Abstract

This paper presents the design of blind user requirements engineering (BURE). It extends wide audience requirements engineering (WARE), a method for data collection, analysis, and presentation of system requirements for users; who are widely dispersed and may have little connection to the organization or technology and little motivation to participate in requirements engineering efforts; to accommodate blind users. We extended WARE data collection and analysis techniques to accommodate blind users' limitations in the use of textual and visual media. We demonstrate use of BURE in an RE effort among users in New Zealand and Germany to develop requirements for mobile service applications and features for blind users and validate its use in a follow-up survey among such users.

Keywords: Requirements elicitation, blind user requirements engineering, wide audience.

1. Introduction

There are approximately 161 million people in the world who are vision impaired, according to the World Health Organization, including 37 million who are blind (Wikimedia 2007). Furthermore, the number of blind people in the world is increasing, largely because of increased life expectancy and age-related causes for blindness, such as cataracts and macular degeneration. Clearly, there is a need to insure that information systems are designed to be accessible and usable for this very large population of users and potential users. Furthermore, we all as users have difficulty in relating what we want from information systems (Sutton 2000). Blind people have special requirements when accessing information systems. Computers and mobile devices are, first and foremost, visual media. Hence, special arrangements are required to make the technology accessible. This requires consideration of appropriate input and output mechanisms on the hardware side and a usable representation of information for applications and content.

Traditionally, user interfaces have been designed to accommodate the information presentation on visual displays. For example, Internet sites have been built based on table layouts with menu items as graphical buttons. Early on, there was little consideration of how alternative input or output mechanisms could effectively process information for the blind.

In recent years, however, voluntary and legislated efforts have begun to address these needs. Section 508 of the US Code commits federal agencies to comply with standards intended to make Internet sites universally accessible. Furthermore, the Americans with Disabilities Act requires that covered employers make efforts to insure that disabled employees are able to
effectively access information systems. Jurisdictions elsewhere have enacted similar legislation. IT vendors such as Microsoft and Apple have integrated accessible facilities in operating systems and third-party vendors made special accessibility hardware available to supplement standard IT configurations.

While these efforts promise the potential to make systems accessible and more usable for blind users, accomplishing this task will require enormous effort in requirements engineering (RE) and design. Ironically, little has been done to insure that RE processes are effectively accessible to the blind.

Can we design an RE process that is accessible and usable for the blind user? Research is emerging that addresses the problem of RE for users who are widely dispersed, outside the organization, and who have little connection to the firm and little familiarity with the technology. Wide audience requirements engineering (WARE) (Tuunanen et al. 2004) is an RE method that involves such users in the RE process in ways that permit rich data collection, that economically involves remote and modestly motivated outside users, and that presents data to decision makers and designers in ways that help them deeply understand user preferences and reasoning, without the need for interactive consultation, thus promoting users' own productivity and creativity (Mich et al. 2005).

Blind users are a special case of the wide audience end user. Such users are widely dispersed, making data collection expensive and difficult (Tuunanen 2003). They come from a variety of local cultures and have their own group culture, so designers may not intuitively understand their preferences (Myers et al. 2002; Overby et al. 2005). Involved in their own everyday activities, they may not be motivated to participate in RE (Peffers et al. 2003). Finally, RE among this user population involves the same accessibility issues as do their use of systems for which their involvement is needed. Research has suggested that “turning personal goals into specific requirements,” (Sutcliffe et al. 2005) as WARE does, may be a good way to understand requirements for systems to be used by disabled persons.

In this study we extend WARE for use among blind user participants to develop blind user requirements engineering (BURE). BURE incorporates accessibility techniques to allow blind users and potential users able to effectively participate in the data gathering and validation parts of the RE process. We employ the design science research paradigm (Hevner et al. 2004) to identify the problem and objectives of a solution, and to design a method to address the objectives. We demonstrate the use of BURE in the context of RE for mobile services and features that would benefit blind users. Finally we evaluate the identified services and features in a follow-up survey of blind users.

This paper makes several contributions to the RE literature:

1. It justifies the need for RE methods that accommodate the needs of blind users.
2. It develops an effective method for data collection, analysis, and presentation of user requirements for blind users.
3. It demonstrates the method with the development of requirements for applications and features that would benefit blind users.

