzy or develop a migraine when there is too much movement; Parallax effects and other invasive scroll-triggered animations that can induce dizziness or nausea	Clear notifications, warnings, or efficient ways to opt-out of unwanted, or unnecessary animations	"I need ways to shield myself from animations and scrolling or parallax effects that can make me feel sick" (Deque, 2023, Jason persona)

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Disability	Challenges	Advice	Quote
ADHD	Easily distracted on the Web; Disruptive websites that make heavy use of pop up or modal windows; Distracting, or busy interfaces that make focusing on content more complicated than it needs to be	Clearly streamlined sets of options on the screen, to help avoid going down unexpected rabbit trails	“I need support with clear content structures, so that I can successfully stay focused on the job to be done” (Deque, 2023, Joyce persona)
Aging	Early signs of dementia, osteoarthritis, and Alzheimer’s plus declining senses of hearing and sight; More easily consumed when experiencing online content; Long-winded, confusing, or overly complex interfaces that lead to convoluted interactions	Simple interfaces, clear expectations, larger, more legible fonts, strong contrasts, and white space	“I need simple, easy to use pages because when it gets too complicated, I just don’t know what to do” (Deque, 2023, Kim persona)
Photo-epileptic sensitivity	At risk for seizures when she unexpectedly runs into flashing or blinking content online; This makes her nervous when browsing the web, especially social media; Ends up needing anywhere between 6 to 10 hours of bed rest when content triggers a seizure	Obvious warnings before being presented with flashing, blinking or strobing materials	“I need to feel safe online, trusting that I won’t run into content that may cause me harm when I least expect it” (Deque, 2023, Lynn persona)

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Applying Post-Occupancy Evaluation (POE) to investigate Inclusive Design in library spaces.

Case studies: Kharazmi, main library and documentation centre, and the Art and Architecture libraries.

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Abstract: Inclusive architecture aims to create spaces that cater to everyone, regardless of their abilities or disabilities. Public libraries play a pivotal role in this endeavour by providing accessible environments for diverse communities. This study conducts a post-occupancy evaluation (POE) of the inclusivity of three libraries in Shiraz, examining how effectively these libraries cater to the needs of all users through an inclusive design approach. The POE process comprised three steps: planning, implementation, and application. During the planning phase, a checklist of 180 items was compiled and adjusted based on theoretical foundations. These items fell into four general categories: 1-Spatial Design (including spatial design requirements, flooring, ceilings, and walls), 2-Accessibility and Circulation (covering movement paths, ramps, lifts, elevators, and staircases), 3-Amenities and Equipment (such as parking, toilet services, entrances, furniture, and guide signs), 4-Sensory and Atmosphere (addressing lighting, colour, texture, materials, shape, scent, sound, and temperature). In the implementation phase, the evaluation was conducted over three days at the indicator level by a two-person evaluation team. They utilised observation, photography, and metric measurement tools. In the subsequent step, field observations to complete the checklist were carried out, and data entry and analysis were performed using IBM SPSS Statistics 26.0 software. The results indicated that all three libraries (MLDC, Art and Architecture, and Khwarizmi libraries) exhibit several weaknesses in terms of inclusive design. The average inclusiveness scores assigned to them were 37.50%, 35.10%, and 34.35%, respectively. As the achievements of the application phase, it can be summarised that the findings of this study provide a practical example for POE research on inclusive design, offering insights for enhancing inclusivity in architectural environments.

Keywords: Inclusive Design, Post Occupancy Evaluation, POE, library, accessibility, disability.

1. Introduction

The need for inclusivity is far more common than usually perceived. Indeed, nearly all individuals encounter some form of disability or impairment at some point in their lives due to a variety of factors such as accidents, illnesses, aging, or even during childhood. This requires the inclusion of design provisions in the products and spaces around them. According to statistics provided by the World Health Organisation, approximately 15% of the global population have some form of disability, with between 2% and 4% experiencing severe disabilities (WHO, 2011). Similarly, in Iran, statistics related to individuals with disabilities are around 11%, with severe disability statistics cited as 4% of the total population (Aslefallah & Hashemi, 2019). These statistics underscore the need for a greater emphasis on inclusive design.

Indeed, a design approach that emphasises inclusive design principles is essential, considering the widespread presence of individuals with physical and mobility disabilities in all societies. Neglecting the needs and desires of these individuals can be seen as a form of discrimination in design, effectively excluding these groups from the user range of spaces and products (Aslefallah & Hashemi, 2019). This highlights the importance of inclusive design in creating a more equitable and accessible environment for all. These limitations ought not to be viewed as a barrier to individuals' access to their preferred spaces; instead, they should be able to live with utmost independence, devoid of limitations and without the burden of restrictions that ordinary members of society are free from. Adapting spaces for individuals with disability is a demonstration of social justice and safety in access, which, in addition to creating physical and health security, will have remarkable psychological effects (Noroziyan Maleki & Hosseini, 2008).

One of the primary research institutions in society that caters to a broad audience (including children, the elderly, individuals with disabilities, etc.) is the library. It must cater to the needs of all its users to establish social justice. To adequately respond to these needs, utilising inclusive design by creating spaces that provide equal access and use for all users is advantageous. In this context, POE, as 'the most effective building performance evaluation that includes building efficiency during operation' (HEFCE, 2006). Is pertinent for measuring the extent to which the library benefits from inclusive design. In other words, utilising design provisions to address identified problems from POE can enhance the accessibility of architectural spaces for everyone. This makes them more optimal in terms of use, more desirable, and, in a word, more inclusive.

Therefore, it can be stated that the theoretical underpinnings of this research are divided into two primary sections. The first section pertains to the concept of inclusive design and its objectives. The second section offers a clear definition of post-occupancy evaluation and outlines its various stages. This framework provides a comprehensive understanding of the primary keywords of this research. It serves as a foundation for further exploration and analysis.

1.1. Inclusive design

The concept of inclusive design was first introduced in England by Roger Coleman in 1994. He argued that human needs and abilities change throughout life. By considering this in the design process, products, services, and environments can be improved for most audiences. This improvement is not accompanied by negative perceptions of illness or disability. Later, the Design Council of England (2008) defined inclusive design as a general approach. In this approach, designers ensure that their products and services meet the needs of the widest possible range of audiences, regardless of age and ability (Heylighen, Van der Linden, & Van Steenwinkel, 2017).

Indeed, the approach of inclusive design aligns closely with the concepts of universal design, accessible design, and design for all. These principles all advocate for inclusivity and accessibility in design. However, there is a gap in the field when it comes to detailed studies. The specific factors that can be used to evaluate a building from the perspective of inclusive design are not yet fully defined or explained. This presents an opportunity for this research to explore in this area to enhance our understanding and application of these principles in building design and evaluation.

1.2. The Post-Occupancy Evaluation

Post-Occupancy Evaluation (POE) is a systematic and meticulous process used to assess buildings after they have been constructed and occupied for a certain period. This process is centred on the building's occupants and their requirements. It offers insights into the outcomes of past design decisions and the performance of the building that results from these decisions. This understanding lays a robust foundation for the creation of superior buildings in the future (Preiser, White, & Rabinowitz, Post-Occupancy Evaluation (Routledge Revivals), 2015). POE serves a pivotal function in a building's life-cycle, specifically in providing feedback. It encompasses a broad spectrum of activities and advantages, such as evaluating the performance of a building, investigating the correlation between the behaviour of occupants and the utilisation of building resources, optimising the indoor environment for the occupants, making more enlightened decisions about future architectural design, and creating opportunities to strengthen the communication within design teams and their collaborators. However, the assessment of building performance and occupant contentment during the post-occupancy phase is relatively less advanced compared to the evaluation techniques employed during the design phase of a building (Li, Froese, & Brager, 2018).

POE stands out from other building performance evaluations due to its focus on the needs of building occupants. The results of a POE are akin to a treasure trove of instructive lessons. These lessons are invaluable for programs that aim to collect and share information about building successes and failures. The ultimate goal is to enhance the quality and cost-effectiveness of future buildings' life cycles. Ideally, the information gleaned from a POE is utilised in curricula, planning, and new designs to ensure success and prevent the repetition of past mistakes (Preiser, The Evolution of Post-Occupancy Evaluation: Toward Building Performance and Universal Design Evaluation, 2001).

Findings from a variety of studies indicate a lack of consistency in reporting, the employment of methods, tools, and data collected in POE studies. This inconsistency presents a challenge for the field and underscores the need for standardisation in POE practices. This highlights the necessity of the research at hand, as no article has yet scrutinised the topic of POE based on inclusive design. The present article is innovative in this regard (Elsayed, Pelsmakers, Pistore, Castaño-Rosa, & Romagnoni, 2023).

Preiser has categorised post-occupancy evaluation into three levels: "indicative," "investigative," and "diagnostic" POE. Each level consists of three stages: "planning," "conducting," and "applying" (Preiser, White, & Rabinowitz, Post-Occupancy Evaluation (Routledge Revivals), 2015). Figure 1 provides an overall schematic of the post-occupancy evaluation levels, stages, and the effective steps at each level. This approach ensures clarity and ease of understanding.

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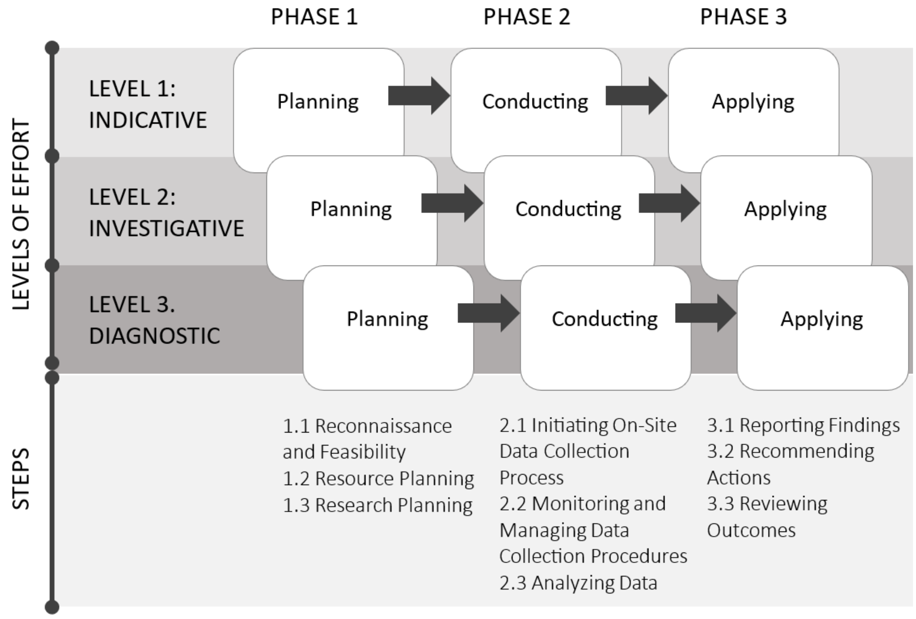
Figure 1. POE process model. Source: (Preiser, White, & Rabinowitz, Post-Occupancy Evaluation (Routledge Revivals), 2015).



