Developing and evaluating web-based assistive technologies for older adults

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A.G. Money, S. Fernando, L. Lines, A.D. Elliman. Developing and evaluating web-based assistive technologies for older adults. Gerontechnology 2009; 8(3):165-177; doi: 10.4017/gt.2009.08.03.013.00 Delivering Inclusive Access to Disabled and Elderly Members of the community (DIADEM) is a three year Framework 6 European Union (EU) funded project. The primary goal is to develop the DIADEM application, a plug-in to a web browser that adapts the online-form interface according to users' needs, making the content more accessible for cognitively impaired older-adults. After providing some background information relating to the DIADEM project and the DIADEM application, a trial protocol is presented. As one of the main contributions of this paper, the protocol has been specifically designed to identify cognitively impaired older adults and to evaluate the usability of online-form content from an older adult user's perspective. To demonstrate the applicability of the trial protocol within the context of an ongoing research project, details of a set of pan-European trials involving 77 eligible users, who evaluated DIADEM enabled online-forms according to the trial protocol, are also presented. Results of the trials reveal a number of online-form design guidelines, which will be incorporated into future versions of the DIADEM application. Although these guidelines have been developed specifically for the DIADEM application, they also represent valuable guidelines for online-form developers more generally, and if adhered to, will ensure that content is more usable for the cognitively impaired older adult user group. This paper concludes by discussing the lessons learned from implementing the trial protocol and how the implications of the findings of the DIADEM user trials may be incorporated into future versions of the DIADEM application.

Key words: accessibility, e-government, older adults, online-forms

Older adults often experience declines in mobility, dexterity, and cognitive ability as a natural product of the ageing process[1]. The proportion of older adults that make up the European population is increasing. As a result, growing numbers of older adults are living within their homes, but with restricted access to services and in their ability to carry out independent living tasks such as grocery shopping, bill payment, and accessing social services. Government initiatives across Europe have identified web services as being a potential means of improving accessibility and quality of life for older adults[2].

Traditionally the process of accessing government services, such as welfare, housing, tax returns, and financial support has been

initiated by completing and submitting paper-based forms. In recent years, these are more commonly presented as online forms, that require the user to complete and submit the form on the web[3]. However, the majority of online forms have not been designed for the specific needs of the older adult, and present significant usability challenges[4]. Online-forms differ from general web content due to their predominantly question and answer based structure. As a result, online forms pose usability challenges that differ from those posed when browsing more general web content[3,5]. However, there seems to be little research presenting online-form specific design guidelines, and an even smaller amount specific to the older adult user[6].

The majority of research to date has focused on developing general web-content design guidelines, and in some cases, has considered the needs of the older adult to be fully incorporated by the needs of disabled users. For example, the World Wide Web Consortium Web Content Accessibility Guidelines (WCAG)[7] provides 14 guidelines for the design of general web-content for disabled users. The United States general services administration section 508[8] also provides standards for supporting inclusive access for disabled users. The National Institute of Ageing (NIA), recognises older adults as a user group in their own right, and presents twenty-five guidelines for general web content for users aged 60+[9]. In terms of the older adult user group, only three small scale studies were found in research literature that present design guidelines specifically for online-form content. Lines et al.[3,10], carried out two small scale studies, in the UK. The most recent of these[3], validated results from a previous study[10] and as a result presented 13 online-form design guidelines. Sayago and Blat[6] also carried out a small scale study, involving one online form and seven Spanish older adult users. The findings revealed that users prefer checkboxes and radio-buttons as opposed to list boxes. They also required optional fields to be grouped into separate sections.

These studies provide a valuable starting point for developing accessible online-form content. However, the majority of e-government web content still fails to conform to the most basic design guidelines[11]. It seems that online-form content will only be more accessible if service providers and designers choose to follow design guidelines, which at present, is often not the case. It is therefore likely that older adults would benefit from a client-side application that adapts and personalises content so that it better conforms to online-form design guidelines. Such an application would provide older adult users with a standardised and familiar interface, which would enable them to access online form content more efficiently and effectively.

The Delivering Inclusive Access to Disabled and Elderly Members of the community (DIADEM) project aims to develop a web-based application that adapts and personalises existing online-forms based on the individual user's preferences, and interactions with on-screen content. We provide a conceptual overview of the application, a trial protocol designed to evaluate the application, the data analysis methods used, the key findings of the user trials, and an overall conclusion.

