The Design Development of a Mobile Alert Device for the Deaf and Hard of Hearing

UDY RAVID

PAUL CAIRNS

UCL Interaction Centre, University College London, 31-32 Alfred Place, London WC1E 7DP

udy@udybility.com; p.cairns@ucl.ac.uk

Tel: +44 (0)20 7679 5208

Abstract. This paper focuses on a novel design of a multi-modal alert device for the Deaf and hard of hearing, which we call the Vibe, implemented on a mobile phone. The Vibe receives information from the surroundings, either from wall mounted receivers or by using its microphone, and transfers the information to users, according to their specific needs, through visual, tactile or auditory channels. This paper describes the elicitation of user requirements and the design and evaluation of the Vibe's information architecture. The paper produces an "on the table" design and product requirements, captured in part in personas and scenarios, that are ready to take on to the development of a working prototype. A key part of the Vibe concept and design is that is achievable with existing technology.

Keywords: Alert device, Mobile, Deaf, Hard of hearing, Multi-modal, Vibe, User-centred design

1. Introduction

Being alert to our surroundings is an ability most of us take for granted. Sound is an important channel for providing awareness so loss of hearing can greatly limit this ability. The Deaf and hard of hearing population thus are dependent to some extent on surrogate devices that are able to convert auditory events into other modalities. These events could be things like a doorbell being rung, a telephone ringing, baby's cry or a fire alarm. They could occur not just in controlled environments like the workplace or home but also in public spaces such as in restaurants or whilst walking in the street. These events contribute situational awareness that not only can secure lives but are a valuable part of social communication.

There are only a few alerting devices currently on the market. Some recent wireless systems include a pager for alerts and wall mounted receivers to detect sounds. When the receivers detect the relevant sound (telephone ring, for example), they send a signal to the pager that usually vibrates. These devices, then, are primarily for a few specific sound alerts arising in specific locations, so do not really provide the full range of alerts a user could benefit from. Also, pagers are old-fashioned and poorly styled, particularly in comparison to other modern handheld devices like PDAs and mobiles. Given these considerations, existing alerting devices do not easily integrate into a pleasurable part of users' lives [5].

For example, using the PPS433 Personal Pager [2] involves the user carrying a pager that presents only the code number of an event (2 for doorbell, for example) and forces the user to memorize the event codes. Additionally, when the pager goes out of its receiver's range, it does not notify the user. The users could end up believing that they have awareness of their surroundings when the channel for such awareness has been lost. Furthermore, as receivers are fixed in particular locations, this (or any other existing device) does not provide a solution for auditory events outside of the home environment (telephone ring at work, fire alarm in a hotel) or non-specific emergency events like the siren of an emergency vehicle or the sound of a breaking vase at home.

Mobile phones present the opportunity for an alternative solution. To hearing people the idea of deaf people using a phone may seem initially surprising, however research done by the Royal National Institute for Deaf (RNID) found that a high percentage, 60% of those of working age, of Deaf and hard of hearing people are using mobile phones, mostly for SMS. It therefore suggests itself to us that integrating a mobile phone with an intelligent multi-modal alert device could create a personal appliance (for home and outdoor use) that would cater for most of the users' essential needs. Such a device would wirelessly connect with the receivers at home, and carry the information from the receivers directly to the user for located events such as a doorbell ring. More importantly, it will be able to detect sounds using its microphone and thus inform a user of non-specific auditory events coming from the surroundings, such as emergency vehicle sirens.

This is the key idea behind our Vibe design described in this paper. The phone will receive information on auditory events and convey the information to the user via alternative modalities. Multiple modes will be used to make it easier for users to discriminate between alerts. That is, the device will use different types of vibration to deliver this information, which will be backed up by screen colours, on-screen icons and even sound depending on the user's hearing ability. For instance, the fire alarm might use siren like sounds in order to attract the attention and help of other people as well as the user. All these, as this paper claims, can be achieved using a novel combination of technologies that are already used in mainstream appliances.