2. Methodology

The execution of POE is of paramount importance in the field of architecture and design. It provides a systematic and rigorous approach to understanding how a building or space performs once it is occupied and used. This process allows for the assessment of whether the design objectives have been met and if the space is functioning optimally for its intended users. Furthermore, POE can identify areas for improvement, inform future design decisions, and ultimately contribute to creating more inclusive, accessible, and user-friendly environments. Therefore, the significance of POE cannot be overstated in the pursuit of excellence in architectural design and practice. The POE process unfolds in three primary stages:

1. Planning: This initial stage involves preliminary planning where key elements such as the level of POE, methods and tools for data collection, the number of evaluators, and the time required, and the approach to data collection and interpretation are determined.
2. Implementation: This stage involves conducting field observations and collecting data. A report encompassing the collected data and their interpretation is also prepared during this stage.
3. Application: The final stage presents a summary of the results and offers design recommendations. Each of these stages is elaborated upon in the following sections.

2.1. Phase one: planning

The parameters for conducting the field research were determined at this stage. To achieve this, the following three steps were undertaken:

1. Reconnaissance and Feasibility:
   The aim of this research was to identify the strengths and weaknesses of the sample libraries in terms of inclusive design and to make comparisons. Consequently, among the three levels of Post-Occupancy Evaluation (POE) - indicator, investigative, and diagnostic - the indicator level was chosen. It was anticipated that this level of research would necessitate one to two

days for each sample library studied. The appropriate tool for data collection would be observation and field collection. The case studies were chosen from the libraries of the University of Shiraz in Shiraz city, including the Kharazmi Library (KHL), the Main Library and Documentation Centre (MLDC), and the Art and Architecture Library (AAL). These libraries cater to a wide audience, including students, professors, and many others. Figure 2 displays images of these libraries.

Figure 2. Library images in sequence: KHL, MLDC, AAL.

2. Resource Planning:
   Before the data collection and analysis, a set of assessable criteria and factors for inclusive architectural space design needed to be extracted from the available resources. The extraction of these criteria should ultimately lead to a summarised POE checklist based on an inclusive approach. Alongside this checklist, tools for photography and measurement were required. For this purpose, a camera, a Leica D2 laser meter, and a standard meter were utilised. A two-person team was considered for the evaluation process.
3. Research Planning:
   At this stage, the literature on inclusive design was initially reviewed. An attempt was made to extract an initial checklist for reviewing case samples by categorising this information. In this process, approximately 200 items were extracted, which were reduced to 180 after removing repetitive or highly dispersed items. Then, similar items that were related to measuring the same elements were categorised and formed 20 main factors under evaluation. These factors are placed in four general categories, which are:

- Spatial Design: Spatial design requirements, floor, ceiling, wall.
- Accessibility and Circulation: Movement path, ramp and lift, elevator, staircase.
- Amenities and Equipment: Parking, toilet service, opening, furniture, guide signs.
- Sensory and Atmosphere: Light, colour, texture and materials, shape and form, scent, sound, temperature.

2.2. Second phase: conducting

This phase was linked to field research and included the subsequent three stages:

1. Launching the On-site Data Collection Process:
   This stage involved data gathering in the chosen libraries. Notably, field surveys for the MLDC, KHL, and AAL of Shiraz University were undertaken on August 3rd, 4th, and 9th, 2022, respectively.
2. Monitoring and Managing Data Collection Procedures:
   The data were meticulously gathered using the tools chosen in the planning phase. To ensure the accuracy of data collection, in each library, checklist data were independently collected by two evaluators. Subsequently, any phrases related to inconsistent responses were re-collected by both evaluators.

3. Data Analysis:
   The data, procured from the surveys, were meticulously processed using the SPSS software, version 26. Each phrase was systematically assigned a binary code; 'one' signified the prevalence of the phrase under review, while 'zero' indicated its absence. This methodology resulted in a binary dataset comprising 180 data points for each library, culminating in an initial dataset of 540 data points. Subsequently, new variables were delineated, each corresponding to one of the 20 factors previously mentioned. The value of each variable was computed as the mean response of the phrases associated with the respective factor. An additional variable, termed 'Overall Inclusiveness', was derived by calculating the mean value of these 20 factors. This rigorous approach to data analysis ensures a comprehensive understanding of the survey results.

2.3. Third phase: applying

In this phase of POE, findings are reported and conclusions are drawn. This stage is composed of three steps:

1. Reporting Findings:
   The discoveries from this stage are detailed in the subsequent section, divided into two categories: descriptive findings and analytical findings.
2. Recommending Actions:
   It's evident that the necessary actions in this step hinge on addressing the shortcomings identified in each library. The analyses conducted in earlier stages yield practical insights for enhancing the current status of the studied samples in terms of inclusive design.
3. Reviewing Outcomes:
   A comprehensive review of the overall results is also provided in the conclusion section. This review provides a basis for future improvements.

3. Results

In the exploration of the research findings, the investigation is divided into two distinct sections. The first section, named as 'Descriptive Findings', is dedicated to presenting the data in a clear and straightforward manner. It provides a succinct summary of the collected data, laying out the facts as they are, without any deeper interpretations or conclusions. The second section, termed 'Analytical Findings', adopts a more in-depth approach. It delves beneath the surface of the data, using statistical tests to scrutinise and interpret the data. The aim of this analysis is to extract meaningful conclusions from the data, thereby aiding in the understanding of the underlying patterns and trends within the data. This comprehensive approach to data analysis ensures a thorough understanding of the research findings.

3.1. Descriptive findings

In this section, the inclusiveness of all items is categorised into four distinct groups:

1. Spatial Design.
2. Accessibility and Circulation.
3. Amenities and Equipment.
4. Sensory Atmosphere.

It should be emphasised that the majority of the figures and specifics mentioned in the ensuing tables are sourced from the book "Urban and Architectural Design Criteria for People with Disability". This book provides a set of guidelines and standards for designing accessible and inclusive urban environments and buildings for people with disabilities (BHRC, 2020).

3.1.1. Spatial design

This category focuses on the physical layout and arrangement of spaces. The factors considered under this category include spatial design requirements, floor, ceiling, and wall. These factors play a crucial role in determining how effectively a space can be navigated and used by all individuals. Table 1 shows the data related to three libraries in the field of Spatial Design.

Table 1. Reviewing inclusivity in the first category: Spatial Design.

Nu	Factor	Item	Item details	KHL	MLDC	AAL
1	Spatial design requirements	Legibility of the placement of various spaces			✓	✓
		Adherence to hierarchy in spatial design				✓
		Utilisation of a specific module in design			✓	
		Expansive vistas and maximum visual connectivity of spaces			✓	
		Implementation of direct and straightforward circulation paths			✓	✓
		Integration of small and large spatial volumes				
		Incorporation of a tranquillity room	At least one			
		Differentiation of spaces with diverse functions			✓	✓
2	Floor	Use of durable materials on the floor			✓	✓
		Non-slip floor coverings		✓	✓	✓
		Smoothness of the floor surface			✓	✓
		No light reflection		✓		✓
		Use of sound-absorbing materials on the floor				
		Control of maximum protrusion on the floor surface	Maximum 2 cm	✓	✓	✓
		Control of maximum distance between floor covering pieces	in: full state: 10 mm/ empty state: 5 mm	✓	✓	✓
		Use of guiding and warning floor coverings				
3	Ceiling	Reducing the ceiling height to adjust the reaction time		✓		✓
		Providing the necessary ceiling height and clearance below suspended objects	Minimum height: 210 cm		✓	✓
		Changing the ceiling height in primary and secondary spaces		✓		
4	Wall	Control of object protrusions on the wall	Maximum 10 cm	✓		
		Placement of handrails at an appropriate height on the wall	Height: 85 and 60 cm			
		Placement of handrails with an appropriate diameter on the wall	Diameter: 3.5 to 4 cm			
		Providing the necessary distance between the handrail and the wall	Maximum 4 cm			
		Absence of sharp objects on the wall		✓		

Table 1 indicates the first spatial design requirement factor comprises 8 items. None of the samples considered combining small and large spaces or including a tranquillity room, key for autism spectrum disorder inclusivity (Karbalaei Hosseini Ghiyasvand, Sattari, Soltanzadeh, & Farahbod, 2018). The KHL struggles with inclusive spatial design due to lack of readability, hierarchy, specific module use, and complex paths. The MLDC excels in spatial design inclusivity. Strengths include clear space location, separated spaces for different uses, direct paths, and open plan for transparency, wide view field, maximum space communication, and specific module use. The AAL also demonstrates hierarchy in spatial layout.

The next factor, floor, encompasses 8 items. All samples overlooked two crucial aspects: sound-absorbing and blind-friendly guiding/warning floor coverings. However, all samples feature non-slip floors. KHL uses diverse floor materials, with parquet in study halls and ceramic in lobbies and communication spaces. The parquet shows wear from furniture movement. In some areas, floor materials change without apparent reason, complicating echolocation for blind individuals. Both the MLDC and AAL use durable, smooth floor materials. The MLDC predominantly uses white ceramic tiles, which can cause glare due to light reflection at certain times (Figure 3).

Figure 3. Floors in the libraries (AAL, MLDC and KHL respectively).

Ceiling design is another important factor in library design. Lowering ceiling height to around 3 meters, as seen in KHL and AAL study halls and open repositories, helps prevent echo and noise (Shabani & Salavatian, 2021). This aspect is less considered in the MLDC Library, with its ceiling exceeding 4.5 meters. Providing necessary ceiling height and at least 2.1 meters clearance under hanging objects is another factor. KHL falls short in some areas with a 1.9-meter ceiling. Changing ceiling height in main and secondary spaces aids blind individuals and other users in distinguishing these spaces. This technique is only applied in KHL Library. In the MLDC, all spaces share the same ceiling height, while the AAL lacks proportionality in ceiling height changes between main and secondary spaces (Figure 4).

Figure 4. Ceilings in the libraries (AAL, MLDC and KHL respectively).

Wall design, comprising 5 items, is another factor. All three examples exhibit a fundamental weakness in this area. Only two items, controlling object protrusion and absence of sharp materials or objects, were observed in the KHL. Controlling wall object protrusion (maximum 10 cm) is crucial for injury prevention. However, some areas in the MLDC and AAL have protrusions exceeding 10 cm, such as bulletin boards or electrical panels. It's also evident that no handrails have been used on the walls in any of the examples (Figure 5).

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Figure 5. Walls in the libraries (AAL, MLDC and KHL respectively).

3.1.2. Accessibility and circulation

This category pertains to how easily individuals can move within and between spaces. Factors such as movement path, ramp and lift, elevator, and staircase are considered under this category. These factors are critical in ensuring that all individuals, including those with mobility impairments, can access and use the spaces without difficulty. Table 2 presents data on accessibility and circulation for three libraries.