The DIADEM concept

From the user perspective, the DIADEM application is a plug-in to a web browser. It employs an Expert System (ES) element that monitors user interactions, and personalises the user interface so that usability challenges faced are alleviated (*Figure 1*).

DIADEM operates alongside existing web architectures. Thus, the web-services interface serves as an intermediary between existing application software, the server, and ultimately the user or client site. The client component is data driven by XML control files from the server, so that it can interface to a range of services. From the client side, the plug-in makes it possible to carry out the final enablement and transformation of existing online forms into a standardised online-form user interface.

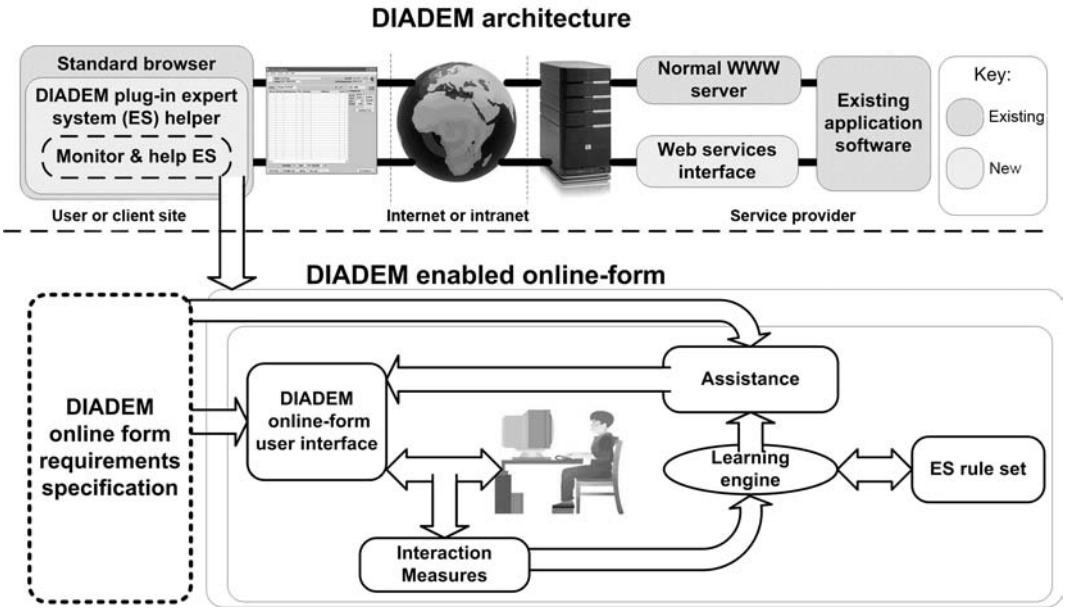

Figure 1: Overview of DIADEM architecture and plug-in

The format and functionality of the initial online-form user interface is derived directly from the online-form requirements specification. The ES element of the application monitors interactions whilst the user accesses online form content. Some Interaction Measures (IMs) may include: user inactivity; typing speed; key stroke accuracy; mouse click accuracy; frequency of backward navigation through the dialogue; frequency of submission errors; question completion rates. The DIADEM learning engine analyses these interactions and attempts to identify when the user appears to be in a problem state. Certain sequences of user interactions trigger ES rules, which in turn prompt the application to provide the user with help (assistance). The current UK version of the application has a number of ES rules, which typically result in providing assistance to the user in the form of pro-active voice assistance (spoken instructions) that are aimed at helping the user overcome the detected problem. This functionality is still in early stages of development, and dependent on the outcome of this round of user trial results.

Trial protocol

To evaluate the recently developed first version of the application, and to identify future design guidelines, a trial protocol was developed and user trials were carried out according to it (*Figure 2*).