The demonstration includes a conceptual proposal for a system, the Virtual Voyager, that could be implemented and would be highly valued by users.

This paper is organized as follows. In section 2 we detail the objectives of a solution to the problem. Section 3 briefly outlines the designed BURE method, an extension of WARE. Section 4 demonstrates use of the method to develop the requirements for mobile service applications
and features for blind users. Section 5 evaluates the requirements. Section 6 concludes the paper with a recap of what we accomplished and a brief agenda for future research.

2. Objectives of a Solution
IT based consumer products intended for blind users are a special case of wide audience information systems, the requirements for which are addressed by WARE, an RE method for use with widely dispersed users. Blind users, geographically scattered as they are, clearly fit WARE’s intended target, “users [who] may have little relationship with the firm, are more costly to reach, may have different world views, and may not be available for iterative RE efforts (Tuunanen et al. 2004).” Additionally, blind users have special needs for RE.

Explicit BURE objectives include:
Because these users are widely scattered and likely to lack motivation to participate in RE efforts for specific new systems, their involvement in RE is likely to require aggressive recruitment, including a layered recruitment effort involving such attributes as the involvement of blind organizations for targeted communications and snowballing.
Because of the inherent ineffectiveness of visual aids for this target group, data collection efforts are likely to require techniques that make heavy use of oral communication with participants, such as oral presentations of stimuli and participant responses, oral thematic descriptions, and the use of scenarios.
Heavy reliance on oral communication, without visual memory aids, is likely to require adaptations, such as stimuli simplification, simplified importance ranking or the substitution of Likert-type ratings, and scenario-based presentation of features for feedback, to accommodate working memory limitations among the participants.
Interestingly, there is empirical support for the idea that structured interviewing, as WARE uses, without the benefit of visual aids, is as or more effective for requirements elicitation than other techniques (Davis et al. 2005).

3. Blind User Requirements Engineering
Here we briefly outline procedures for the BURE method, designed to meet the objectives described in section 2. Figure 1 shows a graphical representation of the method.

Pre-Study. Determine the scope of the study and the desired participant characteristics. Recruit participants with an aggressive, multi-layered approach that may include communications through blind organization channels and snowballing, to elicit participation by the targeted group. If appropriate, screen participants for desired characteristics, such as “lead user” attributes. Lead users are a minority of savvy users whose experience can be exploited to predict future trends (von Hippel 1986). Use interview scheduling as an opportunity to collect stimuli by asking the prospective participants for ideas (Browne et al. 2001). Simplify the stimuli for oral presentation and to accommodate working memory limitations of oral presentation, by reducing the number of items in the stimuli and the verbal complexity of their presentation.

Needs elicitation. Collect data from the participant in a one-on-one oral interview, using the laddering method (Browne et al. 2001). Ask the participant to choose two of the most appealing stimuli. Starting with the most highly ranked stimuli, ask “how would this work for you” to elicit specific features and continue with “why would that be important for you” questions to elicit a chain of consequences and values. Record the responses as chains in a spreadsheet or equivalent and back up the interviews with audio recordings.
**Needs evaluation phase.** Ask the participant to prioritize his/her own ideas, in order to give the participant an opportunity to reflect over the proposed features. In a two step rank ordering process to reduce working memory demands, ask the participant to identify and rank order the several most important of his/her feature ideas and then separately to rank order the remaining ones. Record the data as inverted ranks.

**Model aggregation phase.** Cluster the laddered interview data into themes and create thematic maps. Code the individual statements in the data as attributes, consequences and values items. Determine a number of themes, ideally no more than seven to accommodate working memory limitations, that represent the data in the chains and assign each chain into one or more themes. Create “value maps” for each theme that depict the links between attribute, consequence and value codes as they occurred in each chain. Arrange the value maps to show sub-themes, clusters of attributes, consequences and values, within the themes. These maps provide a graphical picture of all chains in particular themes and sub-themes.