Table 2. Reviewing inclusivity in the second category: Accessibility and Circulation.

Nu	Factor	Item	Item details	KHL	MLDC	AAL
1	Movement path	Inclusiveness of corridor path width	Corridor: minimum 180 cm- appropriate size: 250 cm		✓	✓
		Control of transverse slope of paths	Maximum 2 percent	✓	✓	✓
		Control of longitudinal slope of paths	Maximum 5 percent	✓	✓	✓
		Providing an inclusive emergency exit				
2	Ramp and lift	Placement of the ramp near the entrance and parking				
		Control of ramp slope	Up to length: - 300 cm: 8 percent - 500 cm: 7 percent - 800 cm: 6 percent - 900 cm: 5 percent			
		Providing sufficient ramp width	Minimum 120 cm	✓		✓
		Control of ramp length	Maximum 900 cm			
		Provide minimum depth of step	Minimum 150 cm			
		Providing a minimum tread depth	Less than 5 mm	✓		✓
		Control of ramp railing height	Height: 85 and 60 cm			
		Providing a protective edge with an appropriate height	Height: 5 cm	✓		✓
		Installation of tactile colour indicators with a distinct texture at the beginning and end of the ramp	Width of strip: 4-5 cm			
		Providing the necessary dimensions for the lift	Minimum 90 by 120 cm			
		Control of maximum level difference for using the lift	Maximum 200 cm			
		Closing the space under the platform	Fully enclosed			
		Control of lift handrail height	Height: 85 and 60 cm			
3	Elevator	Placement of elevators on all floors				

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Nu	Factor	Item	Item details	KHL	MLDC	AAL
		Levelling the elevator floor with the tread of each floor		✓	✓	
		Providing sufficient dimensions for the waiting space in front of the elevator	Minimum 150 by 150 cm	✓	✓	
		Providing sufficient dimensions for the elevator cabin	Minimum 110 by 140 cm			
		Control of door width and location	- Width of opening door: minimum 80	✓	✓	
		Use of automatic sliding doors for elevators			✓	
		Installation of a folding chair inside the elevator				
		Installation of a mirror inside the elevator		✓	✓	
		Placement of elevator handrails at an appropriate height	85 cm			
		Control of elevator control button height	Height: 100 to 120	✓	✓	
		Control of distance between elevator control buttons and corners	Distance from corner: 40			
		Control of diameter of elevator control buttons	Minimum diameter: 3	✓	✓	
		Control of protrusion of elevator control buttons	Projection: 1.5			
4	Staircase	Use of straight stairs as much as possible			✓	✓
		Uniformity of tread depth and stair height		✓	✓	✓
		Installation of a protective edge next to the stairs		✓		
		Providing a minimum stair width	Minimum 120 cm	✓	✓	✓
		Control of tread dimensions	30 cm	✓	✓	✓
		Control of stair height	Maximum 17 cm		✓	✓
		Closing the stair riser		✓	✓	✓
		Control of maximum stair protrusion from riser	Maximum 3 cm	✓	✓	✓
		Control of tread edge radius	Maximum 13 mm	✓	✓	✓
		Providing a minimum landing dimension	120 by 120 cm	✓		✓
		Control of the number of steps in each arm	Maximum 12	✓		
		Installation of a handrail at an appropriate height on the stairs	Height: 85 and 60 cm			
		Presence of tactile indicators with a distinct texture on the stairs		✓	✓	
		Avoid creating unnecessary stairs				✓

According to Table 2, another factor is the movement path. The MLDC and AAL meet inclusive standards for path width and slope. However, KHL falls short in some areas, with path widths less than the required 1.8 meters. Despite this, the library's path slopes, under 2% transversely and 5% longitudinally, are commendable. Unfortunately, none of the libraries feature inclusive emergency exits, compromising user safety (Figure 6).

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Figure 6. Movement paths in the libraries (AAL, MLDC and KHL respectively).

Ramps and lifts are crucial for accessibility, especially for those with physical disabilities. Regrettably, all three libraries fall short in this regard. The MLDC lacks a ramp to the first-floor entrance, leaving a long staircase as the only access point. The other two libraries do have ramps, but they fail to meet necessary standards, with only the width, step dimensions, and edge guard appropriately designed. Critical aspects such as ramp location, slope, length, railing height, handrails, and tactile indicators are significantly lacking. Furthermore, none of the libraries have lifts for main entrance access (Figure 7).

Figure 7. Ramps in the libraries (AAL and KHL respectively).

The evaluation of the elevators in the libraries reveals several shortcomings. The AAL, located on the second floor, lacks an elevator. KHL's elevators serve alternate floors, necessitating stair use or multiple elevator trips. Other issues include non-sliding doors, narrow door width (70cm), small cabin dimensions (100x80cm), absence of a folding chair and handrail, and poorly placed control buttons. The MLDC lacks a ground floor accessible elevator, and its cabin dimensions (90x150cm), high handrail height (95cm), and lack of a folding chair further reduce inclusivity. However, both the MLDC and KHL provide ample waiting space, floor-level access, mirrors, and appropriately sized and placed control buttons (Figure 8).

Figure 8. Elevators in the libraries (MLDC and KHL respectively).

While the design of staircases in the libraries incorporates many inclusive features, there are notable shortcomings. None of the libraries have handrails at two necessary heights and on both sides. The MLDC and AAL feature straight staircases with over 12 steps without intermediate treads or protective edges. KHL's design includes unnecessary breaks and interior stairs exceeding the standard height of 17cm by 1cm. Tactile indicators on the tread edges are present in KHL and MLDC but absent in the AAL. Unnecessary stairs and level differences are prevalent in KHL, and the MLDC has stairs at toilet entrances and within (Figure 9).

Figure 9. Staircases in the libraries (AAL, MLDC and KHL respectively).

3.1.3. Amenities and Equipment

This category includes factors that contribute to the functionality and usability of the space. Factors such as parking, toilet service, opening, furniture, and guide signs fall under this category. Table 3 presents data on amenities and equipment for three libraries.

Table 3. Reviewing inclusivity in the third category: Amenities and Equipment.

Nu	Factor	Item	Item details	KHL	MLDC	AAL
1	Parking	Providing a sufficient number of disabled parking spaces	Number: 4 percent of total			
		Ensuring the necessary dimensions for disabled parking spaces	Parking width: minimum 350 cm			
		Controlling the distance from parking to the entrance of the building	Minimum possible distance	✓		✓
2	Toilet service	Providing the necessary number of disabled toilets	Number: 10 percent of total			
		Providing the minimum necessary dimensions for disabled toilets	Minimum 150 by 170 cm			
		Control of toilet bowl height from the floor	45 cm			
		Control of distance between toilet bowl and adjacent wall	Minimum 30 cm			
		Placement of horizontal auxiliary handrails on both sides of the bowl				
		Control of horizontal auxiliary handrail height	70 cm			
		Control of protrusion of horizontal auxiliary handrail from bowl edge	20 cm			
		Placement of vertical auxiliary handrail on adjacent wall to bowl				
		Control of distance between vertical auxiliary handrail and front edge of bowl	30 cm			
		Control of vertical auxiliary handrail height from bowl seat level	40 cm			
		Control of vertical auxiliary handrail height swing range	80 to 40 cm from the floor			
		Providing the necessary space in front of the sink	75 by 120 cm	✓	✓	✓
		Control of faucet distance from sink front edge	60 cm	✓	✓	✓
		Control of free space height under sink	75 cm	✓	✓	✓
		Control of free space depth under sink	- for knee: 20 cm - for toe tip: 45 cm	✓	✓	✓
		Placement of sink mirror at an appropriate height from the floor	90 cm			✓

Nu	Factor	Item	Item details	KHL	MLDC	AAL
		Considering outward opening direction for doors				
		Placement of handrails on doors				
		Installation of emergency bell in disabled toilet at an appropriate height	Maximum 120 cm			
		Control of hanger and shelf height	Maximum 120 cm			
		Control of soap and electric dryer height	Maximum 100 cm			
3	Opening	Providing the minimum required width for the main entrance	Minimum 100 cm	✓	✓	
		Control the width of other entrances	Minimum 80 cm	✓	✓	✓
		Control the opening angle of doors	Minimum 90 degrees		✓	✓
		Control the maximum height of door thresholds	Maximum 2 cm	✓	✓	✓
		Avoid using revolving, rotary, sliding doors		✓	✓	
		Consider a low footrest with a suitable height	Low door sill height: 25 cm		✓	
		Control the height of door handles	90 cm			
		Lever type door handles		✓	✓	✓
		Control the distance of the handle from the door surface	3.5 to 7 cm	✓	✓	✓
		Provide handrails on doors at a suitable height	At a height of 85 cm, with a length of 30 to 65 cm			
		The mechanism of opening and closing the door is automatic, gravity or spring type				
		Placement of coloured signs on glass openings				
		Control the height of windows from the floor	Maximum 80 cm			
		Use double or multi-walled windows				
		Sufficient dimensions of windows to provide natural view and lighting			✓	✓
4	Furniture	Control the height of the loan desk surface	Maximum 90 cm		✓	
		Control the height of the free space under the loan desk	Between 70 and 85 cm		✓	
		Control the depth of the free space under the loan desk	50 cm			
		Provide a sufficient number of tables and benches	Number: 5 percent of total	✓	✓	
		Provide suitable dimensions for the surface of study tables	Minimum 75 by 50 cm	✓	✓	✓
		Control the height of the surface of study tables	Minimum 70 cm	✓	✓	✓
		Control the height under study tables	Between 70 and 85 cm	✓	✓	✓
		Control the height of shelves and cabinets	Accessible height: 40 to 120 cm	✓	✓	
		Control the height of free space under drinking fountains	Minimum 70 cm			✓
		Control the depth of free space under drinking fountains	Minimum 45 to 50 cm			✓
		Control the maximum height of drinking fountain fountains	90 cm			

Nu	Factor	Item	Item details	KHL	MLDC	AAL
		Provide free space in front of drinking fountains	75 by 120 cm	✓	✓	✓
5	Guide signs	Presenting information with simple words and readable font		✓		
		Presenting information in various visual and auditory forms				
		Placement of user guide signs on each floor			✓	
		Placement of floor signs on the wall opposite the elevator door				
		Installation of tactile exit signs				
		Installation of tactile warning signs on doors in hazardous spaces				
		Equipping elevator floor buttons with Braille lines				
		Using signs in emergencies to guide people on their way out				
		Considering the limitations of people with colour blindness in sign design		✓	✓	
		Using audio and visual warning systems			✓	
		Installing signs at a suitable height	Between 140 to 170 cm			
		Simplicity of equipment and providing usage instructions			✓	

Table 3 reveals that parking is a key factor under review, with three considerations for inclusive design: the number of disabled parking spaces, standard dimensions for allocated parking, and proximity of parking to the entrance. None of the libraries studied offer dedicated disabled parking spaces, which should ideally be a marked 2.5m-wide space for car parking, with an adjacent 1m-wide passage. In all cases, parking is employee-only. The MLDC's covered parking is a significant 150m from the entrance, a distance that, coupled with lack of route coverage, poses difficulties even for employees. However, the KHL and AAL have more favourable distances (Figure 10).