Recruitment and briefing

Phase 1 of the trial protocol involves the recruitment and briefing of users. In this case, 94 users were recruited to take part in the trials, mainly sourced from voluntary organisations, providing access to older adult volunteers who offer their time to take part in research. Typically, volunteers take part in two or three research projects per year via these voluntary agencies. Occasionally, these projects have required users to complete paper-based forms and questionnaires as part of the research. From a methodological perspective, there may be a perceived risk in that these users could potentially be more adept at filling out forms, compared with members of the average population. However, since form-filling has become a common task that is carried out as part of our day-to-day activities, it was felt that the increased form-filling activity incurred from taking part in voluntary

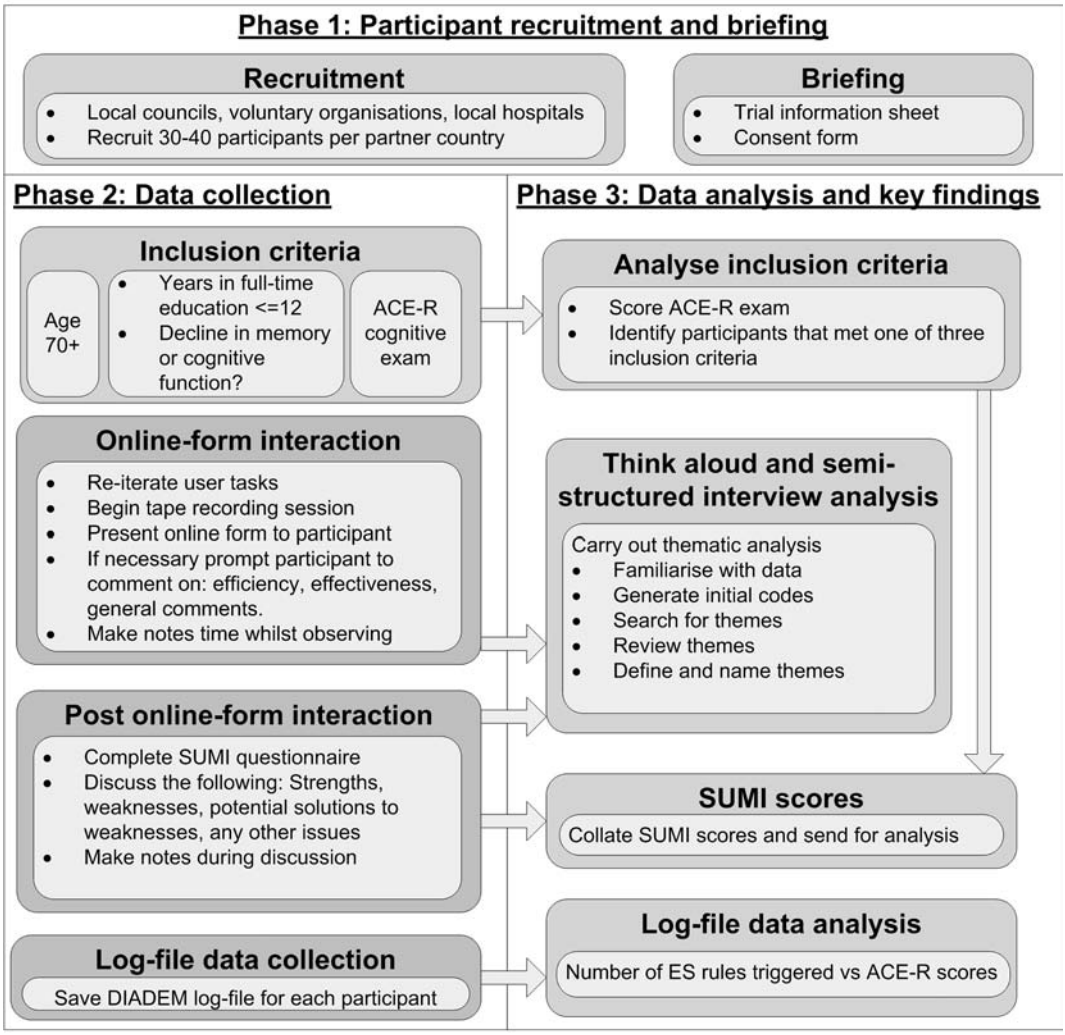

Figure 2: Overview of the DIADEM trial protocol

research was relatively infrequent, and thus did not warrant excluding these users from taking part in the study.

Clear communication with candidate older adult users is important, to avoid potential confusion, and to ensure that users are fully informed and aware of the requirements of the task[12]. Initially, trial information sheets outlining the goals and requirements of the study were sent to the voluntary agencies, who distributed this information on our behalf. Users then contacted the voluntary agency if they wished to take part in the trials, and gave consent for their contact details to be passed on so that further arrangements could be made by telephone.

