Guidelines for Visual and Auditory Presentation for Users Suffering from Vestibular Disorders

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1. Introduction and Overview

1.1 What is a Vestibular Disorder?

The vestibular system is one of the lesser-known systems of the human body, handling the sensing of motion. This includes self-motion, the position of one's head (sense of balance), the orientation of the body and handling of eye movement (Fitzpatrick 315). The system exists within the inner-ear, with different components within the system reacting to different forms of motions, such as turning one's head and rotating it in different directions.

A vestibular disorder can occur when a signal that the vestibular system sends to the brain does not correlate with other signals the brain receives, such as what the eyes are viewing. It can be caused by a physical injury that impacts one of these sensory systems, a disease, or can occur or be worsened by genetic or environmental conditions (Vestibular Disorders Association). There are varying types of vestibular disorders, the most common type being Benign Paroxysmal Positional Vertigo (meaning temporary reoccurrences of vertigo caused by certain head positions) (Vestibular Disorders Association) There are also other types, such as Labyrinthitis (an infection that causes inflammation of the inner ear) and Ménière's Disease (overabundance of a fluid that is normally present in the inner ear). However, potential symptoms shared between the varying disorders are all the same. These can include vertigo, motion sickness, dizziness, difficulties with balance, difficulties with vision control and temporary hearing loss/impact (Vestibular Disorders Association).

1.2 Background Statistics

In the United States alone, there are more than 69 million people (~35%) over the age of 40 who have experienced some form of vestibular impairment at some point in their life, with that number increasing to 80% in people over the age of 65 (Vestibular Disorders Association). The National Institute on Deafness and Other Communication Disorders says that 4% (8 million) of American adults experience chronic balance issues, while an additional 1.1% (2.4 million) experience chronic dizziness (Vestibular Disorders Association). In total, approximately one-third of all documented cases of vertigo and dizziness stem from being a vestibular problem (Vestibular Disorders Association).

Within Canada, up to 35% of the population over the age of 40 (approximately 6 million people) have suffered from a vestibular disorder at some point in their life (BC Balance and Dizziness). According to the BC Balance and Dizziness Disorders Society, one in three British Columbians over the age of 65 fall every year due to a balance issue, further noting that injuries from falling cost the Canadian economy approximately $2.8 billion per year (BC Balance and Dizziness).

1.3 Why should a system support accessibility options for these users?

While there exists a number of accessibility tools that people who have vestibular disorders can utilize, but they are all quite limited in that none of them provide all of the functionality that a user who suffers from the symptoms of these disorders requires. Additionally, as some of the symptoms are temporary and come and go, it is an inconvenience for the user to have their system installed with multiple tools, requiring them to open and close them when needed instead of having all of the accessibility options they require available in one convenient platform. Furthermore, given the statistics above, the issue has a high enough prevalence that it is an issue that should not be ignored by developers.

N.B.: ISO/CD 9241-394 “Ergonomics of human-system interaction — — Part 394: Ergonomic requirements for reducing undesirable biomedical effects of visually induced motion sickness during watching electronic images” (as of February 26th, 2018) addresses some issues regarding visually-induced motion sickness (directly related to vestibular disorder), but provides a short list of guidelines on how to address the issue, focusing primarily on image rotation (pitch, yaw and roll).

1.4 Difficulties to Acknowledge

This document seeks to expand on the work done by those involved in creating ISO/CD 9241-394 by expanding on guidelines for a developer to follow based on results found from conducted studies within the medical field, as well as attestations from personal user experiences and observations. While research into vestibular disorders has been conducted in the past, the details given in the published results appear to be severely limited in scope, focusing much on statistics and not disclosing empirical data. There does not appear to be many published journals or scholarly articles that contain data on any specific triggers that induce or exacerbate symptoms in a person who suffers from a vestibular disorder, instead noting common triggers, such as from visual stimuli. Conclusions will be drawn by comparing the common triggers discussed with personal user experiences, which shall be utilized in developing a new set of guidelines tailored towards this disorder.