Figure 10. Parking areas of the libraries (AAL, MLDC and KHL respectively).

Toilets are another key factor in this study. All libraries studied have significant shortcomings in this area, as none have toilets designed for disabled users. Common issues include inward-opening doors, lack of auxiliary handrails, absence of emergency bells, and non-standard heights for shelves, hangers, and soap dispensers. The KHL and AAL lack toilets on all floors. All libraries meet necessary standards for sinks and faucets. While mirrors are present in all libraries, only the Art and Architecture Library's mirror is at an appropriate height (90cm) (Figure 11).

Figure 11. Toilets in the libraries (AAL, MLDC and KHL respectively).

Doors and windows, crucial to this study, meet standards for interior door width, door thresholds, handle types, and handle distance from the door surface across all libraries. However, KHL struggles with stiff revolving doors, less than 90-degree opening sanitary service doors, high handle heights, absence of coloured strips on glass doors, and lack of door handrails. The MLDC shares similar issues, with high handle heights, lack of door handrails, stiff revolving doors, and no warning strips on glass doors. The AAL's main entrance width is often less than the required 1m, and the sliding door at the study hall entrance could be better replaced with easy-to-open revolving or automatic doors. Issues also exist with handle height on doors, door handrails, and warning signs on glass doors. Window dimensions are satisfactory in the MLDC and AAL, but KHL's small, deep, and generally closed windows limit natural light and airflow (Figure 12).

Figure 12. Doors in the libraries (AAL, MLDC and KHL respectively).

The twelfth factor in this study is furniture, which includes the loan desk, study tables and benches, shelves and cabinets, and drinking fountains. The MLDC has a loan desk that meets the first two standards for height and under-desk space. However, all libraries have shortcomings in other areas. While all libraries use inclusive furniture, the AAL does not have group study tables in the study hall. The height of storage cabinets varies in all three libraries, catering to a wide range of users. The AAL's open repository has upper shelves that are too high for wheelchair users to reach. Despite sufficient space around the drinking fountains, their dimensions and height make them difficult to access for some users (Figure 13).

Figure 13. Furniture in the libraries (AAL, MLDC and KHL respectively).

Guide signs are crucial in inclusive design as they enhance readability, accessibility, and security. The MLDC excels in this area by providing user guide signs on each floor, considering colour blindness limitations, and using audio-visual warning systems. However, information is presented in small fonts and only visually, and glare sometimes hinders readability. The KHL offers clear signage due to suitable font and dimensions, but lacks user guides on each floor and diverse information formats. The Art and Architecture Library lacks designed guide signs altogether, with space names merely placed on paper or small boards above doors (Figure 14).

Figure 14. Guide signs in the libraries (AAL, MLDC and KHL respectively).

3.1.4. Sensory and Atmosphere

This category relates to the sensory experiences within the space. Factors such as light, colour, texture and materials, shape and form, scent, sound, and temperature are considered under this category. These factors can greatly influence the overall atmosphere of the space and the comfort and well-being of its users. Table 4 shows the data related to three libraries in the field of sensory and atmosphere.

Table 4. Reviewing inclusivity in the fourth category: Sensory and Atmosphere.

Nu	Factor	Item	KHL	MLDC	AAL
1	Light	Adequate use of natural and artificial light		✓	✓
		Avoiding intense and dazzling light	✓		✓
		Using light and shadow contrast to display the separation of environments			
		Using lighting to display the separation between floor, ceiling and wall elements			
		Using lighting to display the path and guide the individual			
		Using coloured lights to indicate danger in the event of an accident			
		Avoiding rhythmic or patterned sequences of light and shadow		✓	✓
		Using light dimmers			
		Using light intensity control panels			
		Indirect, extensive and decentralised lighting			
		Not using fluorescent lamps	✓	✓	
2	Colour	Using a specific colour palette in design		✓	
		Using natural colours			
		Using colours with less light reflection	✓		✓
		Using colours that are in contrast to skin colour in space design		✓	✓
		Appropriate colours for people with autism			
		Using a variety of symbolic colours to identify specific spaces			
		Using furniture with a specific colour in each space			
		Benefiting from guiding coloured lines from the lobby to spaces			
		Colour difference between wall, floor and ceiling or using coloured strips at the connection point	✓		✓
		Colour difference between doors and their frames with adjacent walls	✓	✓	
		Colour distinction between columns and walls			✓

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Nu	Factor	Item	KHL	MLDC	AAL
		Colour difference between baseboards and up and down stairs or colour difference between the front edge of stairs			
		Colour difference between elevator control buttons and background colour	✓	✓	
		Colour difference between handrail bars and surrounding environment		✓	
3	Texture and materials	Using natural textures and materials (wood, stone, brick and ...)			
		Using soft textures instead of rough and harsh textures	✓	✓	✓
		Using materials with distinct texture on floor, wall and ceiling surfaces	✓	✓	✓
		Changing floor materials in different spaces (echolocation technique)	✓		
4	Shape and form	Using symmetry in design			✓
		Using repetition in design		✓	✓
		Using rhythm in design		✓	
		Using readable shapes and familiar geometries		✓	✓
		Using organic forms or fractal design			
		Using soft and curved corners		✓	
		Using human scale	✓	✓	✓
		Establishing clear relationships in design		✓	✓
		Avoiding creating unnecessary breaks			✓
		Establishing communication between horizontal, vertical and oblique elements in design		✓	
		Coordination and coherence between different parts to create a single unit		✓	
5	Scent	Using natural materials with a desirable scent			
		Using fragrant flowers and plants in space			
		Preventing the mixing of different smells in space	✓	✓	✓
6	Sound	Preventing noise pollution			
		Using a sound amplification system			
		Using the sound of natural elements			
		Changing the shape, dimensions, distance and depth of space to change the acoustic pattern	✓		
7	Temperature	Changing heat and humidity in different spaces			
		Distinguishing the temperature of materials on different surfaces			

Lighting is key in library design. The KHL Library uses skylights, the MLDC balances natural and artificial light, and the AAL controls glare. However, all libraries lack features like light contrast for space delineation, coloured warning lights, and dimmers. Some spaces in KHL lack natural light, and its windows can disrupt those with autism. The MLDC's study space has intense light, and the Art and Architecture Library's fluorescent lights can be noisy for sound-sensitive individuals (Figure 15).

Figure 15. Lights in the libraries (AAL, MLDC and KHL respectively).

The colour factor, with 14 items, lacks inclusive design in 6 aspects across all libraries. However, KHL uses colour contrasts between walls, floors, door frames, and elevator buttons, and less reflective floor colours. The MLDC uses a specific palette and skin-tone contrasting colours to aid the deaf. The AAL uses less reflective colours and maintains colour distinction between walls, ceilings, and floors (Figure 16).

Figure 16. Colours in the libraries (AAL, MLDC and KHL respectively).

The subsequent consideration pertains to texture and materials. All libraries have focused on two aspects: the preference for soft textures over rough ones, and the differentiation of materials or textures on the floor, walls, and ceiling. Despite the visual confusion caused by the extensive texture variety in KHL, this diversity enhances echolocation techniques by altering floor materials (Figure 17).

Figure 17. Texture and materials in the libraries (AAL, MLDC and KHL respectively).

Research indicates that creating order in design can enhance the capabilities of individuals with attention disorders. Indeed, Karami and Ardalan have identified key concepts that contribute to the establishment of order in design (Karami & Ardalan, 2015). These include symmetry, hierarchy, repetition, rhythm, unity (which involves coordination and coherence), and axis (which provides direction). These principles are fundamental in shaping form and structure in design. They play a crucial role in enhancing the abilities of individuals with attention disorders when applied effectively in the designed environment. In this context, the MLDC and AAL outperform the KHL. The latter's strength lies in its use of human scale. Its exterior design is simple and readable, thanks to a hierarchical approach, use of familiar shapes, repetition, and relative symmetry. However, these elements are absent in its interior design. Conversely, the MLDC uses repetition and rhythm in both exterior and interior designs, resulting in a comprehensive form.

The AAL also employs symmetry, repetition, readable shapes, human scale, and proportionality, while avoiding unnecessary breaks (Figure 18).

Figure 18. Forms in the libraries (AAL, MLDC and KHL respectively).

The scent factor is less emphasised in the samples. This could be improved by using fragrant plants. A strength is the prevention of unwanted odours in the library. The next factor is sound. In this field, several items were scrutinised in this regard: the conspicuous absence of natural sound elements such as water, the deficiency in sound control and amplification systems, and the ineffectiveness of strategies aimed at mitigating noise pollution. It was observed that these limitations were prevalent across all three samples under investigation. The last factor under investigation is temperature. It aids audiences, particularly the visually impaired, in understanding spaces and their elements through touch. This involves variations in heat and humidity across different spaces and temperature differences on various surfaces. Unfortunately, these aspects have not been purposefully incorporated into the design of the studied libraries.

Table 5 present the POE data on inclusive design in the selected libraries. The overall inclusivity scores are low, with the MLDC, AAL, and KHL scoring 37.5%, 35.10%, and 34.35% respectively, highlighting design weaknesses. The inclusivity percentages for the four assessed categories are: Accessibility and Circulation (45.34%), Spatial Design (42.34%), Amenities and Equipment (30.14%), and Sensory and Atmosphere (28.67%).

Table 5. Summary of data procured from post-occupancy evaluation, grounded on the principles of inclusive design.

Category	Factor	Inclusivity ratio			Cumulative inclusivity ratio	Inclusivity percentage	Category inclusivity percentage
Library name		KHL	MLDC	AAL			
Spatial Design	Spatial design requirements	0.00	0.63	0.50	1.13	37.67%	42.34%
	Floor	0.50	0.63	0.75	1.88	62.67%	
	Ceiling	0.67	0.33	0.67	1.67	55.67%	
	Wall	0.40	0.00	0.00	0.40	13.33%	
Accessibility and Circulation	movement path	0.50	0.75	0.75	2.00	66.67%	45.34%
	ramp and lift	0.23	0.00	0.23	0.46	15.33%	
	elevator	0.38	0.54	0.00	0.92	30.67%	
	staircase	0.71	0.64	0.71	2.06	68.67%	
Amenities and Equipment	parking	0.33	0.00	0.00	0.33	11.00%	30.14%
	toilet service	0.19	0.19	0.24	0.62	20.67%	
	opening	0.40	0.60	0.40	1.40	46.67%	
	furniture	0.50	0.67	0.50	1.67	55.67%	
	guide signs	0.17	0.33	0.00	0.50	16.67%	

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Category	Factor	Inclusivity ratio			Cumulative inclusivity ratio	Inclusivity percentage	Category inclusivity percentage
Sensory and Atmosphere	light	0.18	0.27	0.27	0.72	24.00%	28.67%
	colour	0.29	0.36	0.29	0.94	31.33%	
	texture and materials	0.75	0.50	0.50	1.75	58.33%	
	shape and form	0.09	0.73	0.55	1.37	45.67%	
	scent	0.33	0.33	0.33	0.99	33.00%	
	sound	0.25	0.00	0.00	0.25	8.33%	
	temperature	0.00	0.00	0.00	0.00	0.00%	

Figure 19 illustrates the percentage of scores allocated to each component for every library. The chart reveals a significant diversity in the inclusivity levels of the factors, with scores ranging from 0 to 75%. This chart allows a comparison between the libraries in terms of the inclusivity level of each factor. For instance, in the case of the 'Circulation Path' factor, both the AAL and the MLDC are 75% inclusive, while the KHL is 50% inclusive.

