Designing Assistive Haptic Feedback For Visually Impaired Internet Users Using A Scenario-Based Approach

Ravi Kuber, Wai Yu & Graham McAllister
Queen’s University Belfast
r.kuber@qub.ac.uk

Abstract
As haptic technologies develop and devices reduce in cost, designers are beginning to realise the benefits associated with incorporating the sense of touch into web pages. Due to the limited availability of assistive haptic interface design guidelines, designers may arbitrarily select sensations for use on the Web, which may not convey an underlying sense of meaning to the user. The study proposes a five-stage approach, to aid the development of assistive haptic feedback through the use of scenarios. The scenario used in this study, is based upon the task analysis of a visually impaired screen reader user observed whilst interacting with the Internet. Scenario-based techniques are new to the context of haptic interface design and are utilised as a tool for inspiring and evaluating design ideas for assistive feedback. Through a series of iterations, conceptual ideas have been developed into concrete-style prototypes, which once at a sufficient standard, could be used to provide vital guidance for web designers when designing with assistive haptic feedback. Preliminary findings from the study are reported and the design approach taken is evaluated.

1. Introduction
With the growing focus on user-centred interface design promoted by human-computer interaction researchers and practitioners, it is perhaps ironic that the needs of visually impaired Internet users are often overlooked. Non-visual browsing solutions have been developed in order to open-up access to page content, through the use of assistive speech and audio [11, 2]. In contrast, haptic technologies have been relatively underused within this context. This is rather surprising as the sense of touch has been shown to provide benefit to GUI design allowing icons, menus and controls to be tactually perceived [7, 9]. Haptic technologies can be also used to aid navigation and assist in visualisation of complex information, providing an engaging environment for the user. With the wide availability of low-cost force-feedback devices, complete with user-friendly software development kits, and the benefits which the sense of touch can bring to GUI exploration, web designers are beginning to realise the advantages associated with using haptics to produce an inclusive solution for browsing.

Web accessibility guidelines such as the WCAG 1.0 provide valuable design advice, but do not currently extend to the use of haptic feedback. Similarly, haptic design guidelines do not provide the focused assistance necessary for use on the Web. As a result, designers may select and map arbitrary haptic sensations to represent elements on web pages. Design choice may be based on personal preference or ad hoc choice [8], influenced from the limited range of effects offered by current technologies. Poorly designed or inappropriate sensations may not convey an underlying sense of meaning to the user. Each sensation would need to be explicitly learned, requiring time and effort to be invested. Due to the lack of conformity, the same sensations could be used to represent more than one element. Mappings could vary from site-to-site, which could also cause confusion for the user. A framework containing a library of assistive haptic sensations would be able to act as a vital referencing tool, allowing developers to replicate sensations on their own pages. It would help to promote standardisation, and would act as a tool to support developers in both the design and evaluation process.

2. Multimodal Icons & Assistive Icon Design
Icons are common to graphical user interfaces (GUIs), providing a memorable and recognisable representation of objects, words or concepts. They often rely on the use of visual metaphors to reference programs and data structures, which are of little benefit to visually impaired users [3]. Non-visual icons can prove to be advantageous when the field of view is restricted or blocked. In the haptic channel, hapticons (haptic icons) and tactons (tactile icons) have been developed to convey abstract messages, designed to assist the user in a variety of tasks. However, abstract icons which have less obvious connections with the real world can be more difficult to interpret than concrete-style icons, where inferences about function can easily be made [6]. McDougall & Curry [6] have discussed the importance that cognitive characteristics play within icon interpretation, particularly when users have little experience of those icons. Benefit is thought to be gained by depicting the real world concept which the sensation is aiming to represent, reducing the gap between icon and the function it is intending to signify, and using the concept of metaphor. However, representing semantic information through the haptic channel is a difficult process, compounded by device and perceptual constraints. Designing assistive haptic icons which aim to provide a sense of meaning would add benefit to GUI exploration for visually impaired users, particularly on web pages where barriers to access are currently experienced.
3. Study Objectives

Research aims to extend the boundaries of haptic icon design, examining in detail the development of symbolic assistive haptic feedback for a web interface, rather than solely relying on abstract representations dictated by haptic designers. Sensations should suitably correspond with the element being represented, allowing the user to understand the meaning associated with each stimulus. Feedback will be designed to provide spatial awareness of page elements, to assist in the navigational process, and to aid the user to gain an overview of page contents, as identified by [10]. Research aims to culminate in a library of assistive signs that designers can refer to when developing a web page.