This paper follows a user-centred-design process for the information architecture of the Vibe's menu system (based on a Nokia 5100 mobile phone) and indicates some essential hardware recommendations as well. The aim is to produce a set of requirements and a useful design that could be taken forward to the development of a realistic, functional prototype. The next section will outline the target users and the method used to develop the Vibe system. This will be followed by a feasibility study conducted with expert developers in the relevant areas. This leads to an initial design which was presented to and evaluated by users as part of a large focus group style interview. The outcomes of the interviews are captured in personas and scenarios as well as re-designed elements of the Vibe interface. The paper concludes with the approaches that are needed to be taken in order to support such designs in the future.

Before going further, it is worth distinguishing between Deaf and deaf people. With the capital `D', people deliberately define themselves as being part of a community as opposed to merely having a particular disability, as summarised by Kyle and Woll "Whereby the individual expresses himself/herself through identification with a group with whom communication is shared" [6]. To account for the range of possible perceptions of our target users, we have tended to refer to Deaf and hard of hearing throughout.

2. Focus and Methodology

2.1 Motivation

At the “Breaking the Sound Barrier” conference (London 2002), the RNID presented a major human needs research that was conducted with Nokia. This research, based on the questionnaires of 10,376 Deaf and hard of hearing people, proved beyond all doubt the need for alerts, and described the levels of respondents’ concern in this matter as worryingly high. Notably addressed were the areas of approaching traffic and fire alarms while staying in hotels, with this causing worry to nearly 70% of respondents. Similarly, 70% of people said they are worried that they would miss visitors at the door because of not hearing the bell, and over half reported not hearing their alarm clock. The most worrying information from this section, if not from the whole survey, related to domestic smoke alarm systems. Only 60% of respondents were confident that their smoke alarm at home would alert them in case of a fire.

The research also showed an increase in the use of mobile phone within this community. At the working age group (18-65) about 60% are using their mobiles at least a few times a week for text messaging. This makes the mobile phone the obvious device to be turned into a multi-modal enabling device.

2.2 Target users

There are estimated to be about 8.7 million deaf and hard of hearing people in the UK. Of these, 673,000 are severely or profoundly deaf and this number is rising as the number of people over 60 increases. 420,000 severely or profoundly deaf people cannot hear well enough to use a voice telephone, even with equipment to make it louder. There is a huge diversity in the Deaf and hard of hearing community, as 93% of Deaf people suffer from mild to moderate hearing loss. Generally, though, because of age-related hearing problems, the majority of deaf people are in fact over 65 [9]. Though it would seem to make sense to target the Vibe at this larger potential market, we have chosen not to. This is because the Vibe is based on existing technology that lots of under 65's already have and use regularly. In addition there are age-related interface issues that can be considered separately from the core Vibe concept [4]. Of course, this is not to say that older users could not become the target of future products should this idea prove to be successful.

2.3 Methodology

In order to develop the Vibe to the feasible extent (i.e. a concept and structure that are acceptable and tested by the users, rather than a full working product), we chose to conduct a 'small-scale' but almost complete life cycle of a product design. Nevertheless, coordinating the interviews (recruiting a BSL interpreter and deaf participants) took longer than anticipated and were delayed to a later stage of the project. Therefore, the design phase began earlier (based on existing professional knowledge), and the design life cycle was:

1. Feasibility study
2. Design cycle
    a. Initial design
    b. 'Focus group' interviews
    c. Design evaluation
3. Results and analysis of design
    a. Creation of 'personas' and 'scenarios'
    b. Analysis of information architecture

As such, the life cycle resembles the Star life-cycle, common in user-centred design processes [7].

3. Feasibility Study - Expert Views

To examine the feasibility of the basic Vibe concept, the idea was assessed in comparison to existing devices on the market. Chris Bowden, the product evaluation specialist of the RNID, and his team assessed four main products available in the UK at the time of writing. They tested them using the doorbell and the telephone ringing transmitters. The results were presented in the “OneInSeven” magazine, aimed for the Deaf and hard of hearing population [1]. Some specific technical considerations were further explored through an interview with Eran Aharonson, CEO of Art Technologies LTD, Israel.

The product evaluation provided some useful insights. For instance, in order to support situations wherein the vibration cannot be felt by the user, there is a need for redundant and equivalent modalities for the alerts, for example both lights and sounds. Nevertheless, learning from mistakes with existing devices, we suggested limiting the number of different alerts to be used, so that users will not have difficulties coping with all variations of alert signals.