2. Definitions and Abbreviations

2.1
Visually-induced motion sickness (VIMS)
“motion sickness-like symptoms induced by perceived motion within the visual environment, such as when watching movies and screen images of video games
NOTE to entry: The symptoms may include dizziness, vertigo, sweating, odd feelings in the stomach, and nausea which may progress to vomiting” (ISO CD 9241-394 1)

2.2
Dizziness
“a sensation of spinning around and losing one's balance” (Lexico)

2.3
vertigo
“sensation of rotation or movement of one’s self (subjective vertigo), or of rotation or movement of one’s surroundings (objective vertigo), in any plane, caused by diseases of the inner ear, or by disturbances of the vestibular centers or pathways in the central nervous system” [ISO CD 9241-394]

2.4
Labyrinthitis
An infection of the inner ear causing inflammation, resulting in symptoms such as vertigo and dizziness (Fitzpatrick).

2.5
Ménière's Disease
A disorder of the inner ear, characterized by recurring vertigo as well as hearing loss and tinnitus (Fitzpatrick).

2.6
Tinnitus
A sound in one's head with no external source, commonly heard as ringing or buzzing. It is typically a result of damage to the inner ear or due to an infection or disorder (Fitzpatrick).

2.7
Parallax
A visual effect where two or more layers scroll at different speeds (from a bottom-up being slower-faster) to simulate the illusion of depth (Frederick).

2.8
Nystagmus
A condition where a person's eyes make uncontrollable movement (Maslovara).

2.9
Tullio's phenomenon
dizziness resulting from loud sounds (Fitzpatrick).

2.10
Hennebert's sign:
dizziness resulting from pressure changes (Fitzpatrick).

3. An Overview of Existing Accessibility Tools

3.1 Windows 10 built-in Accessibility Tools

Windows 10 offers a wide range of accessibility customization options for users to tweak their work environment to one that better fits their needs. However, many of these options provided are very rigid in nature, and do not offer all of the options that a user suffering from a vestibular disorder may need.

3.11 Display Settings

Make Everything Bigger: This is an option that allows a user to scale the size of text and some in-app icons. The user is given a slider that they can drag to scale up and down a piece of sample text that shows what the size change will be.

ISSUE: • A user with a vestibular disorder may not need to scale everything on the screen, perhaps only wanting the changes to take effect on certain applications.

- Button sizes for operating system icons (i.e. open applications on the taskbar) do not change in size with this scaling. If a user is experiencing nystagmus or has taken calcium beta blockers, this can impact their motor skills and making clicking targets difficult if they are unable to adjust their size.

Make Everything Brighter: This option allows a user to adjust the brightness of their display. The user is given a slider that they can drag up and down between integers 0% and 100% to make the screen dimmer or brighter.

ISSUE: • A user may not wish to increase or decrease brightness for their entire display, instead only wishing to adjust brightness within an application that triggers their vertigo.

Show Animations in Windows: This is a simple toggle option to turn on or off animation effects within the Windows environment.

ISSUE: • A user may not want to turn off all animations within Windows if they are experiencing issues with their vestibular disorder, instead only wanting to shut off some (for example, zoom effects when minimizing an open window).
- This will only take effect on animations that are a part of the Windows environment. This will not have any effect on applications that utilize their own animations nor within web pages that have animations.

3.12 Magnifier

This option allows a user to zoom in on parts of a screen, selecting from three view options: docked (has a zoom view that is docked on one side of the screen), lens view (appears over the mouse for a window size that the user can customize) and full screen. The user can select for the magnifier to focus on the mouse cursor, text insertion point, etc..

ISSUE: • Since the view will follow the selected focus point(s) the user chooses, it is likely that it will trigger motion sickness, as the effect of the view jumping around is increased at higher magnification levels.

