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ORIGINAL ARTICLE

Designing universal access: web-applications for the elderly and disabled

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Abstract Throughout a person's life they are likely to experience some degree of impairment. What must be ensured is that these individuals can benefit from the opportunities afforded by technology in the same way as those who are able bodied. With the Internet becoming an increasingly popular medium for organizations to deliver information and services to the public many of these technological benefits are provided through web applications. However, due to possible visual, physical or cognitive impairments, older users and those with disabilities are more likely to experience difficulties. This paper addresses issues relating to usability of web applications for elderly and disabled users and investigates ways in which it can be improved, and whether doing so will affect usability for younger and more able users. Results from experiments undertaken indicated that it was possible to develop a web application for elderly and disabled users without degrading usability for other users.

Keywords Older users · Web applications · Web design · Web usability · Accessibility

1 Introduction

Increasingly, we are communicating electronically via the Internet, and in particular through interaction with web-based applications. The design of these applications is the key to how they allow effective communication to take place. While able-bodied users may be able to cope with the shortcomings of some sites, elderly and disabled users may find the barriers so great as to prevent effective communication taking place.

All too often the overriding aim of web developers, and the organizations financing them, is to build web applications that provide cutting edge content. As a result, little attention is paid to the user's needs and abilities (Nielsen 1999). The web typically addresses an unknown audience and, consequently, it can be difficult to define the end user and to consider their needs (Nerurkar 2001). Developers, who tend to be young and able, assume that they are typical web users and develop applications to cater for their own abilities (Nielsen 2001). Those who suffer the most in these cases are the older population who find it harder to overcome the usability issues that younger and more able-bodied users can cope with. With the normal ageing process introducing visual, cognitive and physical impairments, designs that do not cater for older users can reduce the level of usability considerably for this user group (Becker 2004).

While this seems to suggest that web applications should be designed to accommodate elderly and disabled users, Hawthorn (2003) argues that moving to the other extreme, where the developer focuses purely on the needs of the elderly and disabled, means usability for the young and able will suffer. Hawthorn (2003) claims that this can result in an application that does not provide the complex functionality many young and able users require. From the studies carried out using an e-mail application, he found that the majority of older users would only ever use the most basic of functions and would prefer for the system to be kept simple and easier to learn. In order to then satisfy these usability needs, Hawthorn argues that the system must be over simplified. This then leads to a restriction on innovation, and those users who appreciate more powerful applications are not

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catered for, however, Hawthorn's work was based on traditional, non-browser based, software and whether his results apply to the web domain remain unclear. Therefore, designing for elderly and disabled users within the area of web applications may not have the same negative effects on younger and more able users as Hawthorn's study suggests. The question remains as to whether a web application that is developed to be usable for elderly and disabled users can consequently be usable for younger and more able users or, at least, not affect their usability negatively.

This research tests the hypothesis that, if a developer were to focus purely on the needs of the elderly and disabled then usability will not suffer for young and able users. This is achieved by collecting qualitative and quantitative data relating to the experience of elderly and disabled versus young and able users, during their use of a set of test software applications, which were designed with different user abilities in mind.

2 Elderly and disabled web-users

A number of web accessibility studies (such as Becker 2004; Chadwick et al. 2003; Hanson 2001; Hawthorn 2003) have identified elderly web-users as a group who are likely to find the use of the web difficult or impossible due to usability issues. Barriers arise due to elderly users generally having less PC and web experience than those who are younger (Chadwick et al. 2003), and due to general impairments brought about by ageing. The defining factor of the elderly group is generally the age of the individual; however, the discriminatory age used varies from study to study. For the purpose of this research an elderly user will be one aged 60 years or over (Becker 2004; Hawthorn 2003).

Web users with a disability have also been identified as a group who are likely to be faced with difficulties in using the web (Newell and Gregor 2002; Carter and Markel 2001). In particular it is users who experience visual, hearing, motor and cognitive impairments that are likely to have the most difficulty in using the web (Carter and Markel 2001; Rowan et al. 2000). As this research is concerned solely with web usability, a disabled user will be defined as an individual with one or more impairments relating to their visual, hearing, motor or cognitive abilities.

While the elderly group and the disabled group of users are distinct from each other, they share a number of similarities. Age can only loosely predict the amount of disablement an individual will experience (Hawthorn 2003). However, elderly people, in comparison to younger individuals, commonly have more general impairments (Newell and Gregor 2002) similar to those experienced by disabled people, which can affect web use. Nearly half of adults aged 65 or over are likely to experience some disability (Hanson 2001), while even elderly users who are fit and active may find current systems difficult to use (Newell and Gregor 2002). Therefore, whether a web site is to be used by users who are classed as elderly or disabled, its design requires similar considerations to cater for these individual's special requirements (Fink et al. 1998). For the purpose of this research, elderly and disabled people have been grouped together to represent those users who face the biggest challenge when using the web.

While elderly and disabled users are rarely considered during the web development process, the probability of such a person using the system is significant. The older group of adults is currently the fastest growing global demographic (Chadwick et al. 2003) with 20% of the developed world's population currently being over 60 and that figure expected to rise to 32% by 2050 (United Nations 2005). There are also over 750 million people worldwide, of all ages, who experience some degree of disability (Huang 2003). These statistics are reflected in the online population with the older group of adults becoming the fastest growing group of Internet users (Hanson 2001) with a 25% increase of adults aged 65 or over using the internet between 2003 and 2004 (Becker 2004). Despite this, many developers are not considering the unique needs of these user groups (Loiacono and McCoy 2004). Sullivan and Matson (2000) note that recent press reports have classed 95% or more of all web sites as inaccessible to users with disabilities.

For a business, excluding users with disabilities through poor usability means a loss of customers and lost revenue. If a business develops an application that is usable by those with disabilities then they will gain an advantage over those who do not, and will have access to the growing group of elderly and disabled users who, in America alone, have a disposable income of $175 billion (Prager 1999). Even when the financial benefit is discounted, ignoring users with disabilities could be in violation of disability laws and result in legal action (Paciello 2000).

In terms of usability, designing for users with special requirements has been shown to produce applications that also provide benefits, albeit smaller, to users without special requirements (Worden et al. 1997). However, Hawthorn (2003) suggests that focusing usability solely on this user group can result in an application that does not provide the complex functionality many young and able users require. From the studies carried out by Hawthorn (2003), which were based on an e-mail application, he found that the majority of older users would only ever use the most basic of functions and would prefer for the system to be kept simple and easier to learn. Hawthorn's work indicates that designing for older users will have a negative impact on younger and more able users. While identifying interesting issues, Hawthorn's work is limited by two factors: firstly, Hawthorn's attempt at providing

usability for elderly users focused on avoiding complex functionality and leaving only basic tasks. No attempt was made to make the more complex functions usable to the elderly and disabled. Secondly, web applications differ from the traditional, non-browser based e-mail application that Hawthorn used. With a web application there tends to be less functionality and it is generally simpler than that found with traditional software.

Attempting to develop a web application that can be used by elderly people, those with disabilities and those with no significant disabilities holds many parallels with the idea of ''inclusive design''. An inclusively designed product, whether this is a physical artifact or something less tangible such as a web application, has been defined as only excluding the users that the product requirements exclude (Keates and Clarkson 2003). Within inclusive design, one approach that has been suggested is to compromise on the product design to meet both the needs of those with impairments and of those without (Newell and Gregor 2000). However, as discussed by Hawthorn, questions are then raised as to whether providing access to people with disabilities then makes it more difficult for people without disabilities to use the product (Newell and Gregor 2000). Unlike inclusive design, this research does not look to include all users within the design of each application. Rather, the research intends to examine the effects of designing purely for elderly and disabled users and attempts to determine whether doing so could itself lead to an ''inclusive'' web application.

From current research it still remains unclear as to whether the argument that a web application that is developed to be usable for elderly and disabled users can consequently be usable for younger and more able users. Although this appears to be reasonable, Hawthorn's (2003) work suggests that this may not be the case, particularly when traditional (non-browser based) applications are concerned. The primary aim of these experiments therefore, was to explore whether the initial argument was correct and how broadly this could be applied in the web application domain.