4. Approach Selected

A five-step approach has been taken with a view to develop assistive haptic feedback for use on web pages, adapted from a framework proposed by Lim & Sato [4] who evaluated the usability of a PDA device:

1. Observation of visually impaired screen reader user performing web task;
2. Task analysis to decompose into sub-tasks and clarify areas for improvement;
3. Construct the scenario based upon previous stages and present to a user group to inspire design ideas;
4. Develop low-fidelity prototypes from findings, and present these to new group for further evaluation;
5. Evaluate and refine feedback with user group, until prototypes reach a sufficient standard.

A visually-impaired participant was observed performing a web search task undertaken, using her preferred screen reader and search engine via her own PC. She was encouraged to “think aloud”, verbalising her actions and thoughts during this process. In order to analyse the observation footage, a hierarchical task analysis (HTA) was conducted in order to assess the challenges faced when performing the task, and to investigate how further assistance could benefit a screen reader user when exploring a page.

Scenario-based design techniques are commonly used for purposes of developing software requirements or evaluating products [1], but are relatively new to the context of haptic interface design. Pirhonen et al. [8] have proposed a semiotic approach to designing non-speech feedback for an auditory interface, taking into account the unique qualities of sounds as a method of conveying information. The design method is based on the assumption that feedback is highly dependent on the context of use. Therefore an understanding should be developed of the environmental (physical, social and psychological) context. The researchers have designed a ‘rich use scenario’ in order to inspire design ideas from a panel of users. In the current study, it was envisaged by developing a scenario based on recommendations from [1, 8] with a main character that a user group could identify with, creative design ideas could be triggered. Qualities of the sense of touch could be taken into account for purposes of conveying information to the user. Consideration would need to be given to the fact that sensations would need to communicate the same information to the user, even if feedback representing different types of elements was also present on a page. Suggestions made could then be evaluated and developed by additional user groups. The scenario itself would be based upon the findings of the observation and task analysis stage, addressing areas where additional feedback would be useful. A participatory approach would be employed to enable visually impaired screen reader users to work together with haptic interface designers, to afford both perspectives which were thought to be vital in the assistive feedback design process.

The scenario was designed to reflect the experience of a congenitally blind student, Aidan – *actor or agent*, who explored the Web using a multimodal browser with a haptic input/output device from his home - *setting*. The *plot* revolved around the actor whose goal was to perform a web search on an audio book title. The haptic device could be customised to provide spatial awareness of elements on a page produce a general overview of page complexity, and if desired, necessary to gain assistive guidance.

The researcher read out the scenario to each user group with up to four participants, asking them to consider how haptics could be designed to represent elements on a page (e.g. images or hyperlinks), and how haptic technologies could assist navigation through a page or convey an overview of contents. The researcher then asked the user groups to discuss design ideas relating to each page element and browsing concept, in turn. Participants were asked to think about the purpose that elements serve on a page, and how users currently interact with them. They were asked to consider the use of metaphor and affordance, in order to suggest design ideas to provide assistance. Creative ideas based on real world sensations or different forms of feedback perceived haptic devices could also be discussed. In each session, writing equipment and objects of various textures (props) were provided. This would allow participants to create examples of any design feedback that they thought were pertinent, and provide a method of externalising sensations which they found difficult to describe. In order to facilitate discussion in the session, participants had earlier been introduced to twelve pairs of haptic feedback primitives, which they could perceive through the Logitech Wingman force-feedback mouse.
Effects included friction, damping, slope, spring, wave and various forces. Participants were asked to describe each pair of sensations, and were questioned on whether they could differentiate between stimuli. This pre-task would allow each user group member to build-up a vocabulary of adjectives related to the sense of touch, which could be used in later discussion. The first user group session would serve as a method for discussing the role that haptics could play within the browser, and members could brainstorm design ideas that could be developed into low-fidelity prototypes for the second session. For the second user group, new participants would be able to provide feedback on these prototypes, either building-upon the previous group’s design suggestions, or alternatively discussing new ideas which could then be mocked-up for further user group sessions. It was thought that an iterative process would encourage the design of feedback appropriate for use, within the context of an assistive web page.