3.13 High Contrast

This option allows a user to select between different high contrast themes and color options for different elements.

ISSUE: • While this option is nearly perfect for a user with a vestibular disorder that may want to customize options to improve their ease of viewing the screen without triggering any of their symptoms, it applies the theme to the entire screen instead of being able to control it on an app by app basis.

3.14 Narrator

The Windows 10 Narrator tool has plenty of settings to assist a person who has a disability. It allows a user to customize voice speed, voice pitch, volume of voice, as well as gives a list of voices to choose from. It gives the user the option for the narrator to highlight the current block of text being read. It also allows the user to choose the degree of details that the narrator gives (text-only, extended formatting, layout and animation info, etc.). The narrator can follow a line of text that the mouse is currently hovering over. Additionally, it can recite to the user the current characters being typed on the keyboard (although this is likely not a feature that would be used by many users who suffer from a vestibular disorder).

ISSUE: • The narrator tool is extremely-well designed, but falls short on some customization options. Namely, the tool even at its lowest details setting (text-only) will want to read plenty of things on the screen that a user may not wish to hear (such as reciting out a long url when the view is changed to a webpage). If a user with a vestibular disorder is experiencing an episode of vertigo, not all of the information present on the screen may be of use to them. Furthermore, they may only require it within a certain program and not for it to narrate what is currently in the view.

3.2 eSSENTIAL Accessibility

eSSENTIAL Accessibility is a multi-tool accessibility program available for Windows and Mac devices. The interface is mounted to the top portion of the screen and contains enable/disable buttons for several features, such as a narrator that will read a block of text that is underneath the mouse pointer, should the mouse pointer stop and remain over it for one second. Apart from this, it includes the same functionality as other text-to-speech programs, such as JAWS and the Windows 10 narrator, allowing the user to adjust different options such as read-back speed, volume and voice selection.

There are a number of other features included within eSSENTIAL Accessibility, such as on-screen keyboards and speech recognition, but none of these features are applicable to the topic at hand.

3.3 Summary

While there exist many accessibility tools and plugins a user with a disability can use in their system, there are very few that are applicable to those who suffer from vestibular disorders. There are those mentioned above that a user with a vestibular disorder can use if their symptoms are impacting their ability to view the screen and instead decide to use a screen reader to read out what is on screen, but apart from this, there are not many options available that address other visual symptoms. As discussed above, Windows does offer some built-in accessibility features, but they are rigidly constructed in some ways, limiting the user's available options for customization to suit their current needs.

4.1 Visual-related Data

4.1.1 Parallax Scrolling

On September 24th, 2013, Apple launched the iOS7 operating system for compatible iPod, iPad and iPhone devices. One major visual upgrade present in this update was the inclusion of parallax scrolling, which would shift around the background and icons present on the screen based on the movement of the device, creating an illusion of 3d depth.

Within a few days, several online news outlets and communities began commenting on motion sickness that users who interacted with these new visual features were experiencing. Online community "iMore" conducted a poll, which (data as of November 13th, 2019) found that 2341 of 7907 voters experienced some form of motion sickness while interacting with the system (Ritchie). This means that almost 1/3 of users who interact with this system experienced motion sickness.

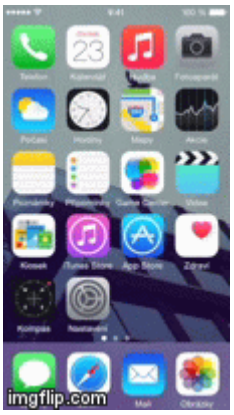

Figure 1. Demonstration of Parallax Effect on iOS7
https://imgflip.com/gif/3g6jke (follow link to view animation)
Image created from YouTube demonstration video:
https://www.youtube.com/watch?v=KGKegMgRNRY

From this data, it can be deduced that users who suffer from a vestibular disorder would see a major impact of usage of the system. Therefore, it would be beneficial for users to offer them a way to taper the effect of the parallax scroll, up to and including to the point of turning it off. Furthermore, it is not necessary for a developer to include parallax effects, as a study done by Purdue University found that while the effect was classified as being "fun", it did not necessarily improve the overall experience for the user (Frederick 48).