3 Experimental design

In order to test whether a web application designed for older users and those with a disability affected its use by young and more able users, a number of experiments were set up. The way in which these experiments were carried out is presented below.

3.1 Outline

The experiments were run with the help of Hillingdon Shopmobility, an organization that provides mobility vehicles such as scooters and wheelchairs. The organization was chosen as its customer base is made up of elderly and disabled as well as young and able members. Four web-based applications were developed for the experiment, which provided a booking system to enable the users to create and manage bookings for the organization's mobility vehicles. The users were given a set of three scenarios. Firstly they had to check a vehicle diary for the availability of a specific vehicle on a given date. Secondly the users had to make a booking for a specific vehicle on a given date. Finally the users had to find the contact information for the organization running the service. Each of the three scenarios was identical for every tester, from both the elderly and disabled group, and the young and able group. These scenarios were chosen as they would commonly be experienced and understood by the elderly, disabled and able customers alike.

3.2 Test software applications

The experiments used four applications (labeled A, B, C and D) that met the same functional requirements, allowing a user to accomplish a prescribed task. The navigational structure, look, screen content and methods for data entry differed between the applications. The non-functional aspects of the application were dictated by two criteria; the target user and the application type:

Target user	Two of the designs (A and B) focused on the usability needs of the elderly and disabled, and two (C and D) focused on usability for young and able users. The designs for the elderly and disabled focused applications were developed using a list of guidelines based on the design suggestions by Chadwick-Dias et al. (2003), Chisholm et al. (2001), Hanson (2001), Nielsen and Molich (1990), Nielsen (2000) and Palmer (2002)
Application type	Two of the designs mimicked traditional, non-browser based applications such as word processors or spreadsheet programs (B and D), using a WIMP (windows, icons, menus and pointers) style interface. Two of the designs were web-based applications (A and C) using a more ''web styled'' interface typically found with web sites that are accessed through a web browser. While this research is concerned primarily with the web, previous studies highlighting the benefits and issues of designing for impaired users has been based on non-browser based systems (Hawthorn 2003; Worden et al. 1997). Testing both application types under the same conditions provided a link between the research of the browser based web applications and the non-browser based applications previously studied and for any differences between them to be examined

The focus of each of the four applications, with regards to the above criteria, is summarized in Table 1.

Applications A and B (see Figs. 1, 2) were both designed for elderly or disabled users and exhibited the following features:

Large text size—font sizes equivalent to 14 point were used to improve the legibility of the content for users with impaired vision (Becker 2004). Text size was also relative rather than definite to enable the user to make adjustments (Chisholm et al. 2001).

Descriptive links—the use of descriptive links helps to avoid confusion by allowing users to easily select the most appropriate path to take when several closely related links were present on the screen (Palmer 2002).

Use of neutral background colors and black text—providing text colors that contrasted well with the background colors was used to improve the legibility of the content for users with visual impairments (Chisholm et al. 2001; Hanson 2001).

No background images—using a plain background with no images or patterns was used to help improve the legibility of the content for users with visual impairments (Hanson 2001).

Limited user input—user input was limited to selection rather then including text box entry. This was intended to reduce the amount of hand movement required and to enable input to be performed with only one input device to assist users with motor impairments (Chisholm et al. 2001).

Table 1 Matrix showing the focus of each application

		Test user	
		Elderly/disabled	Young/able
Application type	Web	A	C
	Traditional (non-browser based)	B	D

Fig. 2 Screen shot of application B

Detailed instructions using simple terminology—to assist users in understanding complex page elements the context and orientation within the application were given (Chisholm et al. 2001). The detailed instructions were given using simple terminology that would be easier to understand for older users who generally have less understanding of web terminology (Chadwick et al. 2003).

Applications C and D (see Figs. 3, 4) were not designed to consider the needs of elderly or disabled users. These two designs focused on the functionality of the application and did not consider any special user requirements. These applications exhibited the following features:

Text size—font sizes of ten points were used to improve the look of the application and fit more information in the same screen area. Text size was set at a definite ten points, which meant that it could not be adjusted.

Links—textual links used fewer words to reduce the amount of screen space used.

Background and text colors—colors used within the application were chosen to match those of the organization.