5. Results & Discussion

5.1 Hierarchical Task Analysis Based On Observation

The task analysis stage based on initial observation of a visually impaired user proved to be instrumental in identifying areas where additional assistive feedback could be directed. The participant initially spent time locating the search box on the page. She was observed using a keystroke to move forward to the next page element, to isolate her current page position. She appeared to have memorised the auditory sequence order of page elements on the Google search page. She knew that if she could move one element back in the sequence order, she would hear the term “Google Search Edit”. She could then enter the “forms mode” and successfully input information into the search box. Providing additional awareness of cursor position and element location was thought to provide benefit to the visually impaired user, as screen readers do not convey information regarding spatial layout. Additional feedback could potentially help to reduce the memory burden associated with remembering the sequence order of elements.

Once the search results page loaded, the participant was observed gaining an overview of contents. To do this, she listened carefully to the screen reader, where she perceived the new page opening, the page title, number of hyperlinks and headings. Listening to this information would not only help her to verify that she was on the correct page, but also provide her with an overview of how much information was contained therein. Summaries were often cut short using the Control key, as it took a long time to listen to all the elements contained on the page, particularly if there were different levels of headings, and nested lists present. A shorter, more effective form of gaining an overview could possibly provide more assistance when opening a page.

The participant moved quickly through sponsored links and adverts, to avoid listening to the associated speech feedback. She then moved through the results (links) using the Tab key to gain an overview of the page, trying to isolate information for the music technology course which she was searching for. Unfortunately, as hyperlinks were poorly labelled, the participant was required to use other keystrokes to read the summary text associated with each hit. Considerable time and effort was taken moving through each of the hits and corresponding summaries on just one search page (74 sets of keystrokes), in order to isolate a relevant match. By providing additional assistance to a web page, a visually impaired user could potentially avoid areas which are not of interest, leaving him/her able to access areas which are relevant to the task in hand.

5.2 Scenario: User Group Session 1

The first user group session was conducted with two haptic interface designers, a visually impaired screen reader user, and an audio interface designer. Participants were asked to describe the role that haptics could play within a browser, and then asked to suggest design ideas. Haptics was thought to provide a means to referencing elements contained within a page, providing a “landmark” or an “anchor”, enabling users to develop a mental map of the page contents. It could be used to help users to follow a set path, and assist in attracting a user to a particular area or avoiding it completely. Participants were more reticent about using haptic feedback to produce an overview of a web page, as the visual channel was thought to present an overview more effectively. A haptic interface designer suggested by moving the mouse over haptically-rendered elements on a page, a texture would be presented to a user, which could be used to form an effective overview of contents. Sensations would need to be brief, perceivable and work in conjunction with the other designed stimuli present on a web page. Feedback should be designed that would be intuitive to the user, and that would suit the element or concept to be depicted.

Participants were able to suggest recommendations arising from the use of metaphor. Assistive navigation could be represented using the metaphor of “holding and guiding a child’s hand” to guide the user to a particular part of a web page. Feedback should not be too intrusive by forcing the user to move. Assistance could be overridden, if necessary. Another suggestion of representing navigation by “drawing a line with your finger in sand” also was thought to provide a gentle motion, with the feeling of slight resistance as the user is directed through a path. The gentle, pleasant sensation discussed was found to be a common theme in general discussion.
of design ideas. Maclean [5] states that gratuitous addition of nice-feeling qualities can often enhance the pleasure of interaction, thereby increasing the perceptual experience for a user.