**Pre-Study**

**Needs Elicitation**

**Needs Evaluation**

*User ranks own ideas*

**Model Aggregation**

**Model Evaluation**

*User evaluates aggregated ideas*

- Selects most important themes
- Selects most important features
- Gives reason for preference

**Presentation**

**Figure 1. BURE**

**Model evaluation phase: Selecting most important themes.** Focus on the topic areas of most importance to the users. Create a list of brief descriptions of each of the themes. Present the participants with the list, asking them to rate the importance of each theme using a Likert-type scale. Record the responses as Likert scale scores to weight the importance of the themes.

**Select most important features.** Develop scenarios that briefly describe attributes and consequences for groups of features, so as to appeal to a user’s imagination about having several features available in a system. Depending on the complexity of each theme, scenarios should contain two or more features. Read the scenarios to participants and ask them to name the features that are most interesting or important to them and record the importance responses as Likert scores and identify the most important features for each participant.
**Give reasons for preference.** For a participant’s most preferred features ask him/her “Why is this feature important to you?” to elicit reasoning for the choices and record the responses. This post-analysis feedback instrument will serve as a constructive critique or confirmation of the analysis phase. If necessary, the users’ critique can be incorporated into the refinement of the suggestions.

**Presentation phase.** Incorporate the collected data, analysis, and specific user comments into a business report written for the client. This report should include an elaborate description of the most-valued systems and their features. Moreover, it should state the consequences and the values the systems address.

**Demonstration of the designed solution**

Here we demonstrate the use of the designed method, BURE, in a case study where we use it to develop requirements for mobile services for the blind. We carried out the study in New Zealand and Germany in 2006. We start with data gathering and continue with analysis, presentation and results.

**3.1 Data collection**

Target participants for the study included blind lead users. Lead users are people who have a propensity to adopt new technology early in its lifecycle and are thought to be particularly valuable for providing data about which new products and features might find favor in the future (von Hippel 1986). We foreswore the use of participant incentive payments, thus insuring that recruiting participants would be challenging.

Our objective was to recruit at least 20 participants, the minimum necessary to make the study results meaningful (Peffers et al. 2003; Tuunanen et al. 2006; Tuunanen et al. 2004). To recruit participants in New Zealand we employed communications channels of the Royal New Zealand Foundation of the Blind. We sent several hundred emailed invitations to the foundation’s lists, inviting list members to take a short screening survey. We posted an announcement on the foundation’s telephone oral newspaper service. In addition, we asked willing participants to nominate other likely participants and contacted them, either by email or through the referring participant. After four weeks, these efforts yielded five participants.

We continued recruitment by making a presentation at a foundation training center, where we explained our research objectives in the classroom. This yielded 5 more participants. Foundation staff contacted some people directly, yielding 3 more and one staff member agreed to participate. In all, we recruited 14 potential participants in New Zealand.

Next we turned our attention to Germany, where Trierische Tonpost publishes a monthly “spoken magazine” for 850 blind and vision-impaired subscribers across Germany. A solicitation in this medium yielded nine, for a total of 23 participants.

To screen for lead users, we asked a series of questions, derived from a screening device used elsewhere (Tuunanen et al. 2006), to assess the use of new technologies. Part 1 contained six statements about the use of mobile and assistive technologies. Part 2 posed two questions about mobile and adaptive technology the participants have used. The survey was available as an Internet questionnaire and by telephone. One participant was screened out of the study in this process.

This left us with 22 participants, for whom table 1 shows sample demographic data. Note that the age distribution is more heavily weighted with people who are less than 40 years old and the sample was male dominated.

All participants that qualified for participation were telephoned to invite them to participate in individual interviews. At the end of each phone call they were asked to give one idea for a
potential system that could be of interest to them. Some participants contributed three or more ideas. After the first seven invitations we developed a preliminary list of stimuli for use with the first interviews. This was gradually extended and refined with new ideas for the remainder of interviews. This allowed us to start with the interviews before all participants had committed to taking part.

<table>
<thead>
<tr>
<th>Table 1. Participant demographic profile.</th>
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<tbody>
<tr>
<td>Age Distribution</td>
</tr>
<tr>
<td>18-29 years</td>
</tr>
<tr>
<td>30-39 years</td>
</tr>
<tr>
<td>40-49 years</td>
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<tr>
<td>50+</td>
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</table>

We conducted the interviews, lasting an average of 35 minutes each, in person or by telephone, using the laddering method (Browne et al. 2001). We audio recorded each interview and took notes on an electronic spreadsheet. To wind up each interview, we asked the participant to evaluate the ideas that they had contributed. To avoid working memory overload, we first asked the participant to identify the three most interesting ideas in rank order. Then we collected a rank ordered list of additional items that they thought interesting.