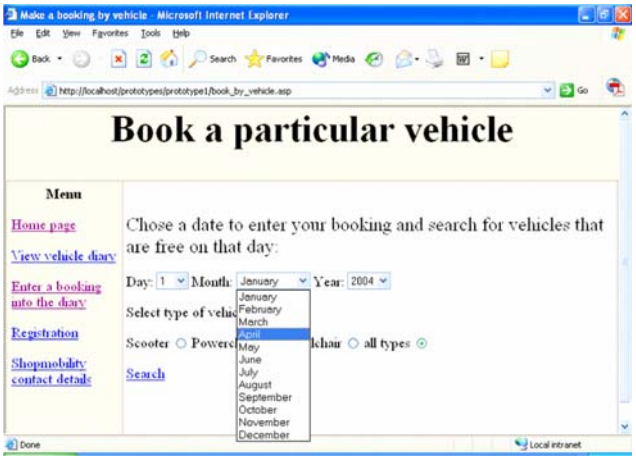

Fig. 1 Screen shot of application A

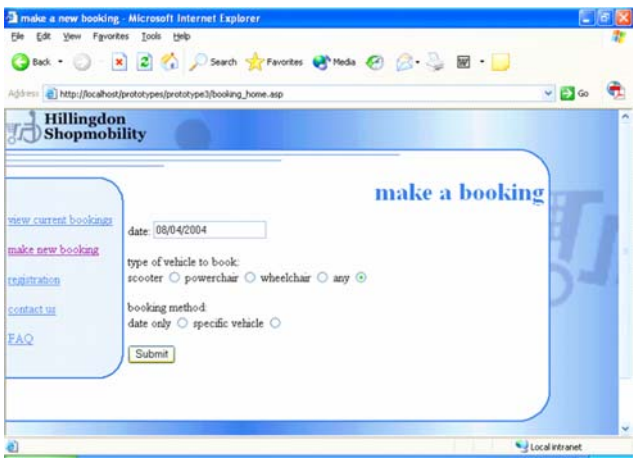

Fig. 3 Screen shot of application C

Fig. 4 Screen shot of application D

While contrast between the text and the background was sufficient enough for text to be read easily by the developers (who had no visual impairment), the background colors used were darker than those of applications A and B.

Images—images were used both in the foreground and the background that included the logo of the organization to which the application was designed for. As with the color scheme, this helped to reinforce the identity of the organization.

Limited user input—user input included a number of methods that were intended to make any entry as quick as possible. This resulted in the need for more than one input device to be used.

Instructions—to reduce the amount of on-screen text, all instructions and information regarding the application were removed from each page and placed within a frequently asked questions (FAQ) section.

Applications A and C were developed in a web style and therefore exhibited the following features distinct from those found with traditional non-browser based software (Nielsen 1997; Wroblewski and Rantanen 2001):

Underlined hyperlinks—hyperlinks were differentiated from other text by using the web standard of using a blue underlined font.

Differentiation between active, visited and unvisited links—links were differentiated to indicate sections of the application the user had already visited and those they had not as well as indicating when the user was hovering over a link.

Un-restricted navigation—the user had control over navigation around the application allowing them to move from one area to another whenever they wished.

Home link on every page—a textual link at the top left of every page allowing the user to return to the home screen of the application at any point.

No pop-up boxes used—all confirmation, error and warning messages were displayed within the web page.

Applications B and D were designed with a traditional non-browser based interface. They exhibited the following characteristics:

Links—buttons were used instead of textual hyperlinks within the main body of the applications.

Text menu—textual links were included in a horizontal toolbar at the top of each screen, however, these links remained black and without any text decoration. They did not differentiate between sections of the application the user had already visited and those they had not.

Restricted navigation—certain functions on the toolbar were not available to users when performing certain functions. If a function was not applicable to the task being performed, the option was grayed out on the toolbar.

No home links—no links back to the start screen were given. Instead the user was forced to follow each function step by step with only the option to go backwards or forwards one step at a time.

Pop-up boxes—pop up boxes were used for confirmation, error and warning messages.