Data collection

Phase 2 of the trial protocol involves collection of data from users. Data collected during user trials consisted of, inclusion criteria data, online-form interaction data, post online-form interaction data. Log-file data relating to the online-form interaction task was collected.

Inclusion criteria

Previous trials carried out on the DIADEM project[13], used The Mini Mental State Examination (MMSE)[14] as the primary inclusion

criteria. However, the MMSE was found not to be sufficiently sensitive to identify mild levels of cognitive decline. Consequently, for these trials, multiple inclusion criteria were used, so that users presenting with mild cognitive declines were more likely to be identified. For data to be included at the analysis stage, users were required to present with at least one of the following criteria:

All users aged 70+ were automatically included at the analysis stage. The rate of cognitive decline is known to accelerate with age[15]. For example, a meta-analysis shows that by the age of 40, an individual's cognitive speed is expected to drop by 20%, this is expected to drop further, to 60% by the age of 80[15]. Therefore, it is considered likely that older adults aged 70+ would present with some level of cognitive decline.

The user has spent 12 years or less in full-time education, and has self-reported a noted decline in memory or cognitive functioning. A high level of education is believed to have a protective effect on the level of cognitive decline an individual may present[16]. Therefore those who reported to have spent 12 years or less in full-time education, were more likely to present with cognitive decline. Furthermore, users were asked whether they have noticed or have been aware of any decline in memory or cognitive functioning. Self-reporting of changes in cognitive functioning or memory is an accepted means of identifying individuals who are presenting with some level of cognitive decline[17].

The user scores lower than average on at least one sub-scale of Addenbrooke's cognitive examination (ACE-R). Although the ACE-R is not as widely tested as the MMSE, since it is a relatively new screening tool, it fully incorporates the MMSE and it is now widely accepted that the ACE-R is significantly more sensitive than the MMSE alone[18]. Like the MMSE, the ACE-R is still considered to be a brief, sensitive, and inexpensive screening tool[19] that can typically be administered in less than 10 minutes. It is also shown to be more effective in picking early cognitive dysfunction/mild cognitive declines[18] compared with the MMSE.

Online-form interaction

The main trial activity took place in laboratory conditions, with one researcher present in the room at all times. Users were presented with a DIADEM enabled online-form, which they were asked to complete whilst 'thinking aloud', and where possible provide comments on the effectiveness and efficiency of the form. Any questions the user had at this stage were answered. Users were advised that minimal assistance from the researcher would be provided throughout the task, in order to achieve a realistic idea of typical challenges encountered when completing the online-form. Each session was tape recorded, and notes were also taken, which would be used along with the tape recorded data at the analysis stage.

Post online-form interaction

On completion of the online-form, users completed a short satisfaction questionnaire. The Software Usability Measurement Inventory (SUMI) questionnaire[20] was chosen as most appropriate for these trials. It consists of 50 short and clearly worded statements, and can be administered relatively quickly (typically in less than 10 minutes). One of the key benefits of SUMI, compared with other satisfaction questionnaires, is that it is made up of short statements that do not use irregular or low-frequency words, which as a result are likely to be easily comprehensible by the older adult target user group[9]. Another benefit of SUMI is that the results can be compared with the benchmark SUMISCO database, which is a collection of over 3000 SUMI questionnaire results collected for a wide range of users and software applications. Finally, users were given the opportunity to elaborate on any of the think aloud comments made during the interaction task.

Log-file data collection

Log files, recording user interaction behaviour and system responses to this behaviour, were created for each trial session carried

out in the UK. The data recorded in the log file served as a valuable source for gaining further insights into the older adult's interaction experiences. One of the key features of the application is to provide assistance to the user by monitoring user interaction measures, and triggering rules from the ES rule set, which result in triggering the system to provide the user with pro-active assistance. The log-file data contained a record of the number of times ES rules were triggered throughout each session. Therefore, this made it possible to carry out an evaluation of the frequency of ES rules triggered for each individual user, compared with their respective levels of cognitive decline, as indicated by corresponding ACE-R scores. The outcome of this evaluation would reveal whether the DIADEM application appeared to achieve its goal in providing increased levels of assistance to users with comparatively high levels of cognitive decline.