In terms of providing assistance to a user, participants were able to suggest affordances for hyperlinks. As hyperlinks afforded being drawn-to and being selected, it would make more sense to find a method of attracting the user to that point. A magnetic style effect was thought to provide benefit in this instance, which would allow the user to hover over the hyperlink, without the risk of accidentally moving away from the target. The visually impaired participant stated that as a keyboard was her sole input device, she may lack the precise training to make the fine movements needed for mouse use. Advantage could be gained by using attractive feedback, as she would not risk moving away unintentionally from the target area. Further haptic design suggestions are shown in Table 1. Both types of suggestions would be followed-up in successive user group sessions.

5.3 Scenario: User Group Session 2

The second user group consisted of a visually impaired haptic designer, a visually impaired audio designer, a fully sighted audio designer. None had participated in the earlier user group session. Participants were generally able to build-on the suggestions made by the first user group, by explaining how these three elements could be differentiated from one another. Instead of providing an additional sensation to represent each element, they recommended using different types of magnetic effect. For example, hyperlinks could be represented by “providing the sensation of being attracted into the centre of a long thin channel”, buttons by “providing a sensation of being attracted into the centre of a funnel”, and lastly image-hyperlinks by providing the same attractive force as a button, with a texture overlaid. Images could be grouped together with image-hyperlinks, providing the same texture when moving on to the body of both elements. The user could associate this particular texture with image-related items, and would know if he/she encountered an attractive effect, he/she would be exploring an image-hyperlink. This process of grouping was thought to aid recognition. Spring effects shown were generally considered to be too strong by the haptic designer. There was a fear that a user may accidentally overshoot his/her target, unless effects were reduced in intensity.

The group evaluated the feedback used to represent a progress bar. A periodic wave increasing or decreasing in magnitude was thought to be an appropriate and intuitive representation of progress by the two audio designers. The demonstration of this effect appeared to move the device away from its point of origin, which was found by the group to be inappropriate. Further discussion prompted the haptic designer to propose increasing the speed of the effect, rather than manipulating the magnitude. This would enable a visually impaired user to return to his/her machine whilst downloading a large file, and monitor progress through the sense of touch. The proposed suggestion was implemented through Immersion Studio, and then presented to the group for further discussion.

6. Discussion Of Approach Taken

The five-stage approach provided a structured means to return rich, informative design ideas for assistive haptic feedback. The observation of a visually impaired user performing a task in her natural environment was key to confirming the barriers to accessing to the Web using current assistive technologies, rather than relying solely on accounts of past usage. Task analysis of the observation footage enabled task interaction between the participant and the browser with screen reader to be analysed. This allowed the researcher to assess how the user could be best supported when accessing the Web, and whether assistive feedback could help in this process. These factors could be taken into account to better inform scenario task description. Observation from a number of visually impaired users performing a web search could have revealed a more representative picture of issues faced.

The scenario adapted from [1] and the structured semiotic approach discussed by [8], provided a useful means to solicit design ideas for assistive feedback. The user groups were generally able to identify with the visually impaired character in the scenario interacting with haptic feedback, and were able to provide suggestions even if they had limited experienced a screen reader or haptic technologies. Through the course of the session, the first group were able to brainstorm ideas for design, taking into account the unique qualities of touch. They were able to communicate effectively through the simple haptic vocabulary informed by the preliminary task, where participants had been introduced to haptic primitives. Consequently they could use terms such as “resistant, smooth, tough, attractive, textured etc” to convey design ideas.
The second user group session followed a more structured format, with a set amount of time to discuss feedback representing each element or browsing concept. A smaller team of three members was chosen expose each participant to sensations arising from the first user group discussion, and to allow the second group to elaborate on these ideas. Introducing this group to haptic feedback proved to be a difficult process. The researcher needed to interrupt the flow of discussion, to play suggested haptic sensations to each participant and provide assistance to visually impaired users when interacting with the force-feedback mouse. Ideally, all members of the group should be able to experience haptic cues simultaneously, evaluate sensations and provide feedback on each others’ thoughts. The participatory approach was found to be key to the design process, as fully sighted designers in the second user group were able to explain the visual concepts associated with elements such as hyperlinks and buttons to visually impaired participants who were unaware of how these would visually appear on a page, triggering some of the creative design suggestions mentioned in section 5.3. Visually impaired users in turn, could inform haptic designers about assistive feedback that could provide them with benefit when interacting with the Web. As the majority of visually impaired users had previously encountered Braille and tactile graphics, they were more aware of the need for using touch as a means for conveying information.