Optional wireless solutions (like Bluetooth) were also considered but later rejected because of their inability to meet basic requirements, such as reception behind walls. Some hard-wired applications were recommended as well, as a result of bad experience with wireless appliances. In particular, it was recommended to follow some manufacturers and supply a vibrating (under the pillow) pad. This pad will be hard wired to the Vibe during the night, to be used as an alarm clock, or in case of emergency (smoke/burglar alarms). The hard wired option in that case is also better trusted by users, even when the wireless solution is robust enough.

The current use of Hearing Dogs that was also mentioned in [1] brought up the need for determining the direction of the sound captured by the device, as these dogs lead their owner to the source of the sound. Although a valid need, there is no existing technology that could accommodate this, taking into consideration the possible movement of the origin of sound, as well as the constant movement of device itself. Other technical considerations that were challenged are the ability of the device to recognize different sounds, and the long-term power supply of an always-on microphone.

On these latter issues, we approached Aharanson. His company specialises in advanced recognition technologies that have so far been implemented in a variety of products. With regard to the recognition capability, it appears that the basic patterns of emergency vehicles are relatively easy to identify, while other sounds (like dog barking, a breaking glass) could be determined by their frequency of occurrence. The power supply, on the other hand, will probably remain a challenge for the manufacturer, as the use of the phone to detect loud noises in the environment requires the microphone to be always-on. Aharonson came up with a few ideas to overcome or at least minimise this problem. One was to have a separate 'Loud Noise Alert' function so that users can choose not to drain the battery if they do not require this facility. Other solutions to reduce power consumption are based on algorithms that keep the system on 'stand by' mode until loud noises occur, for instance. In any case, it is more than likely that with current technology the device will have to be charged overnight every night in order to meet the power needs of the device.

4. Design Cycle

4.1 Initial design

The initial design was developed as far as the information architecture necessary to support the Vibe device. It was structured around the main functions that the Vibe could provide and the modalities that the user might want to use for alerts, as suggested by the RNID human needs research. The functions included usual phone operations such as incoming call and external events such as doorbell ring, fire alarm and the loud noise alert suggested by Aharonson.

In order to give a realistic context, the functions were organised around a Nokia 5100 menu design building on the notion of personal settings. The usual terminology found on

Nokias was applied to the Vibe menu structure. In this way, the Vibe could be understood as a real part of a mobile phone rather than an abstract, separate concept. However, the stress is on a realistic information architecture rather than details of specific screen layouts.

The goal was to arrive at a core set of functions that users would need together with the factory settings for the Vibe functions. After all, the Vibe needs some initial set up and if it is possible to reflect user needs from the outset then at least some users will be happy to pick up and use the Vibe straight “from the box”.

4.2 Focus group interviews

Six interviews were conducted with potential users, during two phases of the design process. The interviewees were aged between 25 and 45. There were 4 men and 2 women and all had owned at least one phone previously and 5 out of the 6 currently used a Nokia. The main use of the phone was for SMS. Only one interviewee regularly used the phone for voice calls. The interviews were made with the help of a BSL interpreter.

In the first phase of the interviews, the interviewees were not given specific designs for the Vibe. Instead, they were asked about themselves, their use of mobile phones and their needs (if any) for a Vibe-like device. To this end, this part of the interview was semi-structured and although people were interviewed individually, it functioned more like a focus group session than a qualitative research interview. The questions centred around the following areas:

1. Description of the interviewee’s daily life (in order to inform personas and scenarios).
2. The nature of use of mobile phones: frequency, carrying, use of vibration/sound, specific problems, and levels of satisfaction.
3. Use or potential use of alert devices: whether needed/tried, specific problems, and levels of satisfaction.
4. Acceptance of the Vibe concept and further suggestions.