Data analysis

After all trials had been completed, a number of tasks were carried out in order to analyse the data collected.

The information collected for each user that took part in the trials was analysed during this phase. Initially, based on the inclusion criteria, this involved identifying user data that was eligible to be included at the analysis stage. Of the 94 users that took part in the trials, 77 were included at the analysis stage of which 39 were female, 38 male, with an overall average age of 67.8. Overall, 31 users were aged 70+, 31 end users self-reported to have experienced a decline in memory or cognitive functioning and were in full-time education for 12 years or less. A total of 58 of the 77 end users were eligible for analysis by scoring below the ACE-R inclusion thresholds for one or more of the five ACE-R subscales.

A thematic analysis was carried out on the 'think aloud', and semi-structured interview data collected during the trials. Five key steps were taken to analyse the data. Initially all audio tapes were transcribed into text format. The textual datasets (including observational notes taken by researchers during trial sessions) were then initially perused to conceptualise the overarching themes that existed within the textual datasets at a high-level, and noted in a coding template. The dataset was then examined iteratively, enabling themes and sub-themes to be developed further. These were spliced and linked together, and text relating to each category and sub-category was appropriately labelled. When no further refinement of the categorisation could be derived, a final group of categories and sub-categories was produced. See Silverman[21] for more detailed descriptions of the thematic analysis process. The key themes and sub-themes that arose from the thematic analysis are now presented.

The analysis of the SUMI questionnaire responses included a comparison of the DIADEM SUMI scores against the SUMISCO database, which is made up of over 3000 SUMI questionnaire responses.

Key findings

On screen input

Theme description: Key issues that arose from users inputting information, and relating to the various input mechanisms used in the online form (for instance, drop-down boxes, radio buttons, free-text boxes).

Drop-down boxes

Drop-down boxes provide a mechanism for inputting information without typing. These posed frequent difficulties to users. In the majority of cases, users commented that they found it tricky to select the drop-down arrow on the side of the menu and in many cases didn't even realise the arrow needed to be selected. The majority of these users clearly stated that they found them awkward to use. For example, some user comments included:

'Why's it do that? It's not allowing me to type in the answer!'

'What do I do now, where's it gone?' (Referring to the flashing cursor that disappears on selection of the drop-down box.)

Free-text boxes
Multi-lined free-text boxes provide a mechanism for the user to provide information in free-text format. In the change of address form, a multi-lined free-text box was used to allow the user to provide their old address details. Users frequently encountered problems with multi-lined free-text boxes, most commonly because they did not realise that the carriage return button had to be pressed to get to the next line of the free-text box. One user summed up the difficulty as follows:

'Why can't they just give you one long line to type in the answer?'

Radio buttons
Users were positive about the radio-buttons within the forms. The standard DIADEM radio button sizes are larger than those found in the original versions of the forms. As a result, it seemed that users were more able to make accurate selections as a result of this. Occasionally, as in previous trials, users attempted to click on the area around the radio-button. Therefore, there may be a case for increasing the size of click-sensitive area around the radio-button.

On-screen navigation
Theme description: Issues relating to how the user were expected to navigate their way around the form.

Scrolling
Users experienced difficulties when required to scroll down the form. Many users found it difficult to use the scroll bar function with the mouse, particularly to scroll to the segment of the form they needed. Consequently, they often attempted to use the arrow keys on the keyboard instead, which only allowed the user to scroll down the screen if they did not have a field selected. Whilst attempting to scroll, they often clicked on non-click sensitive parts of the form. Some users thought they had completed the form when they got to the last question displayed on the page, and then started to look for the 'finish' button. Users summed up their thoughts about the online form sections that required scrolling as follows:

'Why should it be more than one page? If it was all on one page, you wouldn't have to think if you'd finished or not.'

'It's just not obvious when you have to scroll down.'

Other issues with scrolling included that, occasionally, only part of a question was presented on-screen, whilst the other half of the question required scrolling down to become visible. Because some users were not familiar or able to use the scroll function effectively, they attempted to answer the question without knowing what the full question was.

Flashing cursor
The DIADEM application provides the user with an arrow indicator, either side of the selected input field, to help the user identify the location of the flashing cursor. Many users found this to be a useful feature. However, a number of other users still managed to lose sense of the location of the flashing cursor. This may be because users appeared to use different cues to locate the flashing cursor, some relying on the arrow indicators, and some ignoring the arrow, and looking specifically for the cursor itself. For the latter group of users, often the size of the flashing cursor was considered to be too small and cause problems.