3.2 Analysis
The interpretive analysis process involved four steps. First, we determined seven “themes,” or concepts, that would cover all chains. Next, we assigned each chain to one of these themes. Next, within each theme, we grouped participants’ statements by attribute clusters, consequence clusters and value clusters, to highlight clusters, or subthemes, within each theme. Finally, for each theme, we drew a value map, a graphical representation that shows preferences and reasoning of the aggregated chains that it contains.

Two researchers independently examined the data to develop conceptual themes that would incorporate all of the chains; one developing ten and the other seven. They reached a consensus on seven themes by discussion.

Next the two researchers independently assigned each of the chains to one of the themes. They initially agreed for 86% of the chains, a high level of agreement, compared to similar studies (Tuunanen et al. 2006; Tuunanen et al. 2004), and resolved differences through discussion, for six chains including them in two themes each and placing one chain in three themes. One chain was dropped from the analysis due to feasibility concerns.

Each participant expressed his/her preferences and reasoning using different language. Consequently, to interpret the data within themes, we clustered the chains by attributes, consequences and values, assigning a common label to each of similar attribute, consequence and value statements. The names followed the language used by participants to the extent appropriate. By assigning these labels it was going to be easier to get a bird’s eye view of the themes and their features and to depict links among attributes, consequences and values in the themes. By sorting by the labels, this allowed us to see clusters within the themes.

We copied each chain into a spreadsheet and labeled it according to the theme to which it was assigned. Then we grouped the chains into clusters, stepwise, by attributes, consequences and
values. Where chains included more than one attribute each, we copied them into more than one
chain, where necessary, to cluster.
Next, we arranged the codes theme-wise in a graphical representation, to form “value maps,”
creating one map for each theme on partitioned sheets with areas for attributes (left),
consequences (centre) and values (right).
Figure 2 shows a value map for the theme “Shopping assistant”. At a glance, it can be seen that
most system features (left) eventually lead to the value “independence” (far right). With the same
granularity as the chains are noted in the electronic spreadsheet, they were now traceable in an
easy to understand graphical format.
With the aggregated models of user preferences in hand we proceeded to getting post-analysis
feedback from the users. In the initial interviews we grounded user’s individual preferences for
mobile services. In this phase, we gathered feedback on what every user thinks about the features
all participants contributed.
The feedback was gathered in short phone interviews. All participants were called with the
objective to have a 10-minute feedback chat. Three participants could not be reached by
telephone. In total, we successfully contacted 18 for the post-analysis feedback session. The
three steps to elicit user feedback are further described below.
Selecting most Important Themes. The initial challenge was to find a representation that gets
the user familiar with each theme and its associated features. We did not want to overwhelm the
users with descriptions that were too verbose. To limit complexity, we wrote a theme description
that included a refined name of the theme, followed by a summarized enumeration of the related
features. We read out the theme summaries one by one and clarified the specifications if
necessary. After each summary we asked the participant to indicate, on a scale between 1 (not
important) and 10 (very important) how important the particular theme was to him/her.
Selecting most Important Features. We broke down each theme into written scenarios to
summarize groups of features. The narratives aimed to introduce participants to features, of
which they might never have heard. Each scenario started off with “Imagine…”, then named the
features and explained them if necessary. The scenarios also stated what one could accomplish
with a particular feature or features. These constitute the consequences that manifest themselves
when having the feature available. For example, one scenario read, “Imagine you had a rather
bulky phone with, large, raised and well spaced-apart keys, with square-shaped number keys and
differently shaped function keys, arrow keys instead of joysticks, more wheels and switches, and
a dot on the 5. This would result in a more accurate input.” Participants provided importance
ratings for the scenarios in a manner similar to that above for the themes.
Compile Rankings. Using the data from the feedback interviews, we used the Likert ratings for
themes and feature groups, normalized for the number of items rated, to compute rank order
ratings for each theme and feature cluster.
3.3. Results
The post-analysis feedback, revealed that the themes “Navigation and Routing Device”,
“Shopping Assistant” and “Traffic and Public Transport Assistant” were unquestionably most
important to the participants. Furthermore, many participants noted that the first and third of
these themes were highly related.
In Figure 3 we presented the network map for the theme “Navigation and Routing device”. It
lays out the links among system features on the left, consequences in the middle, and personal
values on the far right. A “Navigation and Routing Device” would enable spatial guidance with a
mobile device. It would be a personal city navigator for the Blind that would come with GPS functionality and a route management facility as well as tracking services for guide dogs and family members. A ranking score accompanies the features on the left. The higher the value is the more important the feature was rated. Within the “navigation and routing” theme, the four highest scoring features in descending order were the following.