4.3 Design evaluation

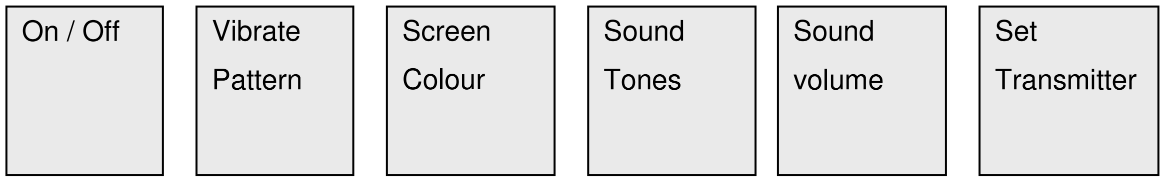
After the focus group part, the interview was then used to investigate specific aspects of the initial information architecture design for the Vibe. The participants were asked to perform two tasks. The first task was a usability test for a first prototype of the menu system. The aim of this test was to challenge the basic structure of the menu system, and to check whether the terms used by the system are clear enough for the users.

The second task was a card sorting task [8]. This task's purpose was to follow the users' mental model with regard to grouping alerts and alarms, in order to inform the factory settings of the Vibe. Since most of the people will not memorize all possible outcomes of 3 different vibrations and 4 different colours, we needed to know which alerts will they group together, and thus require the same signal. For instance, if fire alarm and burglar alarm requires the same level of alert, we could use the same vibration and screen colour for both of them.

4.3.1 Usability testing set up

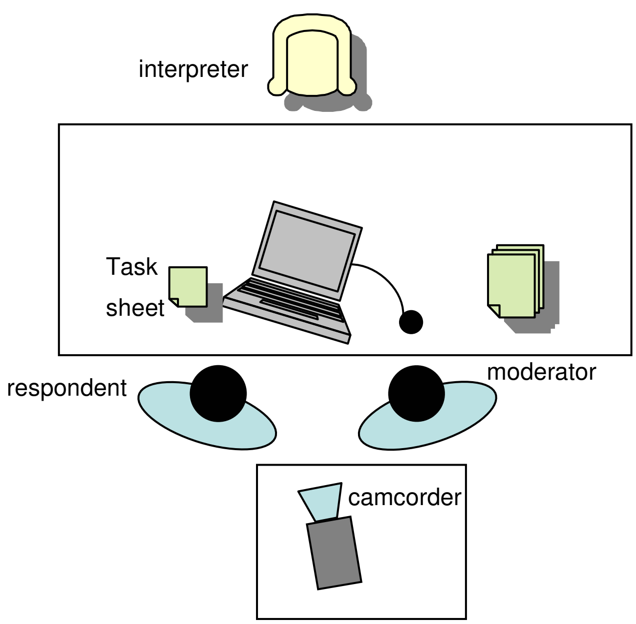
The menu system prototype was created on MS PowerPoint software, so that each slide presented a menu level, as shown in Figure 1. After the user chose one of the options on the menu, the moderator would navigate to the relevant slide (which were named on the slide navigator, on the left) and keep on following the menu. The advantages of this prototype is that similarly to paper prototypes, it is very quick and easy to set, but is much easier to navigate when lots of screens are needed. The usability tests were conducted on a lap-top computer, just after the interviews stage. Every user was asked to perform a set of 6 tasks (one by one) while pointing to the screen.

Figure 1 – Examples of menu level presented on a PowerPoint slide



The user sat to the moderator's left, while the lap-top computer presenting the PowerPoint prototype was in front of them, as shown in Figure 2. The BSL interpreter was sitting behind it. This way, the respondent could use the prototype and raise his or her eyes if they wanted to communicate with the interpreter. The Mini DV camcorder was behind the user and moderator, and captured the activity on the screen, as well as conversation.

Figure 2 - Usability testing set up



5. Results and Analysis

The Vibe concept received a clear positive response from the interviewees even without seeing the initial designs. The concept then is a strong one suggesting further development and evaluation. The usability tests also raised some important issues for the design of the Vibe device and its integration into real mobile phones.

The design requirements elicited from the interviews are encapsulated in personas and scenarios described in the next two subsections. The design implications of the usability tests are then described in the third subsection.

5.1 Personas

From the interview data, four personas were formalized. In addition to personal characteristics, the personas were described in term of their computer skills, social habits, mobile phone use, alert device use, their personal goals when using technology and their specific goals in using the Vibe. Briefly, the personas developed were:

1. **Allen Greenford** - 25. BSL trainer. Profoundly deaf since birth, hearing aid (HA) user, living with her boyfriend, socializing mostly with deaf friends, 'head in the sky' (ex-hippie). Personal goals using technology: To get it over with, not to feel stupid, minimal use – only when necessary.
2. **Roy Travis** – 27. Gym trainer. Severely hard of hearing since birth, was raised within the hearing community, HA user, socializing a lot and very social aware, no Deaf friends. **Goals using the Vibe:** At the new home, to get full functionality of alerts without visible elements (i.e. mobile only. No sirens, no flashes).
3. **Marge Edmondson** – 37. Housewife. Profoundly deaf, HA user, can hear background noise and high pitch sounds, socializing mostly with the family. Personal goals using technology: robustness as primary feature.
4. **John O'Brian** – 38. IT Programmer. Profoundly deaf since birth, serious, protective to his family's safety and life-style. Goals using the Vibe: "I carry my mobile anyway, so why shouldn't I use it for all other stuff as well?" Wants to be available for his family at all times.

We now had to focus our goals of design by prioritizing the personas. In this case, although Roy, Marge and John seemed to be capable of dealing with a rather complicated and powerful design, prioritizing them might lead the process down the wrong path. On the other hand, Allen represents a large section in the population that *can* handle technology to some extent, but does not *want* to. Nothing with her personal goals relates to scrolling down the Vibe menus and making the best out of them. She simply wants to know when somebody comes to visit and when an ambulance is behind her while she is driving. For these reasons, Allen was chosen to be the primary persona.

5.2 Scenarios

"A scenario is a concise description of a persona using a software-based product to achieve a goal" [3]. We played the Allen persona through the scenario, to test the validity of our design and our assumptions. Two types of scenarios were addressed: The *Daily Use* scenarios which are the primary actions that the user will perform, typically with greatest frequency; the second is the *Necessary Use* scenarios that include all the actions that must be performed, but that are not performed frequently and can therefore be located deeper in the menu system. Three scenarios were created, two for the primary persona and one for another persona. Briefly, these were:

1. **1st scenario (daily use, primary persona)** - Allen wakes up in the morning; she leaves home and drives to work. When she gets there, she waits for the students to arrive and begins the lesson. The **tasks** that are related to the Vibe are: to wake up on time, to hear the telephone, to be aware of the traffic around her, to be notified in case the local fire alarm is activated, and to hear the ring that indicates the end of the lesson.
2. **2nd scenario (necessary use, primary persona)** – Allen wants to activate the two wall-mounted transmitters that she got with the Vibe. Her **task** is to activate these transmitters on the Vibe, and to test them.
3. **3rd scenario (daily use, non-primary persona)** - John is coming back home from work. The **tasks** that are related to the Vibe are: To be aware of what is happening in the house, i.e. his baby's cry, telephone ringing, fire alarm, car burglar alarm,

> and the doorbell when his mother-in-law is coming to visit. He also wants to be available for his wife when she needs his help in the kitchen.

The development of scenarios and personas helped us to focus the design. Some usability problems arose as a result of fitting the design to a persona, and some new ideas were introduced. For instance, calling a partner from the other room to come and help (or join the dinner table) is an annoyance mentioned in the earlier interviews. Therefore, the Vibe should include a ‘One-Click-SMS’ button that similarly to speed dial, will send a preset SMS to a preset number. For example: “please come here” (to the partner’s mobile). This might also be useful as an emergency call button for elderly people. This idea was accepted and supported by the interviewees, although a cost-free method was preferred.

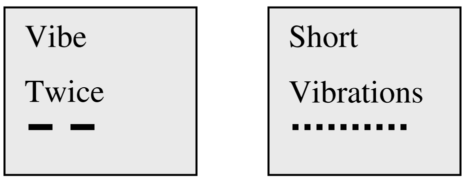
5.3 Analysis of Information Architecture

The usability testing produced some valuable insights into the design of the information architecture. Some of the concepts that were primarily used proved to be too complicated. A good example for this was the two different ways to change the alerts: the ‘Settings’ and the ‘Profiles’. This concept is used on Nokia phones for a long time, but appeared to be unclear to users. Ignoring this concept forced a major change not only on the information architecture, but also on technical aspects of the system. For example, a strong requirement from the users was that they did not want to inform the system about change of location (known as a change of ‘Profile’), so the system should be aware of such change, and change the alert settings accordingly.

The usability tests also helped to cut a few steps from the menu system. Some levels were combined to create a wider and flattened form of menus, and thus shorten the scrolling time. A few problems still remained unsolved, and require further investigation. One of them is related to the terminology that is being used on the sound options. During the theoretical research, it was found that a lot of hard of hearing people are still sensitive to high or low frequencies, and these were therefore used as alerting options. Nevertheless, using this terminology ‘high/low pitch’ on the menu system did not make any sense to Deaf people that did not relate to these terms. Describing the sounds of birds (for high pitch sounds, for example) made things more clear during the tests, but a different solution should be found in practice.

The new design includes some graphical elements that were chosen to ease the understanding of other features, after the usability tests had proved them to be unclear. For example, when choosing the vibration pattern of the alert, the different vibrations are presented graphically as shown in Figure 3.

Figure 3: Graphical representations of vibration patterns



The card sorting task helped greatly in finding appropriate groupings between alerts. Naturally, not all users were interested in all the possible functions. For example, as you might expect, users without children tended to exclude the baby monitoring alert from the sorting exercise. Strong patterns of association did emerge between the different alerts and their corresponding modalities. These led to the creation of the 'factory settings table' that described the most desirable grouping of alerts and alarms. This table is presented in Figure 4.

Figure 4 - Factory settings table

Event	Mobile alert		Friendly alerts		Emergency alarms (attention needed)			
Alerts	Call	Message	Land Line	Doorbell	Loud Noise	Baby Monitor	Fire	Burglar
Vibration	Vibe Twice	Vibe Twice	Steady Vib.	Steady Vib.	Short Vib.	Short Vib.	Long Vib.	Long Vib.
Screen	Yellow	Yellow	Green	Blue	Red	Red	Red	Red
Sound P	Off	Off	Off	Off	Off	Off	Siren	Siren
Sound V	Off	Off	Off	Off	Off	Off	5	5

Vib- Vibration

Sound P – Sound Pattern

Sound V – Sound Volume

6. Conclusions and Further Work

During this research we have provided a feasible design for a need, which was well accepted by users, and proved to be useful, usable, and desirable. The Vibe has had two design iterations and the core information architecture has been established. In addition, even on paper, it is clear that there are hardware issues concerning power and sound detection and recognition that must taken forward in full product development.

The personas and scenarios will be very useful in keeping the focus in further developments. Moreover, they have already suggested new design features such as the one-touch SMS call.

A remark should be made regarding the testing of a fully functional prototype. As a new concept, there are numerous scenarios that could not have been predicted by the designers, and would be accessible only in real time use. More specifically, the 'Loud Noise Alert' might face sensitivity problems and false alarms, while on the other hand some useful implications might be revealed and elaborated. Our goal has been to produce an effective design for The Vibe that is worth taking forward for realistic, *in situ* testing. It must be tested with users from the target population with pilot research. This pilot research might lead it to a higher level of usability, and might support new types of functionality.

Another important issue is related to integrating two main functionalities into one device. In that case, it is most important to assign the right functional prioritisation, i.e. the main use of the Vibe will probably continue to be text messaging and only then alerting and voice communication. The implication of this prioritisation is that clear text input / output components are probably more important for the Vibe than anything else, and should be tested for efficiency and acceptability with users before being implemented.

Finally, the requirements capture for the Vibe focused on the quantitative (the RNID research) as well as the qualitative data (the focus group interviews), and also referenced knowledge gathered by professionals in the field. Any future project intended to influence mass-production cannot ignore these resources, as they all have relevance and are interrelated. Using that approach, there are many future projects that could make significant progress in supporting minority or marginalised populations. Addressing the needs of the deaf elderly should be of a high priority as they are the majority of the deaf population, and providing a better in-house messaging system for the Deaf could be valued as well. All these projects depend on understanding that supporting peripheral communities will eventually be beneficial to all society, especially when the population is getting older. It is hoped that large commercial organizations will support this approach, conceptually and financially.

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