Figure 19. Comparative chart of the level of inclusivity of each factor by libraries.

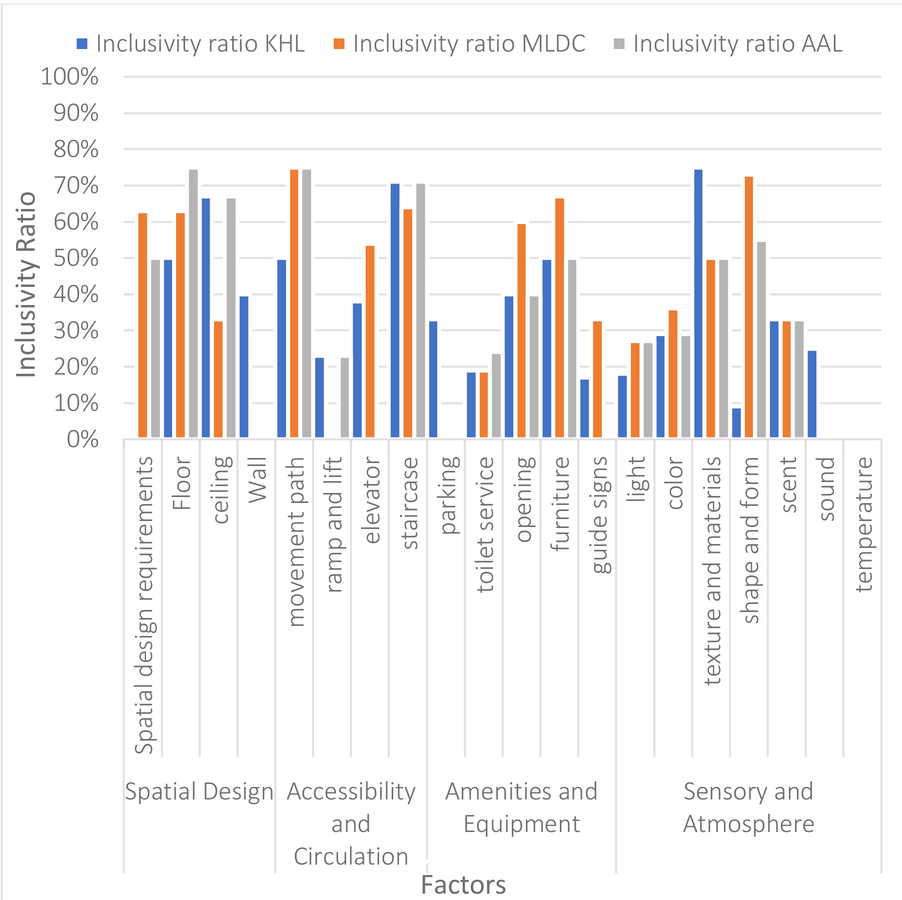

Figure 20 provides a comprehensive summary of all the samples under consideration, enabling the ranking of factors based on their cumulative inclusivity percentage. The chart indicates that the cumulative inclusivity is as follows: Staircase, Movement Path, Floor, Texture and Materials, Ceiling, Furniture, Openings, Shape and Form, Spatial Design, Scent, Colour, Elevator, Light,

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Parking, Restroom, Signage, Ramp and Lifts, Wall, Sound, and Temperature. This chart suggests that in initial cases such as staircases, movement paths, or floors, minor modifications can enhance the level of inclusivity. However, in final cases, substantial changes are required.

Figure 20. Cumulative inclusivity percentage chart of libraries for each factor.

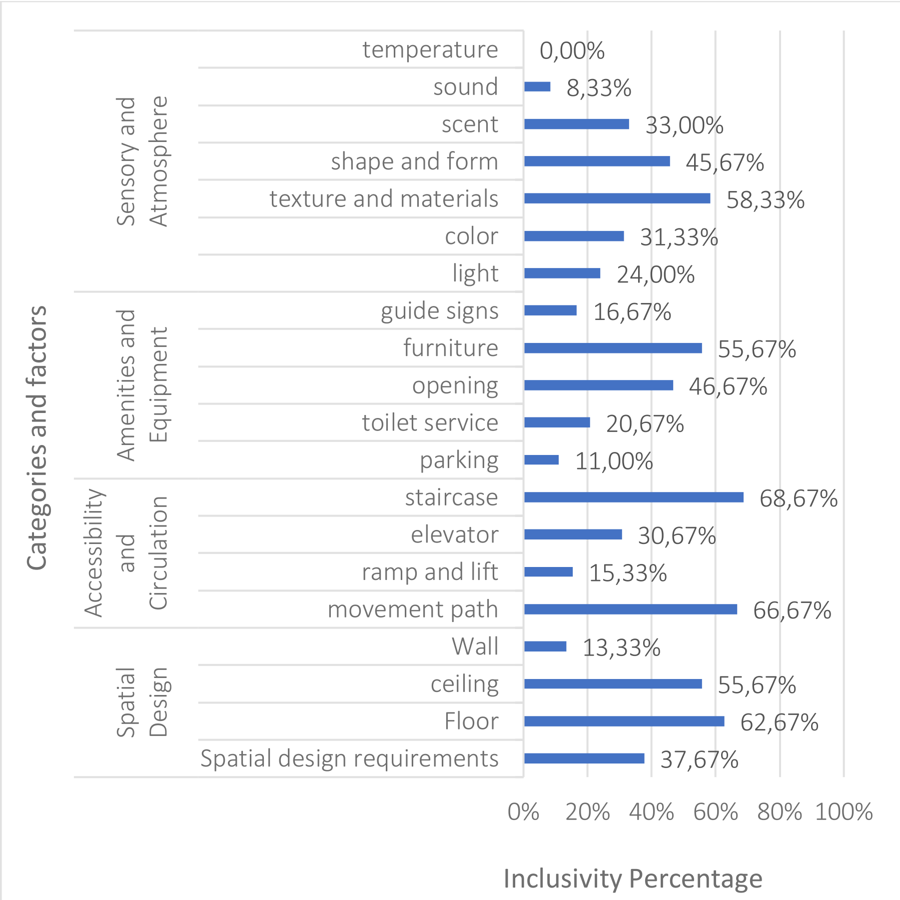
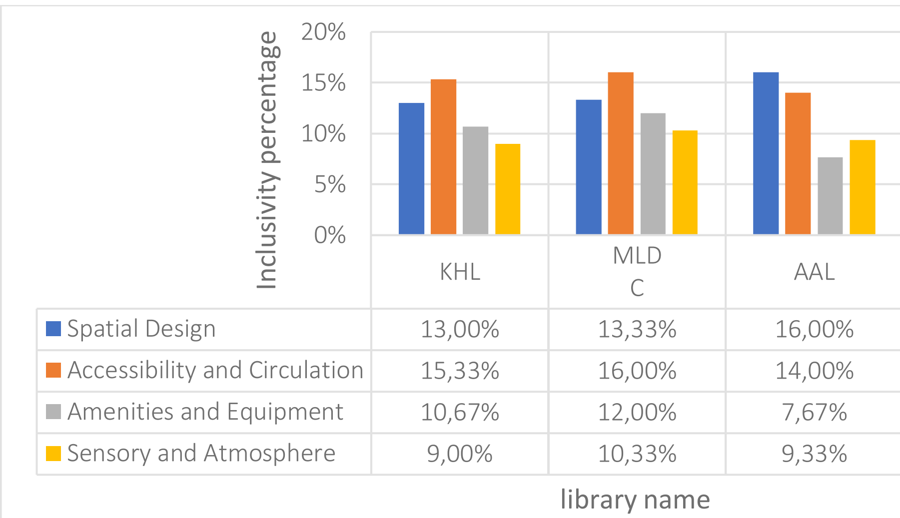


Figure 21 presents a comparative chart of the inclusiveness of four categories. For instance, it suggests that in the Main Library, the categories of Accessibility and Circulation are more inclusive than the other three categories.

Figure 21. Comparative chart of the inclusiveness of the four categories.



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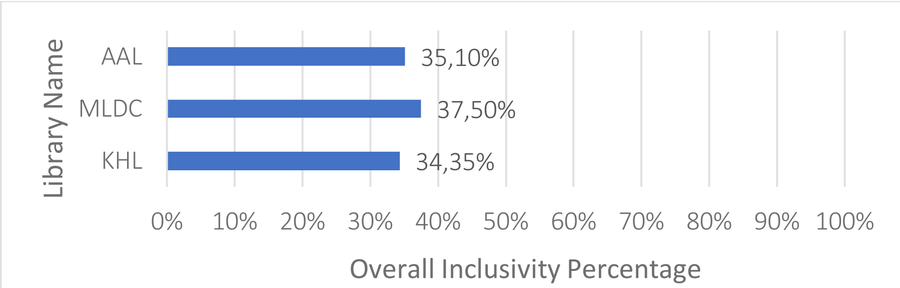
As previously noted, all the samples under investigation exhibit a few strengths and numerous weaknesses in terms of inclusive design. However, based on the preceding charts, it's not possible to rank them in terms of overall inclusivity. Consequently, the subsequent chart compares the overall inclusivity of the samples under investigation, assuming equal value for each item. According to Figure 22, the MLDC, AAL, and KHL have inclusivity levels of 37.50%, 35.10%, and 34.35% respectively.

Figure 22. Comparison of overall inclusivity percentage of libraries.



The low values obtained reaffirm the hypothesis that there is a significant deficiency in inclusive design across all the samples under investigation. Furthermore, due to the minimal difference between the results obtained, it appears that there is no significant difference in terms of inclusivity among these libraries. This needs to be verified with a statistical test. The following section, titled 'Analytical Findings', is dedicated to conducting such statistical tests.

3.2. Analytical findings

This section presents a data analysis conducted using statistical hypothesis tests in SPSS version 26. It's important to note that due to the non-normal distribution of the statistical population (asymmetric triadic data), comparisons should be made using nonparametric methods. The data measurement level is considered ordinal. The significance of the differences between the samples studied has been measured on four different scales. These scales, in order from part to whole, are:

1. Factor Inclusiveness per Library: This measures the significance of the difference between the inclusiveness of factors for each library.
2. Cumulative Factor Inclusiveness: This represents the cumulative inclusiveness of factors.
3. Category Inclusiveness per Library: This denotes the inclusiveness of four categories for each library.
4. Overall Inclusiveness: This signifies the overall inclusiveness of the data.

3.2.1. Factor Inclusiveness per Library

This test compares each factor across the three libraries. All three libraries are evaluated, but the scale for measuring their differences is confined to each factor. Given the independence of the samples and the three-way comparison, the Kruskal-Wallis test is apt for this measurement. The Kruskal-Wallis test, a non-parametric rank-based test, can ascertain whether there are statistically significant differences between two or more groups on a continuous or ordinal dependent variable. Table 6 presents the results of this test on 20 factors studied. The significance value for all cases exceeds 0.05, indicating no significant difference in the inclusiveness of factors.

Table 6. The Kruskal-Wallis statistical test for measuring factor inclusiveness per library.

Nu	Factors	Kruskal-Wallis H	df	Asymp. Sig.
1	Spatial design requirements	2.000	2	0.368
2	Floor	2.000	2	0.368
3	Ceiling	2.000	2	0.368
4	Wall	2.000	2	0.368
5	movement path	2.000	2	0.368
6	ramp and lift	2.000	2	0.368
7	elevator	2.000	2	0.368
8	staircase	2.000	2	0.368
9	parking	2.000	2	0.368
10	toilet service	2.000	2	0.368
11	opening	2.000	2	0.368
12	furniture	2.000	2	0.368
13	guide signs	2.000	2	0.368
14	light	2.000	2	0.368
15	colour	2.000	2	0.368
16	texture and materials	2.000	2	0.368
17	shape and form	2.000	2	0.368
18	scent	2.000	2	1.000
19	sound	2.000	2	0.368
20	temperature	2.000	2	1.000

3.2.2. Cumulative Factor Inclusiveness

This test compares 20 factors in pairs cumulatively to ascertain if a significant difference exists between them. Given the variables are dependent with three repetitions (for each library), the Friedman Test was employed. The Friedman test, a non-parametric test, is used to compare three or more dependent or correlated groups measured at least at the ordinal level. Table 7 presents the test statistic or the final results of the Friedman ranking test. It's evident that there is a significant difference between the average cumulative inclusiveness of the factors in this study, as the significance value obtained is 0.003, which is less than 0.05.

Table 7. The Friedman test for measuring cumulative factor inclusiveness.

Related-Samples Friedman's Two-Way Analysis of Variance by Ranks Summary	
Total N	3
Test Statistic (Chi-Square)	40.054
Degree Of Freedom (df)	19
Asymptotic Sig. (2-sided test)	.003

Upon confirming the significance of the difference in cumulative inclusiveness of factors, pairwise comparisons were conducted. The Friedman test examined 190 cases for pairwise comparison among 20 factors, with significant differences detected in 37 cases. These are listed in Table 8.

Table 8. Pairwise comparison between the cumulative inclusiveness of factors.

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
Temperature - Shape and form	10.167	4.830	2.105	.035
Temperature - Opening	10.667	4.830	2.208	.027
Temperature - Ceiling	12.167	4.830	2.519	.012
Temperature - Texture and materials	12.833	4.830	2.657	.008
Temperature - Furniture	13.500	4.830	2.795	.005

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Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
Temperature - Floor	14.500	4.830	3.002	.003
Temperature - Stairs	15.500	4.830	3.209	.001
Temperature - Path of movement	16.000	4.830	3.312	.001
Sound - Opening	9.500	4.830	1.967	.049
Sound - Ceiling	11.000	4.830	2.277	.023
Sound - Texture and materials	11.667	4.830	2.415	.016
Sound - Furniture	12.333	4.830	2.553	.011
Sound - Floor	13.333	4.830	2.760	.006
Sound - Stairs	14.333	4.830	2.967	.003
Sound - Path of movement	14.833	4.830	3.071	.002
Ramp and lift - Ceiling	10.333	4.830	2.139	.032
Ramp and lift - Texture and materials	-11.000	4.830	-2.277	.023
Ramp and lift - Furniture	-11.667	4.830	-2.415	.016
Ramp and lift - Floor	12.667	4.830	2.622	.009
Ramp and lift - Stairs	-13.667	4.830	-2.829	.005
Ramp and lift - Path of movement	14.167	4.830	2.933	.003
Signage - Furniture	10.000	4.830	2.070	.038
Signage - Floor	11.000	4.830	2.277	.023
Signage - Stairs	12.000	4.830	2.484	.013
Signage - Path of movement	12.500	4.830	2.588	.010
Wall - Furniture	-9.500	4.830	-1.967	.049
Wall - Floor	10.500	4.830	2.174	.030
Wall - Stairs	-11.500	4.830	-2.381	.017
Wall - Path of movement	12.000	4.830	2.484	.013
Light - Floor	10.000	4.830	2.070	.038
Light - Stairs	11.000	4.830	2.277	.023
Light - Path of movement	11.500	4.830	2.381	.017
Bathroom service - Floor	9.500	4.830	1.967	.049
Bathroom service - Stairs	10.500	4.830	2.174	.030
Bathroom service - Path of movement	11.000	4.830	2.277	.023
Parking lot – Stairs	-10.000	4.830	-2.070	.038
Parking lot – Path of movement	-10.500	4.830	-2.174	.030

3.2.3. Category Inclusiveness per Library

This test compares the inclusiveness of four categories in pairs to determine if there is a significant difference between them. The Kruskal-Wallis test was used for this comparison. According to Table 9, the significance value obtained is 0.368, which is greater than 0.05. Therefore, no significant difference can be observed between the inclusiveness of the libraries in terms of the four groups under measurement.

Table 9. The Kruskal-Wallis statistical test for measuring category inclusiveness per library.

Category	Spatial Design	Accessibility and Circulation	Amenities and Equipment	Sensory and Atmosphere
Total N	3	3	3	3
Test Statistic	2.000	2.000	2.000	2.000
Degree Of Freedom	2	2	2	2
Asymptotic Sig. (2-sided test)	.368	.368	.368	.368

3.2.4. Overall inclusiveness

The results of this test are useful for overall comparison between the three libraries. If a significant difference exists, it can be inferred that one or two libraries are superior to others in terms of inclusive design. For this comparison, the Kruskal-Wallis test was used, considering that three independent samples (three libraries) needed to be compared. The results of the Kruskal-Wallis test, as shown in Table 10, indicate that the significance value obtained is 0.368, which is greater than 0.05. Consequently, it can be stated that statistically, there is no significant difference between the inclusiveness of the libraries under consideration, and the samples cannot be ranked based on their inclusiveness.

Table 10. The Kruskal-Wallis statistical test for overall inclusiveness comparison.

dependent-Samples Kruskal-Wallis Test Summary	
Total N	3
Test Statistic	2.000
Degree Of Freedom	2
Asymptotic Sig. (2-sided test)	.368

Statistical tests have demonstrated that there is no significant difference in the overall inclusiveness of libraries or the inclusiveness of each factor individually in the samples studied. However, significant differences can be observed in the cumulative inclusiveness of certain factors. This suggests that in all three samples studied, some factors such as shape and form, opening, ceiling, texture and materials, furniture, floor, stairs, and movement path have been better designed in terms of inclusive design than other factors such as temperature or sound. These statistics provide guidance on prioritisation when addressing the shortcomings of these libraries.

4. Conclusions

The importance of inclusive design in architectural practice cannot be overstated. It is a critical approach that caters to the widest possible range of users, ensuring that spaces are accessible and user-friendly for all, regardless of their abilities or disabilities. This is particularly pertinent in the context of public libraries, which serve diverse communities and play a crucial role in promoting social justice and equality. This study has evaluated the post-occupancy inclusivity of three libraries at Shiraz University, namely the Main Library and Documentation Centre (MLDC), the Khwarizmi Library (KHL), and the Art and Architecture Library (AAL). The research was conducted using a systematic and rigorous Post-Occupancy Evaluation (POE) process, which comprised planning, implementation, and application stages.

In the planning stage, a comprehensive checklist of 180 items was compiled. This checklist served as a guiding tool for the evaluation, ensuring that all relevant aspects of inclusive design were considered. These items were categorised into four main areas:

1. Spatial Design: Factors include spatial design requirements, floor, ceiling, and wall.
2. Accessibility and Circulation: Factors include movement path, ramp and lift, elevator, and staircase.
3. Amenities and Equipment: Factors include parking, toilet service, opening, furniture, and guide signs.
4. Sensory and Atmosphere: Factors include light, colour, texture and materials, shape and form, scent, sound, and temperature.

The implementation stage involved conducting field observations and collecting data over a period of one to two days for each library. A two-person evaluation team carried out the observations, utilising tools such as photography and metric measurement for data collection. The data were meticulously gathered and any inconsistencies were addressed through re-collection by both evaluators. In the application stage, the collected data were analysed using IBM SPSS Statistics 26.0 software. A binary weighting system was employed for each item in the checklist, with 'one' signifying the prevalence of the item under review, and 'zero' indicating its absence. This approach allowed for a detailed and nuanced understanding of the data.

The results of the study revealed several weaknesses in terms of inclusive design across all three libraries. The average inclusiveness scores assigned to the MLDC, AAL, and KHL were 37.50%, 35.10%, and 34.35%, respectively. These findings underscore the need for improvements in the design of these libraries to better cater to all users. Despite the challenges identified, the study highlights the potential of inclusive design in creating more accessible and welcoming public spaces. The findings provide valuable insights and practical recommendations for architects, designers, and other stakeholders involved in the design and management of public libraries and other similar spaces. Looking ahead, future research in this field should consider two key points:

- The data collection method used in this study was primarily based on observation and field measurement. However, to foster a more inclusive POE process, future research could benefit from incorporating a wider range of data collection methods. Specifically, questionnaires could be employed to gather data that cannot be quantitatively measured with common tools. This approach would not only enrich the data but also involve a more diverse audience in the research process.
- In this study, a binary weighting system was employed for each item in the checklist. Future research could address this issue by employing more nuanced weighting techniques such as the Delphi technique or a Likert scale questionnaire. These techniques would allow for the assignment of different value codes to each item, providing a more detailed and nuanced understanding of the data. With a sufficient sample size, the results of such research could serve as a source for scoring and comparing various buildings with different uses in terms of inclusive design, and could even be considered as an evaluation standard by reputable institutions.

In conclusion, this study contributes to the growing body of knowledge on inclusive design and post-occupancy evaluation. It provides a robust framework for future research in this field, offering valuable insights and practical recommendations for enhancing inclusivity in architectural environments.

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Quality archaeological translation into sign language.
An essential prerequisite for the learning of deaf children.

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Abstract: This paper details a significant study on educational accessibility through quality translation processes, specifically focusing on sign language translation in a museum setting. Conducted as part of the Al-Musactra RD project, co-funded by the Spanish Ministry of Universities and the European Union - Next Generation EU, the research focuses on translating content from room 1 of the Archaeological and Ethnological Museum of Granada. The intervention involved a classroom session during the European Heritage Days 2021. It has been designed for students from the Sagrada Familia Special Education School of Granada. The source material was a terminologically rich video featuring a guided museum tour on the prehistoric period of Granada, led by the museum director. The study employed a documented working methodology to address translation challenges, ultimately delivering quality linguistic solutions for the deaf community. Key findings reveal a strong preference among participants for accessible cultural experiences, with technology playing a crucial role in enhancing accessibility. The results emphasize the need for improved staff training in museums to better cater to the needs of visitors with hearing impairments. These findings suggest a broader application of such inclusive practices in cultural institutions to foster greater accessibility and engagement.

Keywords: sign language, accessibility, museum, archaeology, quality.

1. Introduction

At the proposal of the Council of Europe and the European Commission, this year's European Heritage Days 2021 will focus on accessible and inclusive heritage. These days began in Granada in 1985, the year in which the European initiative *Second European Conference of Ministers for Architectural Heritage* was held (Kneubüler, 2009, p. 9)and from which it was adopted to promote access to museums on a European level through *the Historical Monument Open Day*, as had already been held the previous year in France. At the European level, it began to be held following different initiatives from 1992 onwards and its main mission since then has been to disseminate culture and heritage (Étiembre, 2002). The Spanish Ministry of Culture and Sport, through the Spanish Cultural Heritage Institute, coordinates the organisation of the conference, whose main objective is to "raise awareness of the common cultural wealth and increase the recognition and understanding of cultural diversity, contributing effectively to the safeguarding and enhancement of cultural heritage" (Spanish Ministry of Culture and Sport, 2021). In this edition, held under the slogan "accessible and inclusive heritage" with the aim of offering a range of activities, visits, workshops, and conferences on access to culture in which the barriers that prevent approaching heritage are eliminated (European Heritage Days, 2021).

The activity carried out is part of the AL-MUSACTRA project, which has worked on accessibility to museum heritage from the perspective of Translation and Accessibility Studies. The research group TRACCE: Translation and Accessibility (HUM-770), of the Department of Translation and Interpreting of the University of Granada, has been working since 2000 on the different modalities of multimodal translation. He has described the theoretical and methodological foundations and applied the results of the research through the research projects TRACCE. AMATRA, PRA2, OPERA, AL-MUSACTRA, TALENTO and LECPAT, as well as the teaching innovation projects TACTO, DESAM, CITRA, generating content and applications for direct social transfer such as the online application for access to the UGRQR heritage (Patent IPR-729 2018), as well as the platform for the evaluation of accessible audiovisual resources PRA2 (TRACCE 2024). The aim of this project is to improve accessibility to the information displayed in Andalusian museums, including the Archaeological and Ethnological Museum of Granada.

1.1. The right to access to education and culture for hearing impaired children

The right to education is not only about access to the school or educational institution by removing physical barriers, but there are other less visible barriers such as those in access to information and communication, which also need to be addressed and which present a crossroads for many students (Echeita & Domínguez Gutiérrez, Inclusive education. Argument, paths and crossroads., 2011). The right to education is therefore universal:

> *"The recognition and valuing of education as an essential right to be guaranteed to all people, without any kind of discrimination or exclusion, is a fundamental value and principle, openly ideological, not factual (Escudero & Martínez, 2011)."*

In order not to leave any learner behind, it is necessary to plan and guarantee *full access to* ensure fair participation (Skliar, 2003). This perspective understands the need to respect the right of the hearing-impaired child to learn in a bilingual environment, where information is provided in both sign language and spoken language in order for them to achieve the fullest possible development of their cognitive, linguistic and social skills (Grosjean, 1999). The bilingual environment is therefore a key tool for the proper development of the concept of educational inclusion of students with hearing impairment (Domínguez A. B., 2009), since making the right to education effective requires ensuring that everyone has access to quality education with equal opportunities (Ainscow, Booth, & Dyson, 2006) (Echeita & Duk, Inclusión Educativa, 2008). This offers a response from the perspective of removing barriers to full participation and leaves behind previous approaches based on the medical rehabilitative model of deafness. This paradigm shift exposes the value of the commitment to individual abilities and the incorporation of new pedagogical approaches such as the inclusion of sign language in the school context (Domínguez & Alonso, 2004).

This participation includes, therefore, the possibility of accessing in their language to the complementary cultural activities carried out in educational centres, since access to culture and education are two of the fundamental rights recognised in the Spanish Constitution (art. 27 and art. 44) and in the Convention on the Rights of the Child (1989). In this line, it is of particular value to underline that the fulfilment of these rights is achieved under the principle of relationship between them, i.e. the fulfilment of one of them promotes the guarantee of the other (Luna Sánchez, 2015).

1.2. Quality translation into sign language as a tool for cultural accessibility

Interpreting Studies have given rise to the development of a specific line of theoretical and applied research that addresses the challenges posed by accessibility to information and communication and the role of intersemiotic and multimodal translation in this paradigm of study (Álvarez de Morales Mercado & Jiménez Hurtado, 2016). Accessible translation, in the context of access to heritage (Soler Gallego, Translation and accessibility in the museum of the 21st century, 2012), aims to eliminate sensory and cognitive barriers through different modalities such as audio description (Luque Colmenero, 2018), subtitling for the deaf(Martínez, 2015), interpretation into sign language (Arrufat Pérez de Zafra, Abasolo Elices, & Martínez Martínez, 2021) or easy reading (Carlucci and Seibel, 2020), among others. The interdisciplinary research work carried out between art educators and translators has favoured a better understanding of the challenges of access to the museum for all (Álvarez de Morales Mercado & Jiménez Hurtado, 2016) (Cabezas Gay, 2017) (Luque Colmenero Soler Gallego, Painting my ears: a cognitive approach to the study of audio description in art museums, 2018). This scientific journey undertaken by researchers has gone hand in hand with public administrations, although in a progress that in certain places has been limited, as stated by Chica and Martínez (Chica Núñez & Martínez Martínez, 2019, p. 10):

> *"The heritage centres (...) and public administrations are making important efforts to respond to the demands of the different user groups, but the work is being carried out in an isolated, incoherent manner and without adequate dissemination and diffusion. Therefore, in many cases, the possibilities of access to culture for users with functional diversity depend on the economic capacity of the centres and institutions to generate accessible events or exhibitions, on the visits organised by users' associations with their own disability experts, or on the willingness of art educators or museum mediators to offer accessible visits."*

However, there are numerous examples of good practices and accessible content developed by heritage centres in sign language, such as the sign-guide of the Alhambra (Redacción Quo, 2010), that of the Cueva de las Ventanas de Píñar (Jurado Almonte & Fernández Tristancho, 2013, p. 29) or that of the Cueva de Altamira (Zalascky, 2013).

One of the key elements in the development of these materials is to ensure that the content has an adequate quality so that it is fully functional and meets the needs of users (Chica Núñez & Martínez Martínez, 2019). To this end, it is necessary that, once the content has been produced and before its final publication, evaluation systems are used with the participation of a sample of end-users and, in this way, it is possible to find out through questionnaires, interviews, discussion groups or other research tools, whether users have been able to access the information satisfactorily or whether, on the contrary, it is necessary to rectify the content. In the case of content produced in sign language, as González (González-Montesino, 2019, p. 76)state:

> *"(...) Law 27/2007 indicates that the Public Administrations are responsible for promoting the provision of interpretation services in Spanish sign languages so that users of these languages have equal access to cultural and leisure activities in, for example, national museums or historical-artistic monuments of the State heritage (art. 10.d)."*

However, one of the main challenges faced by users is that sometimes the result of the accessible product does not fulfil its function, as the legislation does not include the concept of quality within the necessary requirements for compliance. According to (Arrufat Pérez de Zafra M. , 2020, p. 135) Arrufat, a system of evaluation of accessibility measures needs to be established, as the inclusion of accessibility measures requires monitoring to ensure the quality of their implementation. It is true that in the case of subtitling for the deaf or audio description, these are accompanied in Spain by the UNE 153010 and UNE 153020 standards, which regulate quality, but this necessary review stage is not applied in many cases due to the lack of legal mechanisms.

National institutions such as CESyA, CNMC, CNSE, AICE Federation, FIAPAS, OADIS, ONCE, RPD or RTVE are working on quality indicators that could be standardised and applied periodically to assess accessibility, an initiative that requires legal backing to ensure that quality is another element to comply with regulations (Arrufat Pérez de Zafra M. , 2020). Regarding the percentages of accessible content established in the regulatory framework in Spain, Vázquez (2019) points out that:

> *"A common shortcoming is the conflation of different communication support tools. Thanks to this confusion between them, laws are enacted that can be misleading in their application. When the percentages of audio-description and subtitling are imposed on TV channels, the two systems are equated and it is established that 100% of the programming must be covered in subtitles and a certain number of hours in audio-description, without any further specifications (...). A deaf person needs 100% subtitling of all audio productions, from news programmes to films, including debates, competitions, galas, etc. A blind person understands everything he or she hears, so audio-description should focus on those works with a strong visual environment, and which prevent the understanding of the work itself. This would exclude from the outset all programming including news programmes, debates, quiz shows, talk shows with commentary by voice-over announcers and society programmes. This reduces audio-description to series, films, and documentaries, so that audio-description of 30% of a channel's programming makes almost 100% of its programming accessible to blind people."*

Regarding this perspective, Vázquez explains the logic with which these percentages that must be complied with in television broadcasts should be applied. It is for this reason that legal compliance should be consistent to ensure that its effective application guarantees the rights it is intended to protect.

In addition to the challenge of quality, accessible translations face the challenge of flexibility in order to adapt to different target audiences, i.e., that, given the same source text, the target text can vary to meet the needs of the target audience, such as the elderly, children of different ages, people with deaf-blindness, people with intellectual disabilities, people with hearing disabilities, people with visual disabilities, etc. In the case of children, more and more resources are becoming available to them (Guernsey, 2013)and the quality of the content is directly related to the possibility of adapting to the abilities of children, which are particularly different in the first years of life(Crescenzi-Lanna & Grané-Oró, 2016). A good adaptation will allow them to interact without barriers and to better understand the content.

Minority languages require a standardisation process in which the linguistic code is intervened upon and is often referred to as a process of linguistic normalisation. Defined according to D'Andrés Díaz (D'Andrés Díaz , 2018) as:

> *"A systematic set of socio-political actions that refer, in the linguistic field, to the achievement of normality in the coexistence of two or more languages in the same social space, and more specifically of normality for the language or languages that suffer minoritisation (D'Andrés Díaz, 2018: 19)."*

It is also associated with other terms and concepts such as language policy (Joan i Marí, 1996, p. 26), language planning (Haugen, 1996), or language establishment (Lamuela, 1994). In this procedure, the corpus is *narrativised*, which involves, among other things, the cultivation or elaboration of the lexical inventory of the normative variety established through neologisms (Castellanos, 2000). According to D'Andrés Díaz's (2018: 20) outline of linguistic standardisation, it corresponds to this:

1. Social normalisation (of status).
    a. Selection.
    b. Implementation.
2. Standardisation (corpus standardisation).

a. Fixing or coding.
    i. Dialectal simplification.
    ii. Norms of the standard.
        1) Graphical standards or graphitisation.
        2) Grammatical rules or grammaticalization.
        3) Lexical rules or lexication.
        4) Orthological standards or orthologisation.
    iii. Extra-standard rules.
        1) Dialectal norms.
b. Cultivation or processing.
    i. Lexical cultivation.
    ii. Stylistic cultivation.

This procedure makes it possible to enrich the specialized terminology of the different fields of knowledge and facilitates communication. This process involves both expert linguists and specialists in different fields with a good command of the language. The people who use signed languages and are part of the Deaf community share a culture and it has been defined by Lane, Hoffmeister, and Bahan (Lane, Hoffmeister, & Bahan, 1996)as:

> *"a group of people with common characteristics, including the use of a visual-gestural language and a particular way of life, who have knowledge of their world and share experiences of what it is like to be Deaf."*

Cultural plurality enriches society, however, there is a tendency toward the construction of a national identity in which minority languages, such as sign languages, suffer discrimination (Amezcúa Aguilar & Amezcúa Aguilar, 2018). In this sense, sign languages evolve according to historical, cultural, linguistic, and social factors and are in line with the development of the deaf community (Herrera-Fernández, 2014). This is why the participation of native speakers in the development of neologisms is especially relevant. They are essential for the selection of the most appropriated proposed terms to the context of use.

1.3. Archaeological terminology in the museum and educational contexts

As introduced in the previous section, one of the challenges that sign language has faced is the quality translation into sign language, which, on the part of interpreters in specialised contexts in which they do not have adequate knowledge, may have posed problems for the user:

> *"[...] the interpreter did not master the physical concepts and, in trying to explain these concepts, contributed to reinforcing spontaneous conceptions, very common in the Sciences, or could generate misconceptions regarding the concepts or content since the interpreter had no training in the disciplines he interprets (Santos & Takeco, 2014, p. 457)."*

From a translatological perspective, the efforts of sign language interpreters have been directed towards offering solutions through paraphrasing as the main translation strategy which, without a proper understanding of the concepts, can lead to errors of meaning and content, to a translation by means of calques of the spoken language which do not visually represent the concepts, to the excessive use of the dactylological or the use of generic signs accompanied by borrowed mouths (Valdéz González, Rodríguez Martín, Álvarez Arregui, & Martín Antón, 2020, p. 192):

> *"(...) a linguistic sign, whether a word or a sign, must evoke an image in the recipient's brain; if this does not occur, the sign is empty of meaning and will not give rise to communicative processes. For this reason, dactylology, lip-*

reading, the use of commonly used signs for specific terms, and, in short, resources based on the oral language are going to cause significant harm to signers (...) during the process of acquiring new concepts and their access to information."

In the educational context, quality and equity for the education of sign language learners are directly related to the quality of translations, interpretations, and lexicographic materials produced in sign language, such as glossaries and dictionaries (Valdéz González & Martín Antón, Spanish Sign Language and specific fields. A multidisciplinary and inclusive proposal for the search, analysis and creation of Signs., 2020, p. 160). Within the educational activities of educational centres, museums are presented as a potentially didactic and attractive option for children. The evolution of these cultural institutions has opened the doors to a wide range of users (Soler Gallego, Translation and accessibility in the museum of the 21st century., 2012)who are increasingly committed to quality and accessibility in their offers to the public (Moreno López, Galvez, Ruiz Mezcua, & Martínez Fernández, 2008). In this way, they have gone from being static centres containing works to dynamic entities and social agents in which culture, language, and history make their way to reach citizens, also in sign language (Cruz Aldrete & Sanabria Ramos, 2020, p. 178).

In Spain, the first team of deaf guides to teach the archaeological heritage of the Atapuerca archaeological sites was formed in 2002 (Luque Cortina, 2010). The pioneer museum in obtaining the Accessibility Management Certificate from AENOR was the Guggenheim Museum in Bilbao (2003), which already included a video guide in sign language as part of the adaptations for the hearing impaired. According to this, the municipality of Frigiliana was recognised in 2013 through the Queen Sofia Award for universal accessibility in municipalities for the work carried out with initiatives such as the signoguide of the Archaeological Museum of Frigiliana (Simón Vallejo & Cortés Sánchez, 2017, p. 410). Later, the National Archaeological Museum developed an accessible multimedia guide that integrates, among others, the translation of the content into sign language with the support of the CNSE Foundation and follows the accessibility guidelines for web content WCAG 2.0 (Rubio Visiers & Fernández Tapia, 2014, p. 573). It was not until 2017 that a museum was awarded the AENOR Universal Accessibility certificate, and this was the Museo Nacional Thyssen-Bornemisza. Its offer for visitors includes a signoguide in LSE (Yuste Fonzález, 2018, p. 68). An activity similar to the one carried out at the present European Heritage Days was the one carried out at the Cueva Pintada Archaeological Park in Gran Canaria, in which a pilot experience was carried out with the museum team and the museum educators were trained during two previous sessions and worked together with the LSE interpreter, who brought Arminda, the daughter of the last *guanarteme,* to life through the puppeteer to explain the site as a didactic resource in sign language (Reyes Rodríguez, et al., 2018). This impetus given to the creation of accessible material in quality sign language has led to a specialised corpus of parallel texts from which it has been possible to recover terms and translation strategies used in the workshop.

The study holds particular interest as it explores the transformative impact of quality sign language translation on educational accessibility in cultural settings, a crucial aspect in bridging the communication gap for the deaf community and enhancing their engagement with cultural heritage.

2. Methodology

Since the main objective of this research is to find out the opinion of the hearing impaired children who participated in the day, we have opted for a procedure of data collection through a questionnaire that they have completed in class, in a quiet environment, and with the support of teachers to facilitate the understanding of each of the closed questions.

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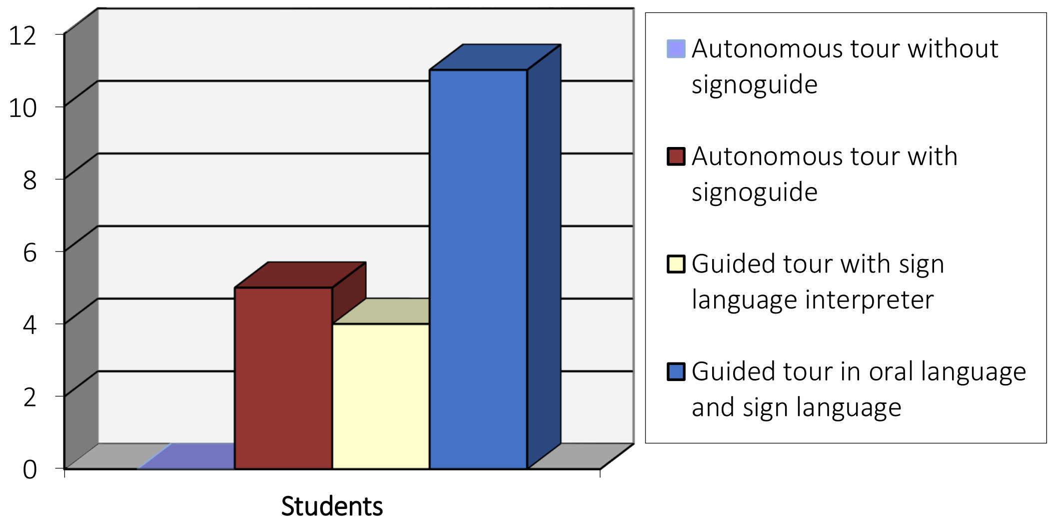
A total of 13 people took part in the study, of which 9 were male and 4 female. In relation to the age of the participants, 4 are between 5 and 11 years old and 9 are between 12 and 25 years old. The participants belong to the Caja Granada Sagrada Familia Special Education School, which offers, in addition to basic compulsory education, an educational offer that includes hearing and language rehabilitation and audiological care, among others. A questionnaire consisting of 9 items was proposed to collect socio-demographic information and 12 specific items on accessibility in museum environments. The quantitative data were collected through closed questions from which the results were extracted through a descriptive statistical analysis using the RStudio program. The valid sample consisted of a total of 13 responses.

3. Results

Statistical analysis of the responses obtained allows for some specific observations, which are set out below. Among the preferred cultural activities, 38.5% chose visits to natural areas, 23.1% cinema, 15.4% reading and 7.7% concerts, 7.7% theatre and 7.7% dance. A 100% of the participants indicated that they liked the fact that the spaces and contents were adapted. According to 53.8%, they visit museums once or twice a year, 23.1% never, 15.4% only on holidays and 7.7% visit them frequently. An 84.6% usually go with friends. An 84.6% usually go with friends or relatives, while 15.4% go in organised groups. An 84.6% said that if museums were more accessible, they would definitely or probably visit them more. As for the purpose for which they visit, 61.5% say they visit museums to learn, while 38.5% visit for fun. A 100% of the participants think that new technologies improve the access of people with hearing impairment to spaces and knowledge in general. The following multiple-choice variable shows that the most highly valued type of visit is the guided visit in sign language and spoken language, as can be seen in the following graph.

The 69.2% prefer to use the museum's apparatus, 23.1% have no preference and 7.7% their own. Finally, 69.2% of the participants consider that in general those responsible for accessibility in museums do not understand the needs of people with hearing impairment, while 30.8% said that they do not know.

Figure 1. Preferred type of visit (own elaboration).



4. Conclusion

The European Heritage Days have promoted a large number of pioneering events to bring heritage closer to everyone. In this sense, the event held with the students of the Colegio de Educación Especial Caja Granada Sagrada Familia, in the Archaeological and Ethnological Museum of Granada, has allowed bringing the prehistoric heritage of Granada closer to the children through an inclusive day in which both oral and sign language have been used. For the translation of the terminology, quality has been a key element to which special attention has been paid due to the educational nature of the day to bring history and culture closer to the children. In this sense, one of the most valued places was the natural space, so it could be very beneficial for the students to carry out more inclusive activities in these environments. Adapted and accessible spaces bring the content closer to all audiences and, taking into account the amount of information they preserve and their learning value, increasing visits by children and young people through group or family activities could be a great commitment for cultural centres. Thanks to their evolution, museums in the 21st century are more interactive and fun, which generates a greater attraction for them. However, as the participants pointed out, it is essential to train museum professionals in hearing impairment so that they can better understand the needs of this public and the barriers they may encounter. Finally, as a future line of research, we will continue with the accessible translation of content from other museums in order to carry out inclusive activities in which oral and sign language are combined to improve access to information for students with hearing disabilities.

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