3.3 Test users

A total of 32 users were used to test the 4 applications ($n = 32$). All users were customers of Hillingdon Shopmobility. During the day of testing, customers visiting the organization were approached to take part in the study. The users were split into two equal sized groups, one comprising of young and able users ($n = 16$), the other of elderly and disabled users ($n = 16$). The members of the young and able group were all aged between 18 and 59 with no visual, cognitive or motor impairments. Within this group nine of the users were female and seven were male. The elderly and disabled group consisted mainly of users aged 60 and over (Becker 2004; Hawthorn 2003).Five of the users within this group were under 60 but had a sufficient level of impairment for them to be registered disabled within the UK. All users within this group had a sufficiently severe level of motor impairment for them to require mobility assistance. These impairments also affected the use of a keyboard and mouse. The users over 60 also had varying levels of visual impairment brought about by old age, although no user was registered as blind. Within the elderly and disabled group eight of the users were male and eight were female.

3.4 Test procedure

To cater for learning or fatigue effects, the order in which the four prototype applications were counterbalanced using a Greco-latin square (Mandl 1985) followed by an adapted Greco-latin square. With the second square applications B and C were swapped to ensure that, with half of the sequences, the users alternated between the young/able focused and elderly/disabled focused designs. Table 2 illustrates the eight sequences of testing.

Table 2 Greco-Latin squares showing the order in which the designs were tested

	Application order
1	A → B → C → D
2	C → D → A → B
3	D → C → B → A
4	B → A → D → C
5	A → C → B → D
6	B → D → A → C
7	D → B → C → A
8	C → A → D → B

The eight different sequences meant that any advantages or disadvantages that a design would have from being tested first, second, third or last was averaged out over the experimentation process.

In order to reduce the effect of an extreme test case, two users from each group were asked to perform the experiments for each of the eight sequences. This gave a total of 16 users for each group and 32 users overall.

3.5 Measurement

The degree to which each application was effective and usable was measured using a number of quantitative measurements. According to Frøkjær et al. (2000), efficiency, user satisfaction and effectiveness are three measures that should all be included within any usability tests. Efficiency is indicated by task completion time (Frøkjær et al. 2000), which itself has been shown to provide an implicit measure for usability as it is linked to the satisfaction or frustration that a user experiences when carrying out tasks (Czerwinski et al. 2001). As with similar studies (Chadwick et al. 2003), efficiency was considered by measuring the time taken to complete each task to find the total time spent using the application.

User satisfaction was measured during post-test interview where each user was asked to rank each application based on a number of aspects. The three key areas of web usability were identified through the work of Becker and Berkemeyer (2002), Palmer (2002) and Becker and Mottay (2001) as being navigation, content and aesthetic appeal. Each user was asked to rank the four applications based upon; ''How easy it was to move through the application, from one page to another''; ''how well the information was displayed to them on each page and whether the information was sufficient, relevant and easy to find'' and ''how visually appealing they found the site''. All users were also asked to comment on why they had given a particular rank. From these comments it was possible to ascertain whether the user correctly understood what was being asked of them. If any confusion arose, a moderator was available to provide further explanation. The four applications were also ranked according to the user's overall preference.

Effectiveness is measured by the quality of the solution (Frøkjær et al. 2000). For the purpose of this research, this involved noting the number of errors made by the user. Errors were defined as actions carried out by the user that would result in the task either not being completed or being completed inaccurately. This included entering the incorrect date for a booking, selecting the wrong vehicle, or not finding the required information. Applications that were rated highly and provided fast and accurate functionality with no, or very few, errors were judged more usable than those that users found to be slow, inaccurate and caused many errors.

4 Results

The main focus of this paper is to test the potential for tailoring applications to elderly and disabled users. The data collected during the experiments relating to this issue is discussed below.

4.1 The effect of user focus on usability

This section presents data on the how the users perceived each application. The users were asked to rank the applications with respect to a number of aspects: navigation, content, aesthetics, and an overall rating. The most highly rated application was assigned a value of 4, the second 3, third 2 and the last 1 for each aspect. The users were also timed for three tasks. Each of the three tasks were the same for each subject and for each application.

An ANOVA with repeated measures was conducted with the dependent variable of user preference value. The analysis took an independent between subjects variable of age (young, old) and independent within-subject variables of focus (young/able, elderly/disabled). The analysis revealed a significant main effect for the focus of the application for the navigation ($F(1,30) = 19.61$; $P < 0.001$), content ($F(1,30) = 9.17$; $P = 0.005$) and overall ($F(1,30) = 13.10$; $P = 0.001$). Closer inspection of the mean values showed that the users preferred the elderly and disabled focused designs to the young and able focused designs in terms of navigation, content and overall. This effect can be seen in Fig. 5, which illustrates the navigation preference. There was no significant main effect for focus with regards to the aesthetics of the design ($F(1,30) = 1.44$; $P = 0.239$). The analysis also highlighted a significant two-way interaction effect for the navigation preference ($F(1,30) = 4.59$; $P = 0.040$) between the focus of the application and the age group of the tester. As Fig. 5

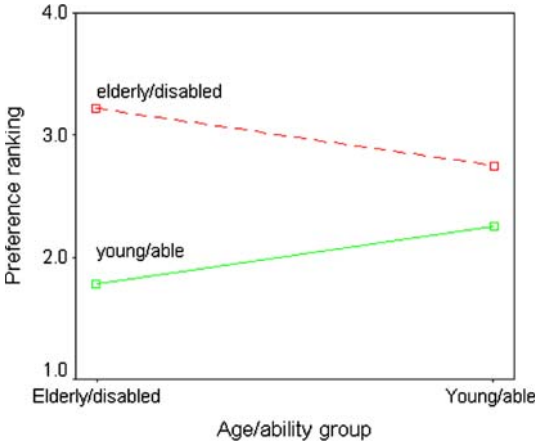

Fig. 5 Mean navigation preference values for each focus of web application

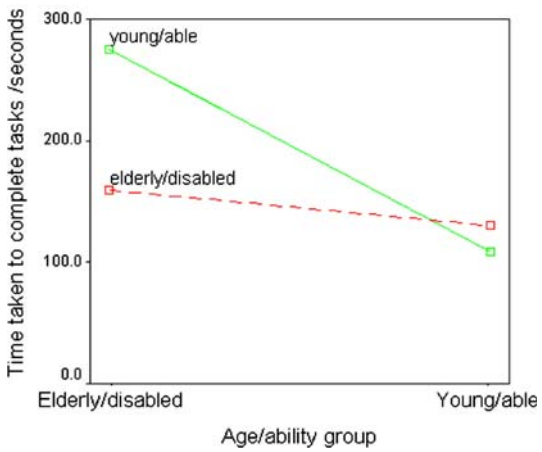

Fig. 6 The mean total times taken to complete the three tasks for each focus of web application

shows, the degree to which the users preferred the navigation of the elderly/disabled-focused design was greater with the elderly and disabled users. Post-hoc tests were not performed because there were fewer than three groups (elderly/disabled vs. young/able).

In general, there was a preference toward the elderly/disabled-focused designs, in particular with the elderly and disabled group. Many users from this group indicated that the descriptive links and buttons enabled them to find where they needed to go much more quickly and easily than with the young/able focused designs. The restricted input methods and on-screen explanation made the functions easy to understand and use, as noted by one of the users; *''(with the elderly/disabled focused designs) it was obvious what I had to do as it was well explained with the links and instructions''*.

The young and able also preferred most aspects of the elderly/disabled-focused designs, although to a lesser extent. A similar preference was observed for the areas of navigation and content. Users found the same descriptive links and detailed help of benefit although some did complain that the on-screen help cluttered the screen and that the data entry methods were slightly cumbersome and slow to use. One tester from the young and able group stated; *''There was too much information on the screen with (the elderly/disabled focused designs), it made it look a bit cluttered and got in the way''*.

Having considered the opinion-based results in the previous section, this section presents the timing-based results of the experimentation.