Mouse pointer size
Users also struggled to move between input fields when using the mouse. The key difficulty was that users often struggled to click on the exact on-screen location to enable them to enter into the next field. One user felt that it would help to increase the size of the mouse pointer, saying:

'That (pointing at the mouse pointer icon) *should be bigger and darker.'*

Moving between questions
The DIADEM application greys out questions once they have been correctly completed. Users found this feature extremely useful, and intuitive. A number of users made positive comments about this feature, for example:
'The colour change helps you.'
'Turning gray is a good indicator.'

Moving between sections
Users often had difficulties in understanding how to move between sections of the online form. Although the application standardised the 'Next page' and 'Previous page' buttons for the users to navigate the form, often the user was not aware of the location of these buttons within the form. The reason for this was that the buttons only appeared when the user scrolled right down to the end of the form, and thus taking into account the difficulties users had with scrolling, many users were oblivious to the 'Next page' and 'Previous page' buttons. One other comment users made, was that the 'Next page' button should be located on the right hand side of the form, and only the 'Previous page' button should be located on the left hand side of the form.

The other mechanism provided for users to navigate between form sections was the tab system at the top of the form. Many users were not familiar with tabs or how they worked. However, even those users that were familiar with tabs, rarely used the tabs without eventually being prompted. The main cause for this seemed to be that when the users were ready to move to the next section of the form, they were near the bottom of the screen, and the tabs were no longer visible. Therefore the tabs did not always serve as a useful means of navigating to the next section of the form.

Assistance
Theme description: Comments regarding audio, textual, and visual prompts and assistance offered within the online-form.

Pro-active voice assistance
Based on user interaction behaviour, the ES rules implemented for the pilot application triggered a system response in the form of pro-active voice assistance (spoken instructions). In principle users felt that the voice assistance was a valuable and positive addition to the form-filling exercise. They felt that it was more useful to have pro-active voice assistance compared with just textual assistance, and gave a personalised feel to the interaction experience. They also liked the idea of having a dialogue with the system. One problem with the pro-active voice assistance was that it kept repeating instructions if the user did not perform the action the application was expecting. This repeated instruction was seen to be invasive and distracting.

Read-out loud question text
DIADEM also offered users audio assistance by reading out loud each of the on screen questions, when the question text was clicked on. Users were positive about this feature, and felt it helped to hear the audio version of the question as well as to read the textual version of the question on-screen. This function helped to add clarity in terms of what was required of them. This version of the DIADEM application, however, did not provide reading out loud of the text displayed in the help sections, which users seemed to be expecting, based on the fact that question text did offer this functionality.

Design recommendations
A number of online-form design recommendations were developed as a result of the thematic analysis (*Table 1*). These will be integrated into version two of the DIADEM application.

Although these design guidelines have been developed specifically for the DIADEM application, they also serve as a valuable point of reference for online form designers. Adhering to these guidelines is likely to result in the development of more usable online-form content for the cognitively impaired older adult user group.

Table 1. Recommendations and suggestions that arose from the thematic analyses of DIADEM version 1

Avoid multi-lined free-text boxes	Use single lined free-text boxes
Enlarge click-sensitive areas around radio buttons	Allow text corresponding with each button to be click-sensitive
Minimise the need for scrolling	Allow user to tab/next page through content
Enlarge the default size of the flashing cursor	Provide users with the added option of altering cursor size
Enlarge the default size of mouse pointer	Provide users with the added option of altering pointer size
Grey out completed questions	Avoid red as users may interpret this as highlighted errors
Keep 'previous page' buttons visible at all times and locate them on the left hand side of the screen	Locate them at the bottom of the screen
Keep 'next page' buttons visible at all times and locate them on the right hand side of the screen	Locate them at the bottom of the screen
Keep navigational tabs visible at all times, and provide additional navigation aids	Provide 'next page' and 'previous page' buttons
Provide the option of pro-active spoken instructions	Spoken instructions reflect textual instructions accurately
Do not repeat pro-active spoken instructions, unless requested by the user	Provide user with a button that plays spoken instructions when clicked

SUMI findings

SUMI reports results on five sub-scales (Efficiency, Affect, Helpfulness, Control, Learnability) and one overall scale (Global), which is the sum of the five sub-scales (*Table 2*). Efficiency represents the extent to which users feel that the software helps them with their work. Affect relates to the user's emotional reaction to the application. Helpfulness is the extent to which the application is self-explanatory. Control measures how in-control of the application the users feel. Learnability is a measure of how quickly the user feels they were able to master the use of the application.