**City navigation guide.** This feature was ranked very high because it came very close to a complete personal navigator that participants wanted. It would incorporate navigation assistance, telling the user where and when to turn. In addition, it would announce the name of the street one is currently on, as well as the name of intersecting streets and house numbers. It would also inform the user about restaurants, cinemas and theatres. Ideally, it would have public transportation assistance integrated.

**Underground reception of service.** Participants reasoned that such a navigator would only work well if it was available anywhere, especially underground and large buildings. This would ensure best possible reliability and it would mean less asking around.

**Bookmark and manage routes.** This feature has been assigned highest priority by all participants who voted for this theme. The main idea is that the service can be personalized. It should be possible to bookmark (or save) and manage all walking routes. Apart from that, landmarks that lie on the route should be saved. Participants wished to ‘record’ routes; i.e. they wished to press a button at the origin and, once again, at the destination to save a route. This feature also incorporates the option to reverse a saved route so that a return path is easy to manage. With such a route management feature, a blind and vision-impaired person would dare to take routes other than his/her standard ones. Moreover, frequently visited spots would not need to be entered again.

**Show where peers are located.** The participants highly valued the usefulness of a mobile system that could track the position of peers, such as one’s children and spouse. The persons to be observed would carry a GPS device that transmits their current position to the observer’s mobile device or home computer. This service would ensure that blind parents knew where their children were located, one of many factors that would assure responsibility and thus equal participation in society.

In the analysis section, all participants were made familiar with all seven themes to get feedback on them. A considerable portion of the participants stated that the themes “Navigation & Routing” and “Traffic & Public Transport Assistance” are highly related and that they would like to see them combined. The two themes together would allow blind people to explore unfamiliar areas. A German participant specifically stated that a mobile navigation device would only make sense if it had routing and tracking functionality combined with Europe-wide public transport and airport information. Overall, these two topic areas were rated first and third. Combining them to one system would certainly yield a service that would be highly valuable.

The theme “**Shopping Assistant**”, ranked second, caters for short-range navigation in stores. Such a mobile service would announce a shop that a user is passing, guide him/her to the correct aisle and identify a product on the shelf. A shopping assistant would fit to the wide-range navigation solution explained above. The name of a shop would be announced while a user is navigating through the streets.
Moreover, all three themes would enable a more “independent lifestyle,” a value that was expressed over and over again when relating to features within these three categories. Therefore, we propose a mobile service that would integrate all three themes: “Virtual Voyager”.

The conceptual model of the “Virtual Voyager” is illustrated in Figure 4. It emerged from the three top-rated themes as well as from the highest rated features within each theme. The themes and their features have been drawn from the theme maps of “Navigation and Routing Device”, “Shopping Assistant” and “Traffic and Public Transport Assistant”. For the purposes of this conceptual model, the features were re-grouped in an interpretive manner.

The first building block of the “Virtual Voyager” is a city navigation guide that navigates a blind person through cities and that takes care of routing and storing of routes. In addition, it integrates public transport information in the form of mobile timetables so that notifications about delays or variations in the schedule would be announced. Secondly, as part of a city-wide navigation service, it would announce certain shops a person is passing, which relates to the next building block, shopping assistance. The third building block of the artifact is a personal safeguard assistant. It is able to warn of barriers on the footpath or elsewhere. It exchanges information with the routing feature to propose hazard-free routes. In addition, it can track the position of a family member or of a lost guide dog.