Another ANOVA with repeated measures was conducted with the overall time taken as the dependent variable and the same independent variables as before. The analysis revealed a significant main effect for the focus of the application ($F(1,30) = 9.75$; $P = 0.004$). Figure 6 shows that in general, it took longer to complete the tasks with the young and able focused designs than with the elderly and disabled focused designs. The analysis also highlighted a significant two-way interaction effect ($F(1,30) = 21.08$; $P < 0.001$) between the focus of the application and the age group of the tester. From Fig. 6 it can be seen that the elderly and disabled group of users were faster with the elderly/disabled focused designs than with the young/able-focused designs. Conversely, the young and able groups of users were faster with the young/able-focused designs. The elderly/disabled focused designs appeared to reduce the time taken to complete the tasks considerably for the elderly and disabled group. However, the young/able-focused designs were found to provide only a small time advantage for the young and able group. When the young and able testers used the young/able-focused designs, the reduction in speed was only small.

During the observation it was noted that the large difference in times for the elderly and disabled group of users was primarily due to the users experiencing problems with the restricted navigation in application D and having to use the browser back button to get back to the start page. Five users from this group were observed using the browser button to return to the start page after every task. While the restricted navigation was also used in application C, users indicated that the descriptive links and buttons explained where they could go and what would occur when it was followed. This allowed the users to spend less time trying to understand what to do in order to complete the task. Users, especially those with motor impairments, found that switching from using the mouse to using the keyboard to use text boxes to enter details such as the date on the young/able designs proved difficult and time consuming. One user commented; *''I didn't like the way I had to keep changing from using the mouse to the keyboard (with the young/able focused designs)''*.

The young and able users disliked the large amount of help text shown on the initial pages. It was noted that users spent a significant amount of time reading the detailed instructions on the first pages of the elderly/disabled focused designs even when the design was not the first to be tested and the users should have started to learn how to complete the task. The users would tend to read the instructions when they first used the design, which consequently increased the time spent on the first task. The younger and more able users also found that the use of text boxes reduced the time taken to input information. One of the users from the young and able group stated; *''I thought the way I had to enter the date (with the elderly/disabled focused designs) was quite awkward''*. However, while this proved to be quicker, the observations noted that three times as many people experienced an error due to incorrect date entry with the text box input.

4.2 Traditional or web applications

An ANOVA with repeated measures was conducted with the dependent variable of preference value. The analysis took an independent between subjects variable of age (young, old) and independent within-subject variables of style (web, traditional). Style had no significant effect on either the navigation preference ($F(1,30) = 4.09$; $P = 0.052$) or the overall preference ($F(1,30) = 2.88$; $P = 0.100$). However, analysis revealed a significant main effect for the style of the application with both the content ($F(1,30) = 1.59$; $P = 0.050$) and the aesthetics ($F(1,30) = 5.47$; $P = 0.026$). As can be seen in Fig. 7, inspection of the means revealed that, in general, users had a slight preference toward the traditional style applications. The analysis also highlighted a significant two-way interaction effect ($F(1,30) = 9.04$; $P = 0.005$) between the focus and the style of the application with regards to the aesthetics. When the application is designed in a web style, the users preferred the aesthetics of the elderly/disabled-focused designs, when the application was designed in a more traditional style the users preferred the aesthetics of the young/able focused design. This is illustrated in Fig. 7.

Users stated that the aesthetic preference toward the traditional style of application was mainly due to the use of icons rather than textual links. Also the uses of a toolbar rather than vertical menu, which increased the work area and made the page, appear less cluttered. In terms of the overall preference however, no significant effects were observed from the style of the application.

An ANOVA was also performed with task time as the dependent variable. The independent variables remained the same as before. There were no significant main effect for the style of the application ($F(1,30) = 0.01$; $P = 0.910$), however, as with the aesthetic preference, a significant two-way interaction effect ($F(1,30) = 21.43$; $P < 0.001$) was found between the focus and the style of the application. In both the traditional and the web style of design, the young/able focused design proved to be the quicker of the two, although the difference between the average times were less within the web style, as seen in Fig. 8.

5 Conclusions

In order to encourage web developers to cater better for the elderly and disabled, this research sought to demonstrate that, with relatively little effort, web applications could be made accessible to this group without reducing the effectiveness of the application to cater for able-bodied users' needs.