SUMI scores have been transformed so that they may be compared against the SUMISCO database average, which is fixed at 50 for each of the scales. The results may be interpreted as follows: If a scale score does not encompass 50 within its Ucl/Lcl range, it may be considered 95% certain that the results are higher (if the range is above 50) or lower (if the range is below 50) than SUMISCO database average. If the score incorporates 50, the results may be considered to be similar to the SUMISCO database.

Table 2. SUMI scores for the 5 subscales and their combination compared with SUMISCO database; UF=Upper Fence; Ucl=Upper confidence level; Lcl=Lower confidence level; LF=Lower Fence

Scale	UF	Ucl	Median	Lcl
Efficiency	80	50	47	44
Affect	84	59	56	52
Helpfulness	82	55	52	49
Control	77	51	49	46
Learnability	91	55	51	47
Global	84	55	52	49

As can be seen, Efficiency, Helpfulness, Control, Learnability and Global all incorporated 50 in the Ucl/Lcl ranges. Therefore it may be inferred that DIADEM-enabled forms achieved levels of user satisfaction similar to the benchmark SUMISCO database. However, the Ucl value achieved for Efficiency was 50, which indicates that DIADEM only just achieved similar levels of efficiency compared with the SUMISCO database. Therefore, it is likely that future versions of the DIADEM application may benefit from focusing effort on improving the ways in which users are offered help by the application. The Ucl/Lcl range for Affect was 59/52, which was above the SUMISCO database average, indicating DIADEM-enabled online-forms on average were more likeable than the benchmark SUMISCO database scores.

Analysis of ES rules

An important outcome of these trials was to evaluate the ES rule triggering mechanisms employed in the DIADEM application. In particular, it was important to establish whether the ES rules appeared to be sensitive to users who presented with comparatively high levels of cognitive decline. In order to explore this, the frequency of ES rules triggered in each session was compared with the ACE-R scores achieved by each respective user (which was used to represent level of cognitive decline). It was hypothesised, that if the ES rules were being triggered effectively, then the number of triggers within a session would increase as the users' ACE-R score decreased (the lower the ACE-R score, the higher the level of cognitive decline).

In order to test this hypothesis, the log files recorded for the UK participants were analysed and the number of ES rules triggered were counted for each user. A Pearson's r correlation test was carried out, comparing the number of ES rules triggered with ACE-R scores achieved by each of the 33 UK users. Since we hypothesised that frequency of ES rules would increase as the ACE-R scores decreased, a one-tailed test was used (*Table 3*).

As can be seen, there was a significant negative correlation between ACE-R scores and the number of ES rule triggers during a session ($r = -0.298$, $n = 33$, $P < 0.05$). Therefore the DIADEM application was successful in triggering significantly more ES rules for users who achieved comparatively low ACE-R scores (presenting with higher levels of cognitive decline). These results are promising, as they indicate that the DIADEM application appears to be sensitive to the user level of cognitive decline, and provides increased levels of assistance accordingly.

Conclusions

This paper has presented a trial protocol and demonstrated how it has been used to identify cognitively impaired older adults, and evaluate the online-forms produced by the DIADEM application. The trial protocol supports the collection of a range of subjective and objective data, including ACE-R scores, think aloud data, semi-structured interview data, SUMI scores, and log-file data, which enabled the effective evaluation of the DIADEM application.

Lessons learned

A number of lessons have been learned as a result of the implementation of the trial protocol within the context of the DIADEM project:

(i) To avoid confusion and maximise participation rates, it is important to provide clear verbal and written instructions to older adult users, including written confirmation of agreed meeting dates, times, and locations.