4.1.2 Animations

A study conducted by Shin C. Beh and others on symptoms and triggers of a vestibular migraine found that of 131 patients, over one third of them suffered from visually-induced vertigo occurring via trigger (730). For spontaneous vertigo, a large portion of patients described the sensation as "spinning", "rocking", "tilting", "swaying", and "falling" (730). Additionally, in an article regarding animations in iOS7 within the UK newspaper "The Guardian", a mobile app developer commented on it, saying:

> *"I now have to close my eyes or cover the screen during transitions, which is ridiculous. It's not apps that affect me, but accessing them. Tap a folder and the view zooms in. Tap an app and it's like flying through the icon and landing in that app's micro world — and I'm getting dizzy on the journey there."* (Grannel)

From this evidence, it can be concluded that these animation effects would not make the user environment a positive one for the user. The user might wish to lower the intensity or disable these animation effects altogether. The only thing that can not be said with certainty from this is if symptoms would not be worsened if the effect did not cover the entire screen (i.e. the zoom transitions) or were used sparingly.

4.1.3 Element Rotation

For on-screen elements that have rotation properties (spinning, tilting), these have the chance of effecting a user's vestibular disorder, either by trigger or by further aggravating a sensation for spontaneous vertigo. According to ISO 9241-394, faster rotations are more likely to increase chance of motion sickness (7).

4.1.4 Element Movement

As discussed in 4.1.2, one of the sensations that a person experiencing spontaneous vertigo can feel is the sense of swaying or falling. This sensation could be invoked if a user has to scroll through contents on a page that has a static fixed background. The result would be text and other elements moving across the screen while the background image stays still, giving the illusion that the user is "falling" past the images and lines of words.

4.1.5 Brightness & Luminosity

In Beh's study mentioned above, 35 of the 131 patients (~27%) experienced symptoms of their vestibular disorder by the presence of bright lights (732), which they documented as being the second-most common trigger (727). This means that a user who has a vestibular disorder is more than likely to experience their symptoms while using a system that has bright backgrounds or imagery.

In a personal anecdote from a developer who suffered from a temporary vestibular disorder, they found their symptoms were triggered by light (Corradini). They were able to lessen the impact by enabling dark mode in their coding environment (Corradini). Therefore, the user benefit from being able to customize their system to adjust the brightness/luminosity of any elements present.

4.1.6 High-Contrast Backgrounds & Elements

The user may wish to adjust the contrast of background or different screen elements to help make them stand out from others (Corradini). This would allow them control over having elements such as lines of text standing out from a background.

4.1.7 Element Size

If a user with a vestibular disorder suffers from nystagmus, this can make viewing elements that are too small prove to be extremely difficult. (Mehlenbacher 723). Furthermore, if elements are too cramped together, this can negatively impact the user's ability to fixate on a specific element or part. In addition to this, the developer mentioned in 4.1.5 suggests in order to decrease the likelihood of experiencing symptoms, measure be made such as keeping line spacing to be at a minimum of 1.5, spacing between paragraphs to be at least 2 lines, and to ensure that fonts have enough weight to them (Corradini).

4.1.8 Shapes & Patterns

A user with nystagmus may experience triggered vertigo if they are required to interact with a system that has elaborate patterns (i.e. diagonal stripes) or tapered lines (Mehlenbacher 723). Corradini comments that any degree of horizontal slants did not appear to exacerbate any of his symptoms, nor did hard vertical slants. However, looking at a subtle vertical slant (where it is almost perfectly straight but just barely off) was enough to instantly trigger symptoms of vertigo (Corradini).

4.1.9 Element Alt-Text

Some users who suffer from vestibular disorders may have their symptoms at such a point that most, if not all, visual feedback exacerbates their symptoms (for example, spontaneous vertigo, resulting in their inability to use the system). It would be very effective in improving usability to offer the user the ability to use a screen reader to complete their work when they are unable to maintain a fixed gaze on their screen.

4.2 Audio-related Data

4.2.1 Volume

In the study by Beh that was previously discussed, it was reported that 16 of the 137 patients (~12%) experienced vertigo that was triggered by being present in a noisy environment. This is further confirmed by other medical documents where patients were reported to have been experiencing vertigo as a result of loud sounds (Mehlenbacher 723). This is something referred to as Tullio's phenomenon, which can point to a vestibular disorder such as Meniere's disease. Therefore, it would be beneficial to the user for there to be a way that no sound produced through speakers (built-in or external), headphones, etc. can exceed a determined decibel level.

4.2.2 Patterns

It is well known from previous examinations performed on patients with vestibular disorders that changes in pressure (i.e. altitude level, being in motion such as a vehicle, etc.) can negatively impact the person and activate or further aggravate their symptoms (Mehlenbacher 723) (Maslovara 1685). This is another well-known sign of Meniere's disease, referred to as Hennebert's Sign. Since this occurs as a result of pressure changes, it could be deduced that if a sound presented to the user follows a wave pattern that simulates a pulsating movement that this could also result the user experiencing symptoms related to their vestibular disorder.

4.2.3 Frequency

In a case study regarding a 26-year-old patient experiencing vertigo due to being exposed to explosions from being in the military, it was documented that some low-pitched noises resulted in episodes of vertigo (Mehlenbacher 723). The author of this guidelines document can further confirm from his own experiences that low-pitched noises are likely to induce vertigo, at least within patients who suffer from Meniere's disease, as his own mother tells him that when she's in a moment of beginning to experience vertigo that the sound of his deep voice "causes [her] head to spin".

4.2.4 Sound Usage

Since it is documented in several medical journals that forms of sound can act as a trigger for a person's vestibular disorder, it would likely be best for a developer to use sounds in their system as sparingly as possible, in order to make the system more accessible to users with this disability.

4.2.5 Alternative Form of Presentation

Some people who suffer from vestibular disorders experience tinnitus or varying degrees of temporary hearing loss. If any sounds in a system that are presented to the user require a form of acknowledgement or an action be performed, and this is not noticeable by the user, the system becomes less accessible to the user.

Design

The following guidelines were created by utilizing the evidence and discussion points given in the analysis above. As information available to investigate in the analysis for some parts was limited in its scope and was for the most part limited to the field of medicine, conclusions had to be drawn and extrapolated for some cases in order to create guidelines that were applicable within the realm of accessible computing. All guidelines written have their title and section number match those provided in the analysis for easy cross-reference.

1. Scope

These guidelines aim to provide guidance for a developer in making their system more accessible and useable for users that suffer from a wide range of symptoms caused by a vestibular disorder. Additionally, these guidelines could be utilized to create a simple program with all of these functionalities in it that can limit what the user is exposed to with a click of a button.

2. Definitions

2.1

Parallax

A visual effect where two or more layers scroll at different speeds (from a bottom-up being slower-faster) to simulate the illusion of depth (Frederick).

2.2

Alt-text

An HTML attribute tied to an image that can describe the contents of the image. This is readable by a screen reader (Tech Target)

3.1 Visual Guidelines

3.1.1 Parallax Scrolling

a) The system shall offer the user a simplistic way to disable any parallax effect
b) If parallax effects are present in the system, the system shall provide an info box or disclaimer during first time usage and offer the user the option to disable these effects outright
c) Parallax effects should not be a major/prominent feature within a system.
d) The user should be able to adjust the intensity of a parallax scroll should they wish for it to be present but to adjust it to a level that they are able to tolerate.