Gumtau [3] has discussed the importance of using low-tech prototypes to provide a quick method of evaluating feedback. In the current study, props such as cardboard and egg box containers were shown to assist participants with externalising textures which they could not describe. The Immersion Studio application enabled effects to be easily manipulated. When suggestions were made, parameters could be iterated on-the-fly, providing a means for discussion. Further user group sessions would ideally need to be conducted to develop and enhance the design ideas suggested by the first two panels, moving from lower to higher-fidelity prototypes. These iterated sensations could be tested within the context of static HTML pages, or within the multimodal browser proposed by [10]. The aim would be to develop refined and salient symbolic haptic feedback, which can be distinguished from other designed sensations. Consideration should also be given to perceptual and device constraints, issues pertinent to designing for the visually impaired community, and individual differences.

The scenario itself could have produced more appropriate ideas for design by considering the environmental context in greater detail. A concise version of the rich use scenario suggested by [8] was developed, in order to provide more time for group discussion. The first user group suggested that further consideration should be made regarding use of the keyboard within the scenario. A visually impaired user may have to continuously move his/her hands away from the device to type or to perform keystroke commands, and then locate the haptic device to perceive further sensations. Feedback should ideally be designed considering these and other contextual issues suggested by [8]. It has also been acknowledged that as only one scenario was used for purposes of designing and evaluating feedback, further scenarios may have to be developed to assess whether the suggestions made for representing elements would continue to provide benefit within other contexts of use. Sensations would need to be designed with consideration for other haptic feedback that may be present on a page.

7. Conclusion & Future Work

This study has reported a five-stage approach for inspiring and evaluating design ideas for assistive haptic icon design. Preliminary findings have provided a starting point for representing symbolic sensations on a web page. A small set of page elements and browsing concepts were chosen for purposes of the study, as it is believed that by building up a haptic library of sensations slowly, the user group can discuss ideas for each element in greater detail. Once feedback is developed to a sufficient standard, assistive guidelines can be proposed, allowing designers to replicate sensations on their own web pages. The intended research hopes not to solely focus on the design of force-feedback, but also aims to examine whether tactile and vibrotactile sensations can be developed to represent similar elements and concepts, adhering towards a universally applicable set of recommendations.