The results of the experiments indicate that designing specifically for the needs of elderly and disabled users

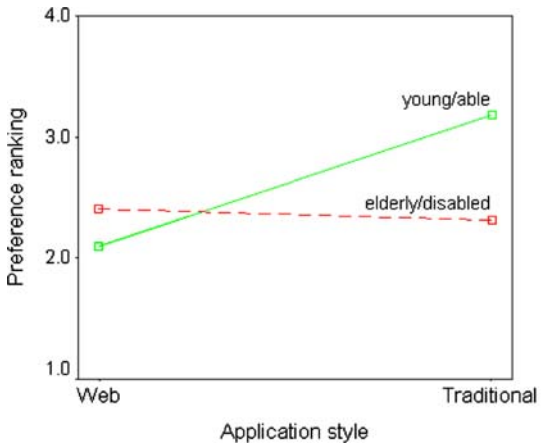

Fig. 7 The aesthetics preference values for each focus of application in a web and traditional style

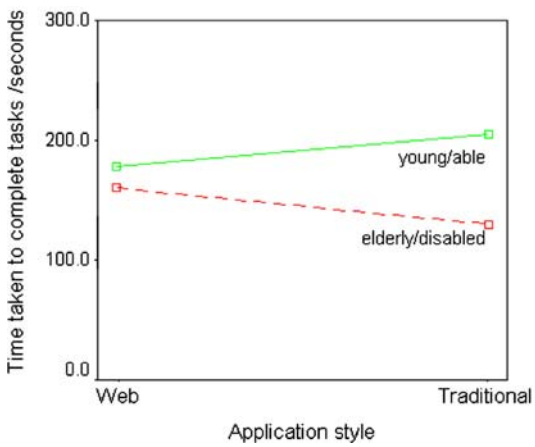

Fig. 8 The time taken for each focus of application in a web and traditional style

improves the experience of this user group considerably in terms of efficiency, effectiveness and user satisfaction as shown with their preference towards these applications, reduced task times and a higher level of accuracy. The benefits in efficiency for younger and more able users are not as significant with the average time for completing the tasks being slightly longer. Despite this, the young and able users generally preferred the elderly/disabled-focused designs, which allowed them to carry out tasks more accurately and with fewer errors.

A possible explanation has been put forward relating to the negative impact on efficiency for the young and able users working with the elderly/disabled focused design, observed through slower tasks times. The large amount of information displayed on the screen and restricted input methods were observed as having a negative impact on the efficiency of the young and able users. However, these features were also commented on by the elderly and disabled users as being a positive aspect that helped to improve the user satisfaction and effectiveness. The question is raised as to whether the benefits to elderly and disabled outweigh the detrimental effects on efficiency it has for young and able users. It may be possible, if approaching the development from an inclusive design perspective, to find a balance so that both user groups could be catered for. Since the reduced efficiency experienced by the young and able users was only small, it would seem this is a reasonable goal.

The two applications designed specifically for the requirement of elderly and disabled users were not developed according to the principals of inclusive design. While the needs of young and able users were not actively excluded from the design of these two applications, an intentional decision was made not to cater for them specifically. However, the results of the experiment indicate that these applications are also usable for young and able users and therefore suggest that the elderly/disabled-focused designs have led to an ''inclusive'' web application.

What the results also suggest is that the domain of web application differs little from that of traditional applications. The style of the application only had a main effect on the content and aesthetic preferences. There was no significant effect on the navigation or overall preferences or the task time. However, while designs B and D had a definite ''traditional application'' look and feel, their functionality remained the same as the other two applications developed from a web perspective. Unlike the traditional application tested by Hawthorn (2003), the functionality of the two designs from a traditional application perspective were relatively basic and required no simplification for elderly or disabled users.

These results not only have implications for future web application developments for elderly or disabled users, but also many others where this user group is not within the expected audience. As stated by Nerurkar (2001), the web typically addresses an unknown audience. Whether or not an individual with impairment becomes a user of the application, if the developer has taken into consideration any possible impairment then users from this group will not be excluded. This is particularly significant in light of recent disability laws (Paciello 2000). Additionally, designing in such a way should not have too negative an impact on other users.

We do not propose that all creativity should be removed from websites indeed the creative content in some websites is what makes them attractive and is a major factor in their success. However, for web-based applications that provide a service which people need to conduct their everyday lives, the results from this paper can be used to argue for a simpler, universally usable interface.

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