3.1.2 Animations

a) The system shall provide the user with a way to disable animations (zoom effect when opening tabs/windows, non-static images, etc.).
b) The system should avoid using animations (animated images/icons, etc.) that cover a large portion (>33% || exist for a long period of time/indefinitely) of the view or zoom effects/screen washes that cover the entirety of the screen

Example: An animation that would be considered NOT acceptable would be something like a website banner that covers the entire horizontal or vertical distance/view of the webpage and contains motion, flashes, blinks, strobe effects, etc.

c) If animations exist that do not fit within the criteria of 3.1.2b, the developer shall give a notification to the user that warns them they could experience motion sickness when using their system.

3.1.3 Element Rotation

a) The system shall provide the user with a way of disabling these rotation animations.
b) The system should not have element rotations be a prominent or main visual feature of the system.
c) The system should avoid using screen elements that have rotation properties (spinning, tilting), unless it can be argued from a visual design standpoint to benefit the user experience.

3.1.4 Element Movement

The system shall avoid presenting a user with elements that are scrollable (i.e. text) that is placed over a stationary image that does not move with the text, due to the possibility of inducing vertigo by having a motionless sensation (the image) combined with one that does move (the text)

3.1.5 Brightness & Luminosity

If the system has backgrounds or screen elements that are overly bright or illuminant:

a) The user shall be provided with a way of lowering the brightness within that specific environment that is causing them difficulties.
b) The system should avoid having backgrounds or screen elements that are overly bright or illuminant.

Example: If bright backgrounds/screen elements are present, the system should offer the user a dark theme.

3.1.6 High-Contrast Backgrounds & Elements

The system should provide the user with a way of adjusting the contrast of background and other screen elements separate from each other in order to increase or decrease the contrast level to one suitable for them to view.

Example: An option within an application could be offered for a low-contrast mode, desaturation mode or monochrome mode.

3.1.7 Element Size

a) The system shall avoid having elements that are too small or require the user to squint/give extreme focus in order to perceive it properly.
b) The system should provide the user with the functionality to increase element size (such as target size for a radio button) or be able to scale font size easily to make it easier to view.

3.1.8 Shapes & Patterns

The system shall avoid designs that use vertical lines that are not a perfect 90° from the horizontal or any form of patterned lines, regardless of line weight.

3.1.9 Element Alt-Text

All non-text elements (images, graphs, etc.) presented by the system should have alt-text available for a screen reader.

3.2 Auditory Guidelines

3.2.1 Volume

In regards to the volume of any audio that the system presents to the user:

a) The system shall provide the user with a way of adjusting audio level between different applications
b) The system shall allow the user to set a maximum peak decibel level for audio playback that is allowed, in which all audio levels will be normalized such that it does not peak.

3.2.2 Patterns

The system shall avoid having sound effects that have a pulsating pattern.

3.2.3 Frequency

The system shall avoid having sounds effects that produce low-pitched frequencies or jingles that are deep in tone.

3.2.4 Sound Usage

In regards to the use of sound effects within a system:

a) The system shall provide a way for the user to mute sounds on an app by app basis.
b) A developer should ensure that a system uses sound effects sparingly, so they do not exacerbate a user's symptoms

3.2.5 Alternative Form of Presentation

a) Any sounds that are to represent imperative messages/notifications given to the user that require acknowledgement for a continued positive usage of the system shall be conveyable through an alternative form, such as a pop-up notification.
   NOTE: In providing an alternative form, it shall not conflict with any of the aforementioned visual guidelines.
b) Any other sounds that are to be presented to the user should be conveyable in the same way as described above.

4. Conclusion

These guidelines given provide an excellent starting point for a developer to make their system more accessible to a user who suffers from a vestibular disorder. Far more research is needed into many of the concepts and data that were analyzed within this document to attain a more precise understanding of the different visual and auditory stimuli that can trigger symptoms of a user's vestibular disorder.

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