(ii) The three-fold inclusion criteria used in the trial protocol provided a significantly higher ratio of user data being included in the analysis phase, compared with previous

Table 3. Pearsons correlation (r) for ACE-R scores and number of ES rule triggers; confidence limit = 0.05 (one tailed)

	ACE-R	ES rule triggers
r	1	-0.298
p		0.046
n	33	33

trials that used the MMSE as the primary means of including or excluding user data.
(iii) Given that the ACE-R cognitive examination is recognised as being more sensitive than the MMSE, this allowed user data to be included at the analysis stage, with a greater degree of confidence.
(iv) The majority of older adult users appeared to grasp the concept of the talk-aloud protocol and seemed to provide 'think-aloud' data readily.
(v) Carrying out a thematic analysis on the 'think-aloud' data and semi-structured interview data, proved to be an extremely useful approach to analysing such qualitative data.
(vi) The SUMI questionnaire provided a useful measure of user satisfaction, and seemed to be well received by the older adult users. Older adult users seemed to understand the questions, and generally completed the questionnaire in less than 10 minutes.
(vii) Collecting post-task data helped to triangulate and confirm the themes identified within the think aloud data and observational notes taken by the researcher during the trial, and provided a useful additional point of reference whilst carrying out the thematic analysis.

Although from a technical perspective there was some overhead in configuring the DIADEM application so that appropriate log-file data could be collected, this data proved to be valuable in validating the trigger mechanisms used for existing ES rule set.

Future work

In terms of the key findings of the trials, the thematic analysis carried out on user think aloud data and semi-structured interview data revealed a number of positive system design features for the overall design of the DIADEM interface, such as the pro-active voice prompts, enlarged radio-buttons, and read out loud questions feature. A number of design guidelines that will be applied to the future versions of the DIADEM application were also identified. Some of these include: extending the read out loud questions feature to include help text, and reducing the repetition of pro-active voice prompts. Indeed these guidelines provide valuable guidance not only for the DIADEM application, but for online-form content more generally. Online-form content designed according to these guidelines, is likely to result in more usable online form content for the cognitively impaired older adult user group.

The results of the SUMI satisfaction questionnaire revealed that four out of the five satisfaction sub-scales (Efficiency, Helpfulness, Control, Learnability) and the overall satisfaction scale (Global) achieved levels of user satisfaction similar to the benchmark SUMISCO database. However, the score achieved for Efficiency was the lowest of these four, which indicates that more work could be done to improve the applications performance relating to this sub-scale. Since the Efficiency sub-scale relates to the extent to which users feel the application assists them in their work, it is likely that future DIADEM development effort could be best spent on improving the ways in which the user is assisted in completing online-forms, and the ways in which this assistance is provided to the user. Conversely, the Affect sub-scale achieved above the average SUMISCO benchmark. These results are extremely encouraging, when considering that these scores were achieved from an older adult user group, that is likely to present with some level of cognitive decline. Indeed, a study by Nielsen[22] found that web content is twice as difficult to use for older adults aged 65 and over, compared with younger users. Hence, if DIADEM was not effectively catering for older adult's needs, SUMI satisfaction scores may well have been expected to be considerably lower than the benchmark SUMISCO database averages.

An analysis of the UK log-file data revealed that the DIADEM application provides more frequent assistance to users that present with higher levels of cognitive decline. These are promising results, which provide valuable support to the overall direction of the project. In particular, the findings indicate that the measures used to monitor user interactions and the mechanisms used to trigger

ES rules appear to be particularly sensitive to users that present with high levels of cognitive decline.

Future research, in the short term, will involve making preparations for user trials that will be carried out to evaluate DIADEM version two against legacy online-forms. This will allow us to verify the value of the DIADEM application compared with the original versions of the online-forms adapted by DIADEM. In the medium term, one of our key research activities will be to evaluate the usability of DIADEM-enabled forms within a variety of real-world settings. This will allow us to develop guidelines specific to the environment in which the DIADEM application is used. For example, it may be the case that audio assistance is only desirable, when completing online forms in private or within a setting that does not have other audible influences such as radio, television, and crowd noise. As a step towards this, we have already commenced with the development of DIADEM enabled online-form browsing kiosks, that will be positioned within foyer areas of County Council buildings in the UK. Other valuable research directions may include exploring the potential of exploiting developments in the modal/continuation-based web-server research domain. This may make it possible to continually monitor the state of the user's progress within the context of the web-based application functionality as a whole and open up new opportunities to expand on the existing DIADEM application functionality.

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