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References

<table>
<thead>
<tr>
<th>Elements &amp; Concepts</th>
<th>Group 1: Descriptions from scenario</th>
<th>Group 1: Basic feedback suggested</th>
<th>Group 2: Shown /discussed cues</th>
<th>Group 2: Responses to Group 1's feedback</th>
<th>Group 2: Ideas for feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Web page background</strong></td>
<td>Feeling that will not attract any attention but will allow user to know that they are on an open page</td>
<td>Smooth feeling without any restriction on movement; Slippery effects could also allow free movement</td>
<td>Damping effect producing a slippery sensation; Smooth texture</td>
<td>General disagreement with need for providing a background effect. Page border would provide all the feedback necessary to show a user that the page was beneath fingertips</td>
<td>No feedback needed</td>
</tr>
<tr>
<td><strong>Images</strong></td>
<td>If image is informative, provide awareness when moving over the image. Image needs to be distinctive from the rest of the page. Image interior should be perceivable and feel different to the borders</td>
<td>Boundary effect - image could be raised from background to differentiate from rest of the page; Texture suggested for interior – pleasant feeling</td>
<td>Enclosure effect covering a rectangle; Smooth texture</td>
<td>Texture can be used as an anchor, however the user may want to be drawn into the image, if it is informative. May not need raised edges as could obstruct user, need more subtle effect. Images should be optional for VI users</td>
<td>Subtle texture on body like cardboard prop presented; May need to use enclosure effect but allow the user to move in to it rather than climbing it. Differentiate image feedback from page border feedback if same sensation is used, to reduce confusion</td>
</tr>
<tr>
<td><strong>Image-hyperlinks</strong></td>
<td>Drawn into image so you can’t fall off to be able to click; Provide awareness when moving over body. Keep feedback similar to cues designed for images.</td>
<td>Attraction effect with feedback so link can be clicked</td>
<td>Spring effect drawing user into centre point; Periodic wave for indicating awareness of body</td>
<td>Spring effect should be reduced from a haptic point of view – otherwise you may overshoot your target. This effect could vary for different images or sizes of images; Instead of wave effect, something pleasant which is not intrusive as you would encounter many of these sensations on a page</td>
<td>Use springs to do this but place texture on image-hyperlinks to differentiate them from hyperlinks. Use same smooth pleasant feeling texture as for the image; Smooth texture needed to convey body</td>
</tr>
<tr>
<td><strong>Hyperlinks</strong></td>
<td>Drawn into link so you can’t fall off to be able to click; Provide awareness when moving over the link; If links are in a cluster, then should be attracted</td>
<td>Attraction effect with feedback to suggest that you are hovering over a hyperlink; Body could feel like a pebble, to alert the user of presence</td>
<td>Spring effect drawing user into centre point; Enclosure effect covering a rectangle</td>
<td>Might not need separate feedback, as image-link would already have texture underneath it – so may not need any additional information other than providing the attractive effect. Attract the user to the vertical centre &amp; ensure that links can be differentiated from image-links and buttons</td>
<td>Spring attracting user to vertical centre; Feeling of being attracted through a “long channel”</td>
</tr>
<tr>
<td><strong>Page border</strong></td>
<td>Constraints keeping the user inside the page, can move out unless they press a button; User should be able to follow the border</td>
<td>Wall effect around page making it harder to leave</td>
<td>Enclosure effect covering a rectangle where you need to push to leave</td>
<td>Described enclosure effect as being too strong, should be easier to override as user should not be totally constrained; Provide the metaphor of the edge of a picture frame – you fall into the page and have to push out of it ; Outside border, place a different sensation to provide locational awareness</td>
<td>Enclosure effect with a depression that makes it easier to override as user should not be totally constrained; Provide the metaphor of the edge of a picture frame – you fall into the page and have to push out of it; Outside border, place a different sensation to provide locational awareness</td>
</tr>
<tr>
<td><strong>Progress bar</strong></td>
<td>Sensation reduces as progress increases or vice-versa</td>
<td>Vibration decreasing to zero value or full value as progress increases or some kind of decay in vibration</td>
<td>Periodic wave increasing and decreasing in intensity</td>
<td>Shown progress bar vibration reducing but felt that mouse moved too erratically moving away from target; Instead of varying wave size, feedback should get faster, providing sensation like a metronome. The user would easily associate faster/slower feedback correspond to lesser/greater progress</td>
<td>Periodic wave with constant magnitude but period which increases or decreases;</td>
</tr>
<tr>
<td><strong>Assistive navigation</strong></td>
<td>Feels like as being guided by another person’s hand when you’re following a path; Moving towards an element could feel like tracing a line in sand.</td>
<td>Gentle sensation which remains constant towards target in a groove; Feedback to convey direction of motion</td>
<td>Spring effect to attract user; Constant effect to move user in direction</td>
<td>You could move from the search box to the Go button on page via a “pipe” using a spring effect; Exploration should not be hampered as this can cause confusion. Rest of information about your progress in audio</td>
<td>Haptic groove using spring effect; Gentle motion to move towards target</td>
</tr>
<tr>
<td><strong>Overview of page complexity</strong></td>
<td>Scanning the page themselves to find the page content. Additional information may serve little purpose</td>
<td>Scanning the page may allow the user to derive a virtual texture from all the elements, providing an overview</td>
<td>Asked to discuss further</td>
<td>Additional feedback not necessarily needed. Could gain overview from moving the mouse over the page</td>
<td>Prefer not to suggest additional sensation</td>
</tr>
</tbody>
</table>