Figure 2. Network Map for “Shopping Assistant”
The fourth functional component of the conceptual model describes the technical specifications that were valued highest in relation to these topic areas. To start with, it should allow switching between car and vehicle modes. Next, it should be available anywhere, both underground and within large buildings. Third, it should be fairly easy to control, ideally with one hand so that the other hand can hold on to a leash or a cane. Lastly, the mobile device should release certain sound signal when approaching particular points of interest.

**Figure 3. Highlighted Network Map of “Navigation and Routing Device”**

4. Evaluation
We evaluated the results of requirements elicitation and analysis in two ways. Firstly, we aimed to clarify which of the ideas proposed by individual participants were most valued by others.
Secondly, we sought to verify whether the system suggestions derived from interpretive analyses, which were carried out by the researchers, are an accurate representation of users’ needs. To evaluate the efficacy of the selection, ranking and rating rounds we here compare the outcomes of these consecutive rounds to each other.

We collected the evaluation data from blind and vision-impaired participants in two independent steps: pre-analysis ranking scores and post-analysis rating figures. During the individual laddering interviews we asked the participants to rank order their top three ideas. This provided us with a first round of data, a portion of which is depicted in the left column of Table 2. The second column of presents a tally of Likert-type rating scores for the ideas that lie within the three top themes. The top three themes, ‘navigation & routing’, ‘traffic & public transport assistant’ and ‘shopping assistant’ accounted for 70% of all rating scores. These rating were derived during the feedback-gathering phase of the study.

<table>
<thead>
<tr>
<th>Table 2. Theme level preferences comparison before/after data analysis.</th>
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<tr>
<td><strong>Pre-analysis</strong> (standardized sum of inverted ranking scores for features per theme)</td>
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<tr>
<td>Navigation &amp; Routing</td>
</tr>
<tr>
<td>Traffic &amp; Public Transport Assistant</td>
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<tr>
<td>Shopping Assistant</td>
</tr>
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</table>

The results provide strong support for the clustering effort of the researchers since the users valued the themes similarly. The difference in ranking of the top three themes is varied by only one ranking point. Since these statistics are based on relative rankings of the features and are not absolute numbers, the size of the numbers is not meaningful. The rest of the themes followed this trend within the data. Table 3 presents more in-depth analysis of the results within a selected theme ‘navigation & routing’.

<table>
<thead>
<tr>
<th>Table 3. Feature group user preferences comparison before/after data analysis</th>
</tr>
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<tbody>
<tr>
<td><strong>Pre-analysis ranking</strong> (sum of standardized, inverted ranking scores)</td>
</tr>
<tr>
<td>City guide</td>
</tr>
<tr>
<td>Show points of interest</td>
</tr>
<tr>
<td>Bookmark &amp; manage routes</td>
</tr>
<tr>
<td>Underground reception</td>
</tr>
<tr>
<td>Locate peers</td>
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Here there is more variation between pre- and post-analysis results, but we can see that the top-ranking feature groups are the same even though the order is slightly different. We should note that the data is based on relative rankings of the feature groups, but the results still provide us means to state that the pre-analysis ranking scheme provides convincing support for the analysis, both at the theme level and the feature group level. Here again, the actual numerical values are not meaningful across columns.
5. Conclusions
In this study we identified an important RE problem, the need to adapt RE methods to accommodate blind users, so as to be able to effectively determine requirements for systems targeted to these users, and we identified three objectives for a method to accomplish this, aggressive participant recruitment, non-visual data gathering, and accommodation to working memory limitations among participants. We designed a method, BURE, to accomplish these objectives and demonstrated its use to develop the requirements for mobile services tailored to blind users. The demonstration includes a conceptual proposal for a system to be implemented. Finally, we evaluated the efficacy of the resulting requirements with follow-up interviews with the participants.

BURE holds promise as a method for use in research and practice to develop a variety of applications, services, products, and accommodations for use by blind people. In addition, our success in using a design science approach to develop this new method suggests that the same approach might be used to design RE methods tailored to other hard-to-reach populations, such as Islamic women or the learning disabled.

References