Assistive Technology: The Official Journal of RESNA
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uaty20

Essential Needs and Requirements of Mobile Phones for the Deaf

Hsiao-Ping Chiu MS [a] , Chien-Hsiou Liu MS [a b] , Ching-Lin Hsieh PhD [c] & Rong-Kwer Li PhD [a]

[a] Department of Industrial Engineering and Management , National Chiao Tung University , Hsinchu, Taiwan

[b] Department of Occupational Therapy , Fu Jen Catholic University , Hsinchuang, Taipei, Taiwan

[c] School of Occupational Therapy , College of Medicine, National Taiwan University , Taipei, Taiwan

Published online: 19 Aug 2010.

To cite this article: Hsiao-Ping Chiu MS , Chien-Hsiou Liu MS , Ching-Lin Hsieh PhD & Rong-Kwer Li PhD (2010) Essential Needs and Requirements of Mobile Phones for the Deaf, Assistive Technology: The Official Journal of RESNA, 22:3, 172-185, DOI: 10.1080/10400435.2010.483652

To link to this article: http://dx.doi.org/10.1080/10400435.2010.483652

Assistive Technology®, 22:172–185, 2010

ISSN: 1040-0435 print/1949-3614 online
DOI: 10.1080/10400435.2010.483652

Taylor & Francis
Taylor & Francis Group

Essential Needs and Requirements of Mobile Phones for the Deaf

Hsiao-Ping Chiu, MS,[1]
Chien-Hsiou Liu, MS,[1,2]
Ching-Lin Hsieh, PhD,[3]
and Rong-Kwer Li, PhD[1]
[1]Department of Industrial Engineering and Management, National Chiao Tung University, Hsinchu, Taiwan
[2]Department of Occupational Therapy, Fu Jen Catholic University, Hsinchuang, Taipei, Taiwan
[3]School of Occupational Therapy, College of Medicine, National Taiwan University, Taipei, Taiwan

ABSTRACT Despite their necessity for deaf people in daily life, mobile phones still lack features and functions required by those individuals. While assessing the daily needs of deaf mobile phone users is an important issue for closing this gap, this issue has seldom been addressed. Therefore, we adopted a qualitative research method to extract and construct needs from deaf mobile phone users and translate them into user requirements for mobile phone development. Semistructured interviews and task observations were performed to obtain information from 12 deaf mobile phone users. Context coding was used to code the collected data into needs. The coded needs were then sorted into six categories (social, communication, consumption, entertainment, transportation, and safety) and translated subjectively into three requirements (specific feature-function, general feature-function, and common). The requirements were compared with the functions of the mobile phones of the participants, and five feature-function gaps were identified.

KEYWORDS disability, qualitative research, user needs, user requirements

INTRODUCTION

Mobile phones have become essential devices not only for people without a disability (Leung & Wei, 2000; Leysia & Marilyn, 2002), but also for those with disabilities, including deaf people. Many studies have established that individuals who are hard of hearing use mobile phones to maintain their social networks (Bakken, 2005; M. R. Power & Power, 2004). For example, D. Power, Power, and Rehling (2007) pointed out that over 90% of deaf people exchange content through a short message service (SMS) on a mobile phone. However, despite the explosive growth of mobile phones worldwide, mobile phones still lack functionality (inadequate or insufficient) for deaf people. For instance, the inability of the deaf to directly call 911 via a mobile phone demonstrates the inadequacy of mobile phone technology. Rather than calling 911 directly, the deaf must text their emergency to a special police station line or to a friend who can verbally call 911. The deaf also cannot receive important environmental sounds, such as fire alarms or doorbells. If their mobile phone could receive those important environment sounds and output the information via a non-sound channel (e.g., visual display or vibration), the daily life of the deaf could be improved considerably.

Address correspondence to Chien-Hsiou Liu, School of Occupational Therapy, Fu Jen Catholic University, 510 Chung Cheng Rd., Hsinchuang, Taipei, Taiwan 24205. E-mail: jodiliu.iem94g@nctu.edu.tw

The reason for these inadequate and insufficient designs of mobile phones was that the demands of deaf users were rarely considered during the development phase (Matthews, Carter, Pai, Fong, & Mankoff, 2006; Tóth & Németh, 2006). The result is that deaf users can have extreme difficulty using mobile phones. Consequently, the design of mobile phones to achieve the necessary acceptable level of usability for deaf people becomes an important issue.

The acceptability of any product is no longer only viewed as dependent solely on user interface features, but also on the way that a system fits into its use context (El-Kiki & Lawrence, 2008; Kujala, 2008). Therefore, designers must understand the needs and contexts of users as a way of informing the design process (Coble, Karat, & Kahn, 1997; Grudin, 1991). However, many designers understand much less about the needs and requirements of users than do the users themselves. The difficult part of developing systems is not building them but, rather, knowing what to build, namely focusing on users' needs and requirements (Armour, 2000).

Most previous studies on deaf people using mobile phones have not focused on such needs and requirements. Instead, they have been directed at how the deaf community applies mobile phones and the features currently available to them. The research methods used by those previous studies were quantitative methods focusing on statistical generalizations, including frequency of and trends in use of mobile phone functions. For example, D. Power et al. (2007) found that SMS was the most common means of electronic communication among the deaf, with 96% of respondents using an SMS on a mobile telephone. Furthermore, Ichiro and Hiroshi (2000) and Ulla-Christel, Jan, and Dick (2004) noted that SMS and mobile video communication via mobile phone have become essential communication technologies and that there is a significant trend toward increasing use of these technologies. Moreover, Gillard, Astbrink, and Bailey (2007) reported that over 85% of hearing- and speech-disabled individuals considered a mobile phone with a QWERTY keyboard easy to use.

Furthermore, Ornella and Stephanie (2006) pointed out that at least 70% of hearing-impaired individuals considered that since people with auditory prostheses generally cannot use their phone for auditory purposes, visual and vibrating alerts are very important. Additionally, Cherniavsky, Ladner, and Riskin (2008); Kamphuis, Frowein, Rikken, and Spoor (1999); Lidestam, Danielsson, and Lonnborg (2006); and Tihanyi (2007) indicated that third-generation mobile systems support real-time video communication, but it remains rare in everyday application because video quality and cost were the main concerns for the deaf when using mobile video communication. As a result of the quantitative approach to disability research mentioned above, the social and cultural contexts of disability have not been addressed (Hartley & Muhit, 2003).

Besides quantitative research, a few qualitative studies have attempted to document barriers and overall concepts related to mobile phone access for the deaf (Bakken, 2005; Cavender, Vanam, Barney, Ladner, & Riskin, 2008; Henderson-Summet, Grinter, Carroll, & Starner, 2008; Vincent, 2006). However, the information contained in these studies is incomplete; for example, they do not cover how these barriers are perceived, which among these barriers are most serious in terms of creating greater inequality for deaf users without access to mobile phones, the potential solutions for encountering these barriers, and so on.

In view of the above, no comprehensive study has examined the needs and requirements of the deaf with regard to mobile phones; thus, we assessed the needs and requirