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THE ROLE OF MULTIMEDIA DESIGN ELEMENTS IN COMPUTER ACCESSIBILITY FOR VISUALLY IMPAIRED: A COMPLETE REVIEW

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ABSTRACT

Designing an accessible computer application for the visually impaired has gained popularity among the researchers over the years. Many researches focus on creative usage of multimedia design elements in extending computer accessibility for users with these special needs. Multimedia design elements plays an important role in the design of any application, be it a mobile application, stand alone computer application, online web applications and many more. A designer acquires knowledge of designing through established standard guidelines and past literatures related to accessibility to produce user-disable friendly computer applications. Despite the constant effort from the designers, visually impaired users are still struggling to access and to use computer applications. Major reason to this scenario is not the fault of a designer but the gap in current state of art is to be criticized. A clear reflection on current state of art was not portrayed all this while leaving uncertainty among the designers in utilizing effectively the design elements in designing an application. Thus, this paper serves as a complete review in analyzing the findings of past literatures as well as established accessibility guidelines relating to visually impaired computer users. About 80 published articles were used to generate this paper. An analysis on the latest literatures has revealed that there exist lists of mandatory and optional elements in considering a design. These finding identifies the gap in current state of art and creates opportunity for future work.

Keywords: *Multimedia Design Elements, Computer Accessibility, Visually Impaired, User Interface Design.*

1. INTRODUCTION

Computer applications such as Word, spreadsheet, PowerPoint, internet browsers and many others are heavily used by computer users for general use as well as for specific work purposes. The same applications are also accessed by the blind users to perform their personal and professional task. However, the representation of an application determines the level of accessibility it offers to this group of users. Apparently, designers tend to design applications based on their own imagination, expectation and understanding, leading to heavy usage of visual cues. This means these applications are not easily accessible by the blind users [1], [2].

Various studies have been reported on user interface designs over the years by many researchers and academicians, though most studies do not take into account end user preferences, such that users are compelled to adapt to the design of a system [3]. Little research has been performed on the expectation, imagination and preference of blind users in terms of information technology context [4], [5]. Blind users feel frustration when they are compelled to adjust to a design meant for sighted users. The process of accessing in terms of selecting and opening an application itself is seen as a challenging task. This is because the expectation of a blind user is quite different compared to a sighted user [6], [7].

A blind user is expected to depend on assistive technologies, primarily screen readers, in assisting them to access and use an application [8], [9]. However, most of assistive technologies, despite being immersive, are unable to completely fulfill the need of a blind user [10]. Designers tend to utilize their own imagination and preference in designing an application, which facilitates the perception process of the sighted users better but leaves behind blind users. An application becomes inaccessible to the blind

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users due to several reasons. The major contributing reasons towards the development of an inaccessible application are the lack of relevant awareness, knowledge and skills among designers [11].

The current state-of-art can be addressed as the main cause of a designer remaining unaware on the need of accessibility to be incorporated in designing. The current state-of-art of designing an application is typically seen from the viewpoint of sighted users, not taking into account the education of designers on the importance of including the design from the viewpoint of blind users. It was noted that recent HCI research makes it clear that most researchers dealing with perceptually impaired people have devoted their time to investigate the accessibility of information and/or functionality via computers in order to enable or enhance usage for diverse user groups [5], [12], [13].

However, they have not focused on usability or user interface guidelines, leaving a theoretical gap to address [12], [13]. A designer designs an application utilizing multimedia design elements of HCI. Multimedia design elements usually play an important role in the design of any application, whether a mobile application, standalone computer application, online web applications and many more [14], [15]. A list of six multimedia design elements has been classified as contributing elements in interface design [15]–[17]. The elements are Text & Color, Graphics, Animation, Interface Layout, Audio and Touch Sensation.

Text element refers to the usage of characters to represent content in an output [18]. Characteristics of text such as font style, font type and font sizes convert a content to be meaningful in the eyes of the viewer. Color is another element which is also used interchangeably with text to create a pleasant display while stressing the importance of it [19]. Color can also be associated with an object such as color peach reflecting the fruit peach. Studies have shown that appropriate usage of color has created positive emotions in the mind of a user facilitating the information perceiving process [20].

Graphics can be an image, a photo, a picture or a drawing which is an illustration of something. The usage of graphics allows the users to remember the message for a longer period of time compared to any other type of learning method [21]. This is due to the effect of visual perception staying longer in the users mind compared to textual perceptions [22], [23]. Animation describes the movement of an object at a rapid pace to present the transition between two states in an interface [23], [24]. Animation also able to reduce the cognitive burden of a user by shifting the task of understanding an interface to perceptual load [24]. A proper usage of animation in a complex environment can facilitate smooth learning process for a user.

A precise definition for interface layout will be the arrangements of right sized object or components on an interface at most efficient manner [25]. This also includes the arrangement of the related objects closely in order to allow the visual skills to more easily parse content [16]. In olden days, interface layout appears static when user interacts with a computer system. However, the growing demands on usability have forced the designers to create a smarter layout which adapts dynamically according to the changes such as resizing windows of an interface [25].

The application of sound in designing an interface to facilitate the process of conveying information to the user is known as audio element [26]. Apart from using audio as a narrator to read the content of a screen, audio can also be used to communicate the emotions behind it using the characteristics such as intonation, stress, and rhythm and voice quality. Greater interpretation of information could be achieved as audio facilitate the cognitive process [26]. As appropriate usage of audio will help a user to be aware of the surroundings, cue visual attention and facilitates in conveying multiple complex information [27].

Touch sensation refers to the usage of Braille or tactile representation in conveying message to the users [16]. Braille codes are used to represent information through Braille device while tactile sensation such as vibration, smooth texture, rough texture, heat sensation, cold sensation and so on is represented using haptic devices [28]–[30]. Touch sensation has proven to be at least 5 times faster in facilitating the learning process comparing to visual perception [29]. The triggering of motor skills in human while using touch sensation reduces the cognitive demands in perceiving information especially in a multi- tasking environment [31].

The guidelines as well as past literatures on multimedia design elements are merely a set of explanations and in some cases, audio and touch sensation are considered as an assistive technology instead of an essential design element.

These descriptions simply provide the definitions of the design element, leaving the designer to make decisions on their own in determining which of these elements are more important. These guidelines have been classified as having little value in educating designers on the usage of certain design elements in designing process [19].

The gap in current literature and the growing number of blind users referring to statistic of world health organization (WHO) has motivated this research. An invitation to improve the guidelines, models, policies and practices relating to accessibility in designing applications for disabled people has been highlighted in recent research [5], [32]. There is a need to focus on the process of establishing these policies and practices to provide a much more inclusive access to the special needs reducing usability issues and improving poor inclusive learning design issues. Thus, this article serves as a preliminary finding which reviews the past literatures on computer accessibility involving multimedia design element for visually impaired.

A reflection on current state-of-art will be the final deliverable of this critical review. The reflection on current state-of-art can be considered as the theoretical model derived from the analysis of past literatures. This model is to provide baseline information to the scholars in understanding the role of multimedia design elements as portrayed generally in the literatures and to serve as a starting point for scholars to work on improvement in terms of accessibility, usability, user interface design catering visually impaired.

The paper is organized as follows: Section 2 describes the selection technique and analysis method of the literature papers. Section 3 presents the past work on multimedia design elements meant for visually impaired. Section 4 discusses on the extent of multimedia design elements coverage in existing guidelines. Section 5 pictures the reflection on current state-of-art. Section 6 concludes the paper.

2. RESEARCH METHOD

The review processes are divided into two major sections. The first section is review process of past literature papers and the second section is review process of existing accessibility guidelines. This review process to identify the issues is different from the usual review process whereby most of the findings are focused only on one category which is either on literature papers or on existing guidelines. However, in this article, both categories have been considered to produce an accurate visualization on the role of multimedia design elements.

In the first section, the articles for review were selected based on three criteria. The criteria are; (i) Year Published, (ii) Targeted Users and (iii) Major Topic. As highlighted in table 1, the articles published between the years 2007 to 2017 with major topic is on overall improvement of computer based applications targeting the visually impaired are taken into consideration.

Table 1: Criteria for Selection of Review Papers

Criteria	Parameters
Year published	2007 - 2017
Targeted Users	Visually Impaired
Major Topic	Improvement in terms of user interface design, usability and accessibility involving multimedia design elements.

The publications within the time span of ten years were chosen as the right duration for review to ensure the latest trend are captured. These papers are carefully studied to know the content of the data discussed in the main body. Subsequently, these content are identified in terms of multimedia design elements used as the main contributor to improve the learning platform for visually impaired. The analysis of these articles includes descriptive summary to show the focus of past literatures on multimedia design elements. The analysis ends with reflection on current state-of-art depicting graphically the role of multimedia design elements in context of visually impaired computer users.

In the second session, the accessibility guidelines for review process were selected based on frequently accessed and referred by past literature papers related to the improvement of overall user interface design and usability of disable group. This is due to the reason that accessibility guidelines meant for only visually impaired is rather limited. Thus, to give an overall overview on the usage of multimedia design elements in relation to accessibility, the general guidelines meant for every type of users were taken into considerations. The analysis on existing guidelines was performed in terms of extensiveness of multimedia design elements covered in context of designing system application. This is to show the extent of importance given on each design element in

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general which will be perceived by the designers as well.

3. MULTIMEDIA DESIGN ELEMENTS IN PAST STUDIES FOCUSING VISUALLY IMPAIRED COMPUTER USERS

Research on various ways of representing information to blind user using multimedia design elements has been in practice for many years. One of the heavily used multimedia design element in computer environment to communicate meaningful information are text and color. Past findings show that some characteristics of these elements could be communicated to the blind users through non-visual design elements such as audio and touch sensation elements. One of the interesting work includes [33] in which steps were taken to communicate attributes of text elements such as font attributes and font hierarchy to the visually impaired.

In this study, font attributes such as bold, italic, underline and font hierarchy such as header, sub-header and paragraphs were communicated through specified braille codes to blind users. An application was developed to translate the content of a webpage to braille codes using braille line. With this invention, blind user now able to understand bolded, italic and underlined words in a website. Alongside, the organization of a webpage in terms of header, sub-headers and paragraphs are also made known to them. Though the findings translated few of text characteristics to the blind users yet the output was limited to only header, sub-headers and paragraphs. Second level sub-headers or levels lower than this were unable to be translated.

Similar importance were given by [34] in their study when their research proved enhanced text user interface (ETI) encourages the visually impaired to navigate better compared to Graphical User Interface (GUI). These authors drafted nine guidelines concerning context and orientation of information, navigation, clarity and simplicity to construct an enhanced text user interface (ETI) which was tested with 39 visually impaired users. The outcomes were significantly greater in terms of efficiency, error rate and satisfaction results comparing to a GUI based website complying with Web Content Accessibility Guidelines (WCAG). The focus of these guidelines was very much based on the concept of providing "alternative text" for object used on an interface design. However, the focus should also consider touch sensation as another medium of output as blind user possesses rich tactile sensitivity skills which could be utilized to enhanced learning process.

In [35], a software system using bilingual audio element were developed. This is a dictionary system meant for blind users allowing them to translate certain language from any sources including user interface languages. The main element used here was audio element while the user interface of this system is extremely simple layout with text and partially color based display indicating simple appearance is sufficient to encourage the usage of computer system among visually impaired. The main idea was to deliver information in simplest format taking into account the user task, behavior, semantic and device. However, the study failed to look at the importance of providing equal opportunity in accessing the existing interface design meant for both sighted and non-sighted users without any compromises in terms of the output.

Another finding which focused on translation of text to speech is [36]. In this work, the researchers invented a prototype to capture an image containing text and using optical character recognition (OCR) technology, the fonts are extracted and printed on a notepad. The audio will read this text output to the blind users. The end results are very interesting due to the ability to convert a text based image to audio based output. However, the authors have not discussed on the possible inaccurate translation that might occur if the image does not contain a clear boundary between one font and another.

Recent studies which also looks into translation of image based information to the blind users are [37] and [38]. However, unlike the previous authors, these latest findings involve the use of touch sensation in conveying the message. In [37], the main idea is about generating tactile graphics from any online based sources through the extraction of information from the metadata and then produced it as an output through tactile device. This practice will ensure any image rendering to tactile output. It is an interesting finding yet it involves the usage of expensive devices and it is still unclear in terms of the technical implementation.

While in [38], the authors went beyond converting online materials. They focused on representing an actual environment virtually through sensory, layout, colors and graphics which helps

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visually impaired to relate it to real environment later. The application facilitates the learning process of a new environment for the visually impaired thus reduces the potential mistake that they could make if they were to navigate the environment for the first time ever. However, in terms of practical implementation, the various touch stimuli to represent the real environment maybe limited and in larger scope, there lays huge difficulties in converting a spacious environment or in fact every single environment.

Research has also shown that interface layout plays a very big role in some situations especially in an e-commerce environment [39]. Interface layout becomes one of the key deciding factors for a user to proceed on an e-commerce website apart from the factor price and product offered [39]. Unlike color and text, a good interface layout does have an effect on blind users [40].

A proper arrangement of related information, tabs, sequence of the topics, placement of the subtopics and few others on the screen do help a blind user to perceive the information more easily compared to a cluttered layout which does not follow any kind of appropriateness [39]. A similarity of idea between [39] and [41] could be seen when the latter agreed on the advantages of properly arranged interface layout for the blind user. Abidin's work showed that the structural representation of an interface layout creates two dimensional views for the blind users.

Structural representation in the form of various complexity levels of tables containing text were tested for navigation purpose with 10 blind users. The navigation process was performed with the help of multimodality output which revealed the formation of two dimensional representations in the mind of a blind user. However, their research also shows that the theory is applicable only if the layout appears simple and not much of a difference could be seen for a complex layout [42]. The work of [43] has added to [39] and [41] findings on simple structural layout for the blind.

The travel on the virtual world was related with the travel on the real physical world in terms of the concept [43]. Connors used game based approach application involving multiple design elements such as animation, graphics and audio in transferring the spatial information on an environment to facilitate the blind in real life navigation. There is a similarity between Connors's work and Maidenbaum's findings whereby both attempted to facilitate the navigation in real life easier for visually impaired.

In [44], it was highlighted that related object should be placed together as it creates an information scent and tends to improve the navigation process. The information which is related is grouped or arranged together to form a sense of belonging in the topic. A blind user who skips their targeted topic while navigating through a layout will realize that the scent of the current topic is different from the previous topic.

The concept of information scents was tested among e-commerce websites. Both, Kuo & Chen, (2011) and Takagi et al., (2007) has agreed that interface layout plays a big role in e-commerce websites [39], [44]. The latter has discovered that blind user possess various scanning method in navigating through an information. An automatic analysis and visualization method for non-visual navigation known as "Nonvisual Usability Visualization Method" were developed to measure the accessibility of e-commerce websites. This method basically calculates the time taken by a blind user to reach specific part of a layout, while taking into consideration different types of navigation style.

Thirty popular online shopping sites from three different countries (UK, US and Japan) were evaluated using this method. It was found that 87% of the sites were not accessible to the blind user [44]. This result reveals that interface layout was not considered from the view point of blind users. Many applications fail to realize that a well-designed interface layout impacts positively the navigation process of a blind. The usage of the correct layout of blocks improves the accessibility features of an interface. An accessible interface layout allows blind users to travel around an application much faster and feel more satisfied. The findings of [44], [39] and [43] interrelates real life environment in classifying objects as cues or obstacles in facilitating their navigation process as well as placing related topics closely could be combined to form a complete concept on interface layout. However, in the case of a cue turned into an obstacle or mislead of subtopics for certain users which could be due to influence of their past experience or interaction style was not given much thought in this research. This in return, might create a smooth navigational process only for specified users and might not be applicable for others.

Most of the mentioned work uses audio

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alongside with other design elements in delivering the intended message to the visually impaired. It is undeniable fact that audio is seen as a delivery mode more than an essential multimedia design element. A clear definition on audio was not found in recent research as many authors still referring to olden days literatures. Therefore, the papers published five years before the year 2007 was referred for this particular section. However, the reference is merely to provide definition on types of audio exist and are not included as part of the content review relating to the topic.

The input of a system comes in the form of speeches from the user while the output from the system is delivered in the form of speech and non-speech audio to the user [26], [45], [46]. Speech audio refers to the words communication such as usage of a screen reader, and non-speech audio refers to auditory icons, music, and environmental sounds to deliver certain messages [26], [46].

A non-speech sound can be further categorized as synthetic and natural. Synthetic sound refers to the usage of any sound to deliver information such as a "ping" sound for an alert message. While natural sound refers to the usage of original sound relating to the scenario [16]. Appropriate usage of audio will help a user to be aware of the surroundings, cue visual attention and facilitates in conveying multiple complex information to the users [27]. Audio is as a complement that works with other types of design elements [26], [27].

A pattern on the past research relating audio element with blind users has been detected. The first pattern is audio as a sole element in translating the content of an interface and the second pattern is the inclusion of another design element mainly the touch sensation or another technology to work along with audio. The findings of [47], [48] and [49] are some of the significant examples of research on audio as a sole element. The work of [50], [41], [51] and [52] could be classified as examples of research involving audio with other design elements and technologies.

In [48], a tool was designed and developed to overcome the currently lacking of browser-based tools for post-production audio description. This tool allows users to describe the visual characteristics in a video and add as part of the communicated dialogue. Thus, the visual characteristics such as action, characters and settings are made known for the blind viewers. The exploration of audio was also extended to ease the usage of different types of computer applications and practices for the blind. Applications such as programming platform, 3D tools, computer games and practices such as cross-platform remote access have been considered.

The work of [47] used computer games for rehabilitation purpose in the field of health and telemedicine meant for blind teenagers. Audio were used as the main element in facilitating this specially designed computer game to allow the visually impaired to feel the same experience as the sighted users. Unlike other researchers, [49] look at the problem faced by the blind users beyond the simple application usage. The incompatibility of screen reader when there is a need for usage in cross platform or remotely accessed environment was highlighted. A solution utilizing the audio element was introduced to facilitate usage of screen reader across platform.

Though many recent works have produced successful solutions solely involving audio, there are also some significant findings which pairs up audio with other design elements or technologies in producing an accessible platform for the blind. This can be seen in the work of [50], whom made the surroundings of blind user much easier to access, through the application of audio alongside with touch sensation. Kiosk and hand held devices incorporate touch screen tips and audio descriptions to extend the usability to the blind users. Strong relations may be sensed between the work of [50] and [51] whereby the later also applied similar software solution in assisting the blind user in navigating through a large environment.

While [51] worked on navigation of real environment, [41] explored the navigation of web pages. The performance of audio in combination with QR technology was also seen as an improvement when it was used to translate the graphics within the textbook of blind students [52]. It could be summarized that audio is more effective when presented with other design elements. Audio tends to deliver the intended message accurately when it is in multimodality environment. Despite many successful implementation of an audio, the limitations of screen readers make the interpretation of some output more challenging. At present, audio is unable to interpret mathematical expression, illustrations, diagrams, maps, visual layout, and hierarchy [53].

Some other work was found incorporating audio, text and animation to provide a better

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learning environment for visually impaired. Animation is another visual cue; therefore, the visually impaired will have trouble in perceiving information which is presented using animation. Many designers failed to create an accessible animation for the visually impaired (Whit et al., 2016). The characteristics of an animation need to be communicated to the blind user in order to deliver the meaningful information. It is also important for a designer to realize that only relevant descriptions of an animation are able to accurately translate an intended message [56]. This means not all information can be translated using animation. The constraint on the condition of usage on animation creates a limitation to the designers in utilizing much this element as the main contributor of an application and practices.

Recent research has applied touch sensation more than just the usual representation of text. Spatial information was attempted to be translated to the blind users through the application of touch sensation [57]. This research made sense of spatial representation on an interface to the blind user which initially was a challenging task. The intervention of touch sensation in facilitating the blind to learn their surroundings started many years ago and is still being explored progressively [58], [59].

Navigation of the real environment became more sensible for the blind when touch sensation systems were introduced. A tactile wayfinder system was developed to assist blind users to find their path of travel through the vibration features [59]. This system guides a blind to move around and able to avoid any obstructions along the way. In addition to this finding, a digital map on a touch screen device was translated in the form of vibration and audio output to help the blind users to get an overview of the layout [60]. The intention of [60] was very similar to another past finding, [61] whereby the latter worked on representing HTML elements to the blind users using force feedback. The representative view of the web layout was achieved through this representation hence bringing the blind user closer to their navigating environment.

The amount of information that could be learnt by a blind user with the usage of touch sensation can be highly related to the type of sensation that is being used in representing particular content. The work of [62] has demonstrated this by exploring various types of stimuli to produce an effective pattern which is believed to increase the effectiveness of representing information to the user. Seven classes of different tactile patterns, which consist of different time length, strength level and base effects, were created and tested as "match the pattern" game. The finding concluded that different activation time length, with various base effects and by combining a set of patterns with variation of vibration strength as a good design principle as the test result reflects the fact that users tend to remember patterns created with this design principle.

It could be summarized, that the research interest on touch sensation and its use in facilitating the blind users has increased tremendously over the years. However, this technology is still at a beginning stage; thus, it requires plenty of improvements in order to translate every object and content of a computer system into a readable format for the visually impaired. Research on improving the design and modeling of touch sensation technology is still in focus showing that there is always a room for an improvement to be made [63].

Table 2: Summary of Previous Findings (2007-2017)

Sources	Multimedia Design Elements	Findings
Chen et al., (2007)	Audio, Touch Sensation	Covers human performance issues relating to user interface design.
Kuber et al., (2007)	Touch Sensation, Interface Layout, Audio	Used touch sensation as the main element in representing HTML elements to give an overview of a webpage.
S. H. Kurniawan, (2007)	Audio, Touch Sensation, Interface Layout, Graphics, Text & Color	Essential elements in designing.
Takagi et al., (2007)	Audio, Interface Layout	Navigation style and focused on the implementation of audio.
Alonso et al., (2008)	Audio, Touch Sensation, Graphics, Text & Color,	Developed bilingual software system allowing the blind user for language translations.
Heuten et al., (2008)	Touch Sensation, Audio, Graphics	Wayfinder system using PDA and Tactile belt to translate and guide the pathways on the map to the users.

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Sources	Multimedia Design Elements	Findings
Leuthold et al., (2008)	Audio, Interface Layout, Text & Color, Graphics	Developed Enhanced Text User Interface (ETI) based on nine guidelines and tested the performance comparing to Graphical user interface (GUI).
Vanderheiden, (2010)	Audio, Interface Layout	Combined the two techniques to improve the usability of touch screen kiosk and handheld devices.
Kuo & Chen, (2011)	Interface Layout, Graphics, Text and Color	Case study on online sites.
Nishino et al., (2011)	Touch Sensation	Investigate on the type of touch sensations.
Poppinga, (2011)	Touch Sensation, Audio, Graphics	Applied touch sensation and audio to translate the content of a map for reading purpose.
Xu et al., (2011)	Audio, Touch Sensation, Graphics, Text & Color	Translated school book using the four elements.
Abidin et al., (2012)	Audio, Touch Sensation, Interface Layout, Text & Color	Used audio and touch sensation to convert various complexities of tables.
Francis et al., (2013)	Audio, Animation, Graphics	Guided the usage of these two elements in designing e-commerce website.
Sulaiman et al., (2014)	Touch Sensation, Text &Color	Applied touch sensation in presenting the text attributes.
Connors et al., (2014)	Audio, Interface Layout	Translation of spatial knowledge.
D.Patil, (2015)	Audio, Graphics, Text & Color	Utilizes OCR technology and speech synthesis technology to translate images.
Baker et al., (2016)	Audio, Touch Sensation, Graphic	Developed mobile application for graphics translation.
Bose & Helmut, (2016)	Touch Sensation, Graphic	Using tactile to translate images from online sources.
Cavaco et al., (2016)	Audio, Graphic, Animation, Interface Layout, Text & Color	Used audio as the main element in computer games for health education.
Hamilton-Fletcher et al., (2016)	Audio, Interface Layout, Graphic, Text & Color	Looking into translation of visual information into substitute sensory.
Whit et al., (2016)	Audio, Animation	Focused on post-production audio description.
Maidenbaum et al., (2016)	Audio, Graphics	Used graphics and audio to deliver meaningful information.
Merabet & Sánchez, (2016)	Audio, Touch Sensation, Interface Layout	Investigates on translation of spatial knowledge in real world.
Syed et al., (2016)	Audio, Animation	Overcome incompetency of screen reader when accessed crossed or remote platform.
Swaminathan et al., (2016)	Touch sensation, Graphics	Tactile based output to translate spatial information.

As a summary of this section, multimedia design elements such as text and color, graphics, animation, interface layout, touch sensation and audio have been seen as essential components in promoting accessibility and usability features of an application [14]–[17]. Past work has been reviewed in this section to show the extent of adoption and usage of design element in delivering content and functionality of an application. The findings of this section have been summarized in the form of a table (table 2) at the end of the section. This table gives an overview of previous research interest and highlights their focus as well.

The pattern shows that each research involves few of the design elements rather than covering all of the design elements at once. In the context of in-depth study, this is a good approach as the focused has been channeled to solving a specific problem of visually impaired. However, this could be an issue in the eyes of a designer. Designer depends on the past studies as well as established guidelines to know the importance of multimedia design element in designing an application. Past studies have definitely highlighted the need for each of these design elements; however, the importance of these design elements in the context of blind users might not have been clearly depicted.

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Past research has shown audio, touch sensation, text & color, animation, graphics and interface layout as important elements in delivering meaningful information to the blind. However, the pattern of the research shows that most of the time the designers work on audio and touch sensation relatively as mode of translation to the visually impaired therefore the end results emphasized on either one of these element only. Maximum benefit could be attained if the work viewed both audio and touch sensation as contributing elements and focused on using all design elements accordingly in translating the existing environment to the visually impaired.

As mentioned earlier in introduction section, the main reason such pattern of work exist could be highly related to the gap in existing established guidelines. The next subsection will review on the existing guidelines relating to computer accessibility and the viewpoint of multimedia design elements as portrayed by these guidelines to the designers.

4. MULTIMEDIA DESIGN ELEMENTS IN EXISTING GUIDELINES

In this section, frequently accessed guidelines relating to the usage of multimedia design element has been reviewed, analyzed and summarized in table 9.

4.1 Web Content Accessibility Guidelines (WCAG 2.0)

One of the frequently accessed guidelines which serves as the baseline findings for many designers are the well-known Web Content Accessibility Guidelines (WCAG 2.0) by W3C which are meant for web applications [32], [64], [65]. These guidelines are categorized into 4 principles; perceivable, operable, understandable and robust [64].

The principles are summarized in table 3. Each of this principles are well defined to ensure that the web content is accessible by variety range of users which includes users with disabilities, visually impaired, hearing impairments, learning disabilities, cognitive limitations, speech disabilities, photosensitivity and combinations of these [64].

The listed guidelines are very thorough and detailed [32], [64]. Web developers, user agent authors and web authoring developers tend to benefit from the provided guide as these guidelines are meant for all [32], [65]. The "design for all" rule has an objective of ensuring an easier browsing platform is developed for the impaired users, especially those users with common experience in using screen readers, mice or keyboards [65].

Table 3.The Four Principles of WCAG 2.0 [64]

Principles	Description
Perceivable	▪ Provide text alternatives for any non-text content. ▪ Provide alternatives for time-based media. ▪ Create content that can be presented in different ways. ▪ Make it easier for users to see and hear content.
Operable	▪ Make all functionality available from a keyboard. ▪ Provide users enough time to read and use content. ▪ Do not design content in a way that is known to cause seizures. ▪ Provide ways to help users navigate, find content, and determine where they are.
Understandable	▪ Make text content readable and understandable. ▪ Make web pages appear and operate in predictable ways. ▪ Help users avoid and correct mistakes.
Robust	▪ Maximize compatibility with current and future user agents, including assistive technologies.

The principle "perceivable" and "robust" does highlight on the importance of delivering visual based information non-visually. The usage of alternative text for all non-text based information presented on web content has been stressed. This is to smoothly facilitate the translation into different format such as large printing, braille, speech, symbols and simpler language. The need to ensure on compatibility of the content to work with assistive technologies has also been highlighted.

However, the focus on providing an alternative for a visual based cue was pointed out as text based. This gives an impression as though, text based description for a visual representation is sufficient in translating the web content. In reality it takes more than just text explanation to deliver meaningful information. The element of audio is only referenced from the context of audio production for videos. In addition, the usage of touch sensations was not addressed in this guide at all [48]. The guide in WCAG 2.0 has less contribution towards the development of an application, as the guideline does not generalize

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to computer applications. It is very specific for the presentation of web content to users.

4.2 Accessibility Guidelines for People with Disabilities / Aging

Trace R&D has been working ever since 1971 to improve the designs of consumer products for both types of users; (i) normal users and (ii) users with special needs and had even produced the first set of guidelines on accessible web content which became the basis for World Wide Web Consortium's Web Content Accessibility Guidelines 1.0 [66]. Referring to another recent development by Trace R&D Centre on computer design, the set of guidelines were meant for the design of consumer products to increase their accessibility to people with disabilities or aging [67], [68]. These guidelines are summarized in table 4.

The guidelines developed by Trace R&D are extensive and address many issues related to the usage of computer by both normal users and special need users, which include those with visually impairments, hearing impairments, physical impairments, cognitive/language impairments, seizure disclosure and multiple impairments. The description on section "output/displays" suggested some design options and idea to consider in ensuring the delivery of visual based output to the visually impaired by using audio and/or tactile.

Table 4: Guidelines for More Accessible Design by Trace R&D [66]

Section	Description
Output / Displays	Includes all means of presenting information to the user: O_1 hear auditory output clearly enough O_2 not miss important information if they can't hear O_3 have line of sight to visual output and reach printed output O_4 see visual output clearly enough O_5 not miss important information if they can't see O_6 understand the output (visual, auditory, other) O_7 view the output display without triggering a seizure
Input / Controls	Includes keyboards and all other means of communicating to the device: I_1 reach the controls I_2 find the individual controls/keys if they can't see them I_3 read the labels on the controls/keys I_4 determine the status/setting of the controls if they can't see them I_5 physically operate controls and other input mechanisms I_6 understand how to operate controls and other input mechanism I_7 connect special alternative input devices
Manipulations	Includes all actions that must be directly performed by a person in concert with the device or for routine maintenance (Ex: inserting disk, loading tape, changing ink cartridge): M_1 physically insert and/or remove objects as required for operation M_2 physically handle and/or open the product M_3 remove, replace, or reposition often-used detachable parts M_4 understand how to carry out the manipulations necessary
Documentation	Primarily operating instructions: D_1 access the documentation D_2 understand the documentation
Safety	S_1 perceived hazard warnings S_2 use the product without injury due to unperceived hazards

The implementation of a screen design using simple layout, appropriate images, suitable font and color has also been stressed here. However, the usage of animation was not mentioned clearly in the guide. In overall, it gives good information for the designer yet in many instances the guideline indicated audio and tactile as alternative elements of each other rather than depicting then as co-existing elements. This portrays an impression that some of the design elements are not necessarily needed to be included in a design process and thus may lead to a situation whereby the information delivered to the affected group of users might not be complete.

4.3 Nordic Guidelines for Computer Accessibility

Nordic Guidelines for computer accessibility were established in 1993 by Nordic Committee on Disability [69]. This included cooperation on disability, under the wings of Nordic Council of Ministers, a joined collaboration between Denmark, Finland, Iceland, Norway and Sweden [69]. The set of guidelines were generated based on the concept of "Design for all" which is also known as

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"Universal Design". The basic principles of Nordic approach maximize the accessibility of public systems and corporate systems to be accessible to the widest range of users [32], [69]. The guidelines are summarized in table 5.

Nordic guidelines do consider most of the problems faced by the special need users; however, the guide consists more of general advice on what to be included in an application design and hardware design. In fact, the guideline gives less focus on visually impaired users but more attention to physically impaired, sensory impaired, cognitive impaired, elderly people and temporary disabilities (broken arms, pregnant, no glasses, and so on) [70], [71].

Table5. Guidelines on Computer Accessibility [69]

Guideline	Description
Technical Platform	Referring to the ability of system software and application software in supporting the basic features of accessibility such as customizable user interface, keyboard access to all features, output redundancy, system standards and compatibility with assistive device.
System Unit	Referring to the ability of hardware functions in supporting the assistive technology.
Controls	Referring to the ability of the controls (switches, etc.) on the hardware to be operated by the impaired users.
Perception of alert messages	Referring to the ability of any kind of messages such as alarms, warnings, status signals and error messages to be communicated to the impaired users.
Keyboard	Referring to the incorporation of ergonomic features on keyboard which satisfies all types of users.
Pointing device	Referring to the variations of pointing device available which satisfies all types of users.
Perception of display	Referring to the incorporation of ergonomic quality onto the display unit which satisfies all types of users.
Printers	Referring to the ability of a printer to be operated by all types of users.
Requirements of persons with hearing impairments	Referring to the reduction of noise emitted from equipment with electromagnetic characteristics and other devices such as hard disc or printers which could be irritating for the hearing-impaired users.
Application Software	Referring to the compliance of application software and web contents to the accessible guidelines.
Documentation	Referring to the On-line help and documentation to be written in the most convenient presentation that can be easily perceived by the impaired users.
Security	Referring to the available options for verification and validation process as part of safety precautions to be easily adapted by the impaired users.

The need to incorporate accessibility requirements related features were not classified as mandatory, recommended or even desirable in these guidelines [69]. Referring to table 5, "Application Software" covers on the importance of providing an accessible system for the visually impaired. It was suggested either to provide text alternatives for images, graphics and video or to generate text-only screen representing the graphics based screen to be available in parallel for the blind. Conversion of meaningful information should not be limited to only text based rather other elements such as usage of non-speech audio and touch sensitivity should be considered as well.

The examples provided for good accessibility practices for the designers revolve around the importance of text in converting the meaningful information to the blind users. Moreover, audio and touch sensation has been mentioned as an assistive technology rather than an essential component which is to be a part of the design elements [69]. This leads the designers to falsely believe that the designing of an application highly depends on some of the design elements rather than all of the design elements. Thus, an accessible application may not be achievable for the blind users.

4.4 Guidelines and Standards for Tactile Graphics

Guidelines and standards for tactile graphics were published by the Braille Authority of North America (BANA). It is a joint project between the Braille Authority of North America and the Canadian Braille Authority [72]. The main intention of this project is to ensure the tactile readers perceives the information presented in graphic format by enforcing some standardization on the representations of images, graphs, symbols and any others in the format of graphic [72], [73].

The principle behind this guideline is to apply the most appropriate and effective medium of representation on a graphic to produce the most meaningful output rather than an exact output [72], [73]. In other words, the reproduction of a graphic does not have to be an

exact representation, as the most important point is to present the meaning of a graphic which could be presented differently. The guidelines are summarized in the following table 6.

Table 6.Guidelines and Standards for Tactile Graphics [72]

Section	Description
Braille formats for tactile graphics	Refers to the placement and order of the tactile graphics, headings, titles, numbered figures, print illusions, keys and legend, symbol placement, label placement, page numbering, special symbol page and graphic symbol page.
Mathematical and scientific diagrams	Refers to the representation of clocks, spinners, circle graphs, money, line formation, pictographs, counting symbols, thermometers, measurement tools, 2D and 3D drawings, Venn diagrams, tessellations, stem-and-leaf plots, orthographic drawings, ancient numeration systems and chemistry.
Complex diagrams	Refers to the representation of typical characteristics of complex diagrams, procedures, design techniques, biology, social studies, charts and graphic organizers.
Orientation and Mobility	Refers to the representations of various types of complex tactile maps.
Tactile graphics supplements	Refers to the representation of separate supplements containing all the tactile graphics which may exist in some circumstances.
Quality control	Refers to measurement techniques to be applied on a tactile conversion of a graphic.
Graphics for early grades	Refers to graphic representation to younger generation between kindergartens to grade 3.

A set of extensive guidelines on tactile graphics is a valuable resource for many; however, quite a number of these guidelines seem to end up creating further confusion among the readers [74]. In addition, the importance of these guidelines was directed to the reproduction of a graphic using only tactile element and the focus of the graphic was more towards mathematical and scientific images [74], [75]. It was highlighted that the inclusion of audio to work along tactile sensation is a useful addition. However, no further elaboration was provided in this context.

The guidelines benefit the tactile-image producers much more compared to an application designer even though the practice has taken place sometime ago in HCI environment. Since the focus of BANA is only on usage of tactile for the visually impaired, the exclusion of the rest of the design elements in presenting an accessible computer application seems very apparent. BANA guidelines are complete within the scope of touch sensation. However, in the context of producing accessible applications, BANA might not be suitable to be considered as a complete guide for the designers.

4.5 ISO Standards on Computer Accessibility

International Organization for Standardization is a body consisting of ISO technical committees who works closely with related commissions in establishing international standards [76]. These standards were established based on a compilation of W3C, Trace R&D, Nordic guidelines, Jakob Nielsen and many other findings [77]. There are many standards exist on accessibility of software, however here, the coverage will be given to ISO 9241 as the standard is the most recently revised [78]. Generally, ISO 9241 has many parts which are tied to ergonomics of human-system interaction. One of it will be ISO 9241-171 which consists of an in-depth guidance on software accessibility [79].

The intention of this standard is to allow maximum accessibility to be experienced by the impaired group of users [76], [79]. The range of users being covered are blind, deaf, hearing impaired, physical disability, elderly people, cognitive disability and sensory disability [76]. The standard take into account the usage of assistive technologies by the impaired users thus enforces the design of an accessible system must have the ability to be connected to the common assistive gadgets such as head-mounted pointing device, various level of magnification, screen readers and so on [76], [78].

However, the standard failed to cover tactile and haptic interaction which have become increasingly popular among the blind users over the years [78]. As an addition to the standard of ISO 9241, another part which focuses on the tactile and haptic sensations was developed. ISO 9241-920 was designed to focus on the guidance of tactile and haptic interactions [76], [78]. The guidance of ISO 9241-920 has been summarized in table 7.

Table 7.Guidance on Haptic and Tactile [76]

Area	Description
Applicability considerations for Tactile/Haptic interaction	Refers to the considerations of effectiveness, efficiency, satisfaction, accessibility, safety and so on.
Tactile/Haptic	Refers to the application of

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inputs, outputs, and/or combinations	uni-modal and multi-modal concept in guiding the interaction styles, navigation information and so on.
Attributes of tactile/haptic encoding of information	Refers to the usage of an object properties, attributes involving patterns, texture, sensory, vibration and etc.
Content-specific encoding (what to encode)	Refers to the encoding and usage textual data, graphical data, subjective data and controls involving Braille, kinesthetic, landmarks, scales, size and spacing elements.
Layout of tactile/haptic objects	Refers to the manipulation of resolution, separation and consistency.
Interactions	Refers to the usage of interaction task and interaction techniques.

ISO 9241-171 and ISO 9241-920 provide a wide coverage on development of an accessible system. Despite producing a thorough document for reference, the international standard seems to project a concept which looks at touch sensation as a non-important design element in designing an application due to the establishment of separate guidelines. The existence of two individual guidelines addressing the accessibility of a system gives an impression that touch sensation can be an optional element instead of an essential item which is supposed to be a part of guidance on the development of accessible software. These impressions were made as the earlier standard (ISO 9241-171) stresses the usage of all the multimedia design elements interchangeably in designing an application except for the usage of touch sensation drafted as separate guidelines.

4.6 Computer Accessibility Guide by Others

A very recent finding [80] has suggested some good practices to be followed by the designer as an effort to acknowledge the requirements of the blind computer users. It was mentioned that the blind users tend to rely on screen readers which projects the synthetically produced voice or in some cases, the usage of touch sensation in perceiving information in a computer system. Table 8 shows the six good practices established in this article.

Table 8.Good Practices for Computer Accessibility [80]

Practices	Description
Provide descriptive alternatives of the entire diagram.	Stresses on usable text or audio for diagrams However, it may be difficult to provide a good alternate text for complex diagrams thus usage of hyperlinks for multiple nodes on the diagram may help the blind users.
In articulated diagrams, provide accessible names for direct exploration.	Stresses on actual text representation instead of image of text or text label of a graphic for individual element that exist in a diagram. This is to serve the blind users' need for direct exploration especially for a diagram with many semantic.
In articulated diagrams, provide a meaningful reading sequence.	Stresses on the ordering of the elements in a diagram to provide a meaningful navigational path for the blind (Ex: ordering of the city names when displaying a sightseeing information)
In articulated diagrams, reflect content hierarchies in nested structure.	Stresses on displaying content in the form of structures using list.
Provide alternative encodings of graphic decision trees.	Stresses on different representations for diagrams with processes such as flow charts. May use hypertext for every node, capturing of voice input and etc.
Make articulated network diagrams navigable.	Stresses on ensuring accessible nodes for network based diagram via keyboard navigation. Users must be able to go back and forth by just using up/down arrow button on the keyboard.

The conversion of image, graphics and diagrams using text or audio has been stressed in this study. Usage of text alternatives were suggested to include hyperlinks when complex diagrams or hierarchies are translated. The implementation of touch sensation was also suggested to depict the diagrams. The findings benefit the representation of map oriented diagrams to the blind users. The listed practices give options in terms of usage of audio, touch sensation, layout and text in representing a diagram. However, portraying these elements as optional may lead a designer to have a perception that some of these elements are considered important and some are not.

4.7 Summary of Existing Computer Accessibility Guidelines and Standards in Context of Visually Impaired

Referring to table 9, the level of coverage explains the extent of importance and

the viewpoint of the standards and guidelines on multimedia design elements in the context of blind users. Most of the guidelines and standards do not emphasize much on the usage of touch sensation except for BANA's guidelines which focus mainly on touch sensation. The rest of the guidelines and standards merely look at audio as a medium of translation of interface content through the usage of speech based audio. Less emphasis was made on the usage of non-speech audio or in mandating audio in delivering information to the blind.

Furthermore, text & color, interface layout and graphics have been stressed in many circumstances from the viewpoint of sighted users. The usage of animation was highlighted directly in some guidelines such as WCAG 2.0 and ISO standards and has seen an indirect coverage in Nordic and in computer accessibility guide by others. The literature findings imply there is an empirical insufficiency in portraying the role of multimedia design element from the viewpoint of blind computer users. Perhaps this can be a good future research for the scholars.

Table 9.Summary of Standards and Guidelines Relating to Computer Accessibility

Standards /Guidelines	Coverage Level (High to Medium) / (Low to None)	Findings
WCAG 2.0	**High – Medium:** Text & Color, Interface Layout, Graphic, Animations, Audio **Low – None:** Touch Sensation	Visual cues are translated using all multimedia design elements except for audio and touch sensations. Audio is seen as alternative text for video content (audio production).
Accessibility guideline for people with disabilities/aging	**High – Medium:** Text & Color, Interface Layout, Graphic, Audio **Low – None:** Animation, Touch Sensation	Audio and Touch sensation has been portrayed as alternative elements of each other rather than co-existing elements.
Nordic Guidelines for computer Accessibility	**High – Medium:** Text & Color, Graphics, Audio, Animation, Interface Layout **Low – None:** Touch Sensation	Covered all the design elements in translating the content of the web page. However, portrays the usage of touch sensation as an optional element.
Guidelines & standards for tactile graphics	**High – Medium:** Touch Sensation **Low – None:** Animation, Audio, Interface Layout, Graphic, Text & Color	Main focus was on touch sensation element and on the usage of other elements in enhancing the conversion into touch sensation. Animation was not mentioned.
ISO 9241-171 & ISO 9241-920	**High – Medium:** Text & Color, Audio, Graphic, Interface Layout, Animation **Low – None:** Touch Sensation	Maintained two different standards.
Computer accessibility guide by others	**High – Medium:** Text & Color, Graphics, Audio **Low – None:** Animation, Touch Sensation, Interface Layout	Included all of the design elements however stressed more on graphic, text and audio element.

5. REFLECTION ON CURRENT STATE-OF-ART

In this section, a graphical representation of the design elements based on the past work and existing accessibility related standards and guidelines are presented. In here, the underlying concept on how the design elements are portrayed has been viewed and studied to show the current state of art. The past work as portrayed in table 2 and existing accessibility related standards and guidelines as in table 9 have been used as a direction to understand on how the design elements are exhibited for illustration purpose. The concept of the design elements as projected by previous findings is represented in visual form as shown in figure 1. The model is designed to represent the gist of the current theoretical literature.

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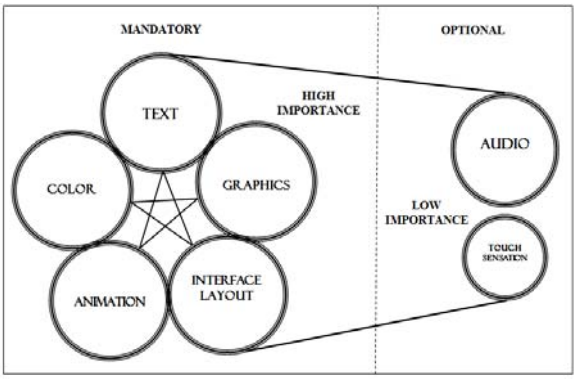

Figure 1.Reflection on Current State-of-Art

There are two groups in this model. The first group is known as the mandatory group, which consists of the design elements: (i) Text, (ii) Graphics, (iii) Interface Layout, (iv) Animation and (v) Color. The meaning of "mandatory" here shows that the elements in this group are essential in designing applications. These five design elements are interconnected to show that the past studies have worked on them interchangeably. The elements are arranged in a circular format with no variation in physical magnitude indicates that there are no empirical evidence found in literature to show significant differences in the roles of these design elements.

The second group in the model refers to optional groups which consist of two design elements; (i) Audio and (ii) Touch Sensation. The meaning of "optional" here shows that the items within this group are considered as not necessarily needed to be included in usual designing process. The "non-connected" relationship between these elements portrays that past work views these elements as substitutes of each other. For an example, if a screen reader has been used to present an output to the users, then touch sensation is not necessarily needed. This could be seen in real life situations, as the number of information converted using a screen reader is higher compared to the use of touch sensation in representing the same information.

Again, this state exists due to two situations: (i) existing accessibility related standards and guidelines documents audio and touch sensation as an optional element and (ii) very few researchers practiced the combination of audio and touch sensation as a solution for translating information to the blind. Even then, the solution is usually an "after development" remedy in the form of assistive technologies. Both situations fail to highlight the importance of providing a solution, which includes all the design elements as a complete solution to be implemented during the design stage of a computer application itself.

The element of audio has been placed on top position and shown significantly larger than touch sensation to indicate that most of the past studies have attempted to focus on relating audio in facilitating the blind user compared to the focus on touch sensation element. Lastly, note the two bars which connect the elements of the "mandatory" group and the elements of the "optional" group. These bars indicate the level of importance given for all the elements within their own group. The design elements within the "mandatory" group are considered to be more important in the process of designing an accessible computer application compared to the design elements in the "optional" group.

The dotted line which separates the mandatory group items and the optional group items is to indicate the "soft" separation between these design elements. These are due to many researchers viewing audio and touch sensation as a separate item rather than bundling them together with the rest of the design elements. In addition, audio and touch sensation have been seen in the form of screen reader and braille/tactile devices most of the time rather than focusing on the other characteristics which could deliver much more meaningful information to the blind users.

Figure 1 depicts the idea that forms in the mind of a designer when they read through the literature and refers to accessibility related standards and guidelines. An overall view shows that audio and touch sensation is seen as a separate element compared to text & color, interface layout, animation and graphics in most of the past studies. The illustration shows that the role of multimedia design elements is not specified in terms of their contribution and importance in context of visually impaired.

Therefore, it can be said a gap exist in the reflection on current state of art which could be a good prospect for future work. Some of the possible work that could be extended from here is to perform empirical study on the role of the multimedia design element in context of visually impaired, analyze the coexist multimedia design elements for visually impaired and sighted users in terms of merging the different roles and evaluating the behavioral components of visually

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impaired which could influence the role of multimedia design elements.

6. CONCLUSION

Visually impaired users face many challenges in accessing computer applications for personal as well as for work purpose. The main reason such obstacles surfaced are due to lack of awareness and knowledge among the designers in designing and developing an accessible computer application. The existing guidelines and past work related to accessibility of blind computer users did not really educate the designers on the role of design elements in designing applications. The contribution and importance of multimedia design elements in context of visually impaired are not portrayed clearly in current state of art thus leaving an uncertain knowledge to be acquired by the designers.

The role of multimedia design elements portrayed in past literatures as well as existing guidelines was represented visually for better understanding of the current state of art. The representation shows that text, color, animation, graphics and interface layout are seen as interrelating design elements in a design process while audio and touch sensation are viewed as independent elements which can be optional choices for a designer. The visualization of current state of art achieves the objective of the research to highlight the imperfection of the concept in illustrating the relation of design elements in the context of computer accessibility. This finding serves as an achievement in providing baseline information for scholars to extend the work as well as for policy makers to improve the guidelines.

REFERENCES

[1] M. R. Morris, A. Zolyomi, C. Yao, S. Bahram, J. P. Bigham, and S. K. Kane, "'With most of it being pictures now, I rarely use it' Undertstanding Twitter's Evolving Accessibility to Blind Users," in *Conference on Human Factors in Computing Systems - CHI '16*, 2016, pp. 5506–5516.

[2] S. Abduljalil and D. Kang, "Analysis of Human Factors in Software Application Design for Effective User Experience," in *13th International Conference on Advanced Communication Technology (ICACT)*, 2011, pp. 1446–1451.

[3] M. Madiah and S. Hisham, "User-interface design: A case study of partially sighted children in Malaysia," *2010 Int. Conf. User Sci. Eng.*, pp. 168–173, 2010.

[4] M. Fakrudeen, M. Ali, S. Yousef, and A. H. Hussein, "Eliciting Usability from Blind User Mental Model for Touch Screen Devices," *Trans. Eng. Technol.*, 2014.

[5] M. M. Ashraf, N. Hasan, U. Lewis, and M. R. Hasan, "A Systematic Literature Review of the Application of Information Communication Technology for Visually impaired People," *Int. J. Disabil. Manag.*, vol. 11, 2017.

[6] M. C. Murphy, A. C. Nau, C. Fisher, S. G. Kim, J. S. Schuman, and K. C. Chan, "Top-down influence on the visual cortex of the blind during sensory substitution," *Neuroimage*, vol. 125, pp. 932–940, 2016.

[7] F. Jiang, G. C. Stecker, and I. Fine, "Auditory motion processing after early blindness," *J. Vis.*, vol. 14, no. 13, p. 4, 2014.

[8] S. B. L. Ferreira, R. R. Nunes, and D. S. Da Silveira, "Aligning Usability requirements with the accessibility guidelines focusing on the visually-impaired," *Procedia Comput. Sci.*, vol. 14, no. Dsai, pp. 263–273, 2012.

[9] R. Erdem, "Students with Special Educational Needs and Assistive Technologies: A Literature Review," *Turkish Online J. Educ. Technol.*, vol. 16, no. 1, 2017.

[10] V. R. Schinazi, T. Thrash, and D. R. Chebat, "Spatial navigation by congenitally blind individuals," *Wiley Interdiscip. Rev. Cogn. Sci.*, vol. 7, no. 1, pp. 37–58, 2016.

[11] WebAIM, "Screen Reader User Survey #4 Results," no. January 2014, pp. 1–16, 2014.

[12] S. Brewster, *The Human-Computer Interaction Handbook*. London, 2003.

[13] J. A. Jacko, H. S. Vitense, and I. U. Scott, "Perceptual impairments and computing technologies," in *The human-computer interaction handbook*, Erlbaum Associates Inc, 2003.

[14] I. Norshahila, W. A. Wan Fatimah, and S. A'fza, "A Study on Design Principles and Requirements for Multimedia Application

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Development: MFolktales Application for Children's Education," in *International Symposium on Mathematical Sciences and Computing Research (iSMSC)*, 2015.

[15] V. Costello, *Multimedia Foundations: Core Concepts for Digital Design*, 2nd ed. CRC Press, 2016.

[16] S. H. Kurniawan, "CMPE 131: Human Computer Interaction," University of California Santa Cruz, 2007.

[17] A. Pete and S. Posey, "Effects of Applying Multimedia Design Principles in Powerpoint Lecture Redesign," *Curr. Pharm. Teach. Learn.*, 2016.

[18] T. Vaughan, "Importance of Elements in a Multimedia Presentation," in *Multimedia: Making it Work*, 8th Editio., McGraw Hill, 2011, pp. 1–14.

[19] E. Papachristos, N. Tselios, and N. Avouris, "Inferring relations between color and emotional dimensions of a web site using Bayesian Networks," *Human-Computer Interact.*, pp. 1075–1078, 2005.

[20] J. F. Hoffer, G. J. F., and J. S. Valacich, *Modern Systems Analysis and Design*, 6th ed. Prentice Hall, 2013.

[21] L. J. Najjar, "Principles of educational multimedia user interface design.," *J. Hum. Factors Ergon. Soc.*, vol. 40, no. 311–323, pp. 311–323, 1998.

[22] W. O. Galitz, *The essential guide to user interface design: an introduction to GUI design principles and techniques*. John Wiley & Sons, 2007.

[23] M. O. Leavitt and B. Shneiderman, *Research-Based Web Design & Usability Guidelines*, vol. 1. U.S Government, 2006.

[24] B. B. Bederson and A. Boltman, "Does Animation Help Users Build Mental Maps of Spatial Information," in *Proceedings. 1999 IEEE Symposium on Information Visualization*, 1999, pp. 28–35.

[25] C. Lutteroth, R. Strandh, and G. Weber, "Domain Specific High-Level Constraints for User Interface Layout," *Constraints*, vol. 13, no. 3, pp. 307–342, 2008.

[26] M. H. Cohen, J. P. Giangola, and J. Balogh, *Voice User Interface Design*, no. January. 2004.

[27] J. Y. C. Chen, E. C. Haas, and M. J. Barnes, "Human Performance Issues and User Interface Design for Teleoperated Robots," *IEEE Trans. Syst. Man, Cybern. Part C Appl. Rev.*, vol. 37, no. 6, pp. 1231–1245, 2007.

[28] L. Bonanni, J. Lieberman, C. Vaucelle, and O. Zuckerman, "TapTap : A Haptic Wearable for Asynchronous Distributed Touch Therapy," in *Conference on Human Factors in Computing Systems*, 2006, pp. 580–585.

[29] I. Poupyrev and S. Maruyama, "Tactile interfaces for small touch screens," *Proc. 16th Annu. ACM Symp. User interface Softw. Technol. - UIST '03*, pp. 217–220, 2003.

[30] J. C. Lee, P. Dietz, D. Leigh, W. S. Yerazunis, and S. E. Hudson, "Haptic pen: a tactile feedback stylus for touch screens," *Proc. 17th Annu. ACM Symp. User interface Softw. Technol.*, pp. 291–294, 2004.

[31] K. Hinckley and M. Sinclair, "Touch-Sensing Input Devices," *Hum. Factors Comput. Syst.*, 1999.

[32] M. Cooper, D. Sloan, B. Kelly, and S. Lewthwaite, "A challenge to web accessibility metrics and guidelines: putting people and processes first," in *The 21st International World Wide Web Conference*, 2012, pp. 1–4.

[33] S. Sulaiman, D. Rohaya, A. Rambli, M. M. Mokhtahir, and S. Ghayas, "Representing Text Attributes Haptically on a Webpage for the Visually Impaired," pp. 149–152, 2014.

[34] S. Leuthold, J. A. Bargas-Avila, and K. Opwis, "Beyond web content accessibility guidelines: Design of enhanced text user interfaces for blind internet users," *Int. J. Hum. Comput. Stud.*, vol. 66, no. 4, pp. 257–270, 2008.

[35] F. Alonso, J. L. Fuertes, and Á. L. González, "User-Interface Modelling for Blind Users," 2008, pp. 789–796.

[36] Y. D.Patil, "Text to Speech Synthesis for Blind Person," *Glob. J. Res. Anal.*, vol. 4, no. 8, pp. 229–231, 2015.

[37] R. Bose and J. Helmut, "Online Graphics for the Blind : Intermediate Format Generation A Framework for Multimodal Graphics," in *International Conference on Computers Helping People with Special Needs*, 2016, pp. 220–223.

[38] S. Maidenbaum, G. Buchs, S. Abboud, O. Lavi-Rotbain, and A. Amedi, "Perception of

graphical virtual environments by blind users via sensory substitution," *PLoS One*, vol. 11, no. 2, pp. 1–13, 2016.

[39] H.-M. Kuo and C.-W. Chen, "Application of Quality Function Deployement To Improve the Quality of Internet Shopping Website," *Int. J. Innov. Comput. Inf. Control*, vol. 7, no. 1, pp. 253–268, 2011.

[40] American Foundation for the Blind, "Creating Accessible Computer Applications." [Online]. Available: http://www.afb.org/info/accessibility/creating--accessible-computer-applications/25. [Accessed: 14-Jul-2014].

[41] A. H. Z. Abidin, H. Xie, and K. W. Wong, "Blind users' mental model of web page using touch screen augmented with audio feedback," in *International Conference on Computer & Information Science (ICCIS)*, 2012, pp. 1046–1051.

[42] A. H. Z. Abidin, H. Xie, and K. W. Wong, "Touch screen with audio feedback: Content analysis and the effect of spatial ability on blind people's sense of position of web pages," *Int. Conf. Res. Innov. Inf. Syst. ICRIIS*, vol. 2013, pp. 548–553, 2013.

[43] E. C. Connors, E. R. Chrastil, J. Sanchez, and L. B. Merabet, "Action video game play and transfer of navigation and spatial cognition skills in adolescents who are blind," *Front. Hum. Neurosci.*, 2014.

[44] H. Takagi, S. Saito, K. Fukuda, and C. Asakawa, "Analysis of navigability of Web applications for improving blind usability," *ACM Trans. Comput. Interact.*, vol. 14, no. 3, p. 13–es, 2007.

[45] V. L. Hanson, "The user experience: designs and adaptations," in *Proceedings of the 2004 international cross-disciplinary workshop on Web accessibility (W4A)*, 2004, pp. 1–11.

[46] A. Pirhonen, S. Brewster, and C. Holguin, "Gestural and audio metaphors as a means of control for mobile devices," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. Chang. our world Chang. ourselves CHI 02*, vol. 11, no. 4, p. 291, 2002.

[47] S. Cavaco, F. Ferreira, D. Simões, and T. Silva, "The Role of Audio in Two Accessible Vision-Rehabilitation Games for Blind Teenage Users," *Encycl. E-Health Telemed.*, pp. 812–826, 2016.

[48] M. Whit, R. M. Ali, and D. Fels, "LiveDescribe Web Redefining What and How Entertainment Content Can Be Accessible to Blind and Low Vision Audiences," in *International Conference on Computers Helping People with Special Needs*, 2016, pp. 224–230.

[49] M. B. Syed, D. E. Porter, and I. V Ramakrishnan, "Sinter : Low-Bandwidth Remote Access for the Visually-Impaired," in *Eleventh European Conference on Computer Systems*, 2016, p. 27.

[50] G. C. Vanderheiden, "Use of audio-haptic interface techniques to allow nonvisual access to touchscreen appliances," Trace R&D, 2010.

[51] L. B. Merabet and J. Sánchez, "Development of an audio-haptic virtual interface for navigation of large-scale environments for people who are blind," *Univers. Access Human-Computer Interact. Appl.*, vol. 9739, no. June, pp. 595–606, 2016.

[52] C. M. Baker, L. R. Milne, R. Drapeau, J. Scofield, C. L. Bennett, and R. E. Ladner, "Tactile Graphics with a Voice," *ACM Trans. Access. Comput.*, vol. 3, no. 8, pp. 1–21, 2016.

[53] C. Xu, A. Israr, I. Poupyrev, O. Bau, and C. Harrison, "Tactile display for the visually impaired using TeslaTouch," *Proc. 2011 Annu. Conf. Ext. Abstr. Hum. factors Comput. Syst. - CHI EA '11*, p. 317, 2011.

[54] J. Mankoff, H. Fait, and T. Tran, "Is Your Web Page Accessible ? A Comparative Study of Methods for Assessing Web Page Accessibility for the Blind," *Chi 2005*, pp. 41–50, 2005.

[55] W. Yu, R. Kuber, E. Murphy, P. Strain, and G. McAllister, "A novel multimodal interface for improving visually impaired people's web accessibility," *Virtual Real.*, vol. 9, no. 2–3, pp. 133–148, Dec. 2005.

[56] H. Francis, D. Al-Jumeily, and T. O. Lund, "A Framework to Support E-Commerce Development for People with Visual Impairment," *2013 Sixth Int. Conf. Dev. eSystems Eng.*, pp. 335–341, 2013.

[57] S. Swaminathan, T. Roumen, R. Kovacs, D. Stangl, S. Mueller, and P. Baudisch, "Linespace: A Sensemaking Platform for the Blind," in *Proceedings of the 2016 CHI Conference on Human Factors in*

Computing Systems - CHI '16, 2016, pp. 2175–2185.

[58] G. Hamilton-Fletcher, M. Obrist, P. Watten, M. Mengucci, and J. Ward, "'I Always Wanted to See the Night Sky,'" in *Conference on Human Factors in Computing Systems - CHI '16*, 2016, pp. 2162–2174.

[59] W. Heuten, N. Henze, S. Boll, and M. Pielot, "Tactile Wayfinder : A Non-Visual Support System for Wayfinding," in *Nordic CHI*, 2008, pp. 18–22.

[60] B. Poppinga, "TouchOver Map : Audio-Tactile Exploration of Interactive Maps," in *Mobile HUman Computer Interaction 2011*, 2011, pp. 545–550.

[61] R. Kuber, W. Yu, and G. McAllister, "Towards developing assistive haptic feedback for visually impaired internet users," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. - CHI '07*, p. 1525, 2007.

[62] H. Nishino *et al.*, "A Touch Screen Interface Design with Tactile Feedback," in *International Conference on Complex, Intelligent, and Software Intensive Systems*, 2011, pp. 53–60.

[63] Y.-M. Park and K.-J. Kim, "The dynamic modeling and design improvement of a piezoelectric exciter of a touch screen device for efficient tactile feedback," *Smart Mater. Struct.*, vol. 20, no. 5, p. 55008, May 2011.

[64] B. Caldwell, M. Cooper, L. G. Reid, and G. Vanderheiden, "Web Content Accessibility Guidelines (WCAG) 2.0," 2008.

[65] J. Sarraipa, S. Baldiris, R. Fabregat, and R. Jardim-Goncalves, "Knowledge Representation in Support of Adaptable eLearning Services for All," *Procedia Comput. Sci.*, vol. 14, no. Dsai, pp. 391–402, 2012.

[66] G. C. Vanderheiden and K. R. Vanderheiden, "Accessible Design of Consumer Products: Guidelines for the design of consumer products to increase their Accessibility to people with Disabilities or who are aging," 1991.

[67] J. Abascal, M. Arrue, and I. Fajardo, "The use of guidelines to automatically verify Web accessibility," *Univers. Access Inf. Soc.*, vol. 3, no. 1, pp. 71–79, 2004.

[68] M. Cooper, A. Kirkpatrick, and J. O. Connor, "Techniques for WCAG 2.0," 2015.

[69] C. Thoren, *Nordic guidelines for computer accessibility*. Nordic Cooperation on Disability, 1998.

[70] J. Gulliksen and S. Harker, "The software accessibility of human computer interfaces – ISO technical Specification 16071," *Univers. Access Inf. Soc.*, vol. 3, no. 1, pp. 6–16, 2004.

[71] J. Gulliksen, S. Harker, and J. Steger, "The ISO approach to the development of ergonomics standards for accessibility," *Incl. Des. Guidel. HCI, Taylor Fr. London*, 2001.

[72] Braille Authority of North America (BANA), "Guidelines and Standards for Tactile Graphics , 2010," 2010.

[73] A. B. Pather, "The Innovative Use of Vector-based Tactile Graphics Design Software to Auto ...: Discov ... Page 1 of 9 The Innovative Use of Vector-based Tactile Graphics Design Software to Automate the Production of Raised-line Tactile Graphics in Accordance with BANA," *J. Blind. Innov. Res.*, vol. 4, no. 1, pp. 1–9, 2014.

[74] A. Stangl, J. Kim, and T. Yeh, "Technology to support emergent literacy skills in young children with visual impairments," in *Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems - CHI EA '14*, 2014, pp. 1249–1254.

[75] M. Mech, K. Kwatra, S. Das, P. Chanana, R. Paul, and M.Balakrishnan, "Edutactile – A tool for Rapid Generation of Accurate Guideline-Compliant Tactile Graphics for Science and Mathematics," *Comput. Help. People with Spec. Needs, Springer*, vol. 8548, pp. 34–41, 2014.

[76] I. 9241-171:2008, "Ergonomics of human-system interaction -- Part 171: Guidance on software accessibility," 2006.

[77] D. W. Fourney and J. A. Carter, "Ergonomic accessibility standards," in *Proceedings of the 16th World Congress on Ergonomics*, 2006.

[78] J. B. F. Van Erp, J. Carter, and I. Andrew, "ISO' s Work on Tactile and Haptic Interaction Guidelines," in *Haptics: Perception, Devices and Scenarios*, 2008, pp. 936–940.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[79] Usability Partners, "ISO standards Standards in usability and user-centred design," vol. 25010, no. 2011, pp. 1–6, 2015.

[80] D. Fischer, "Best practices for accessible diagram design," 2015. [Online]. Available: http://www.incobs.de/articles/items/diagram-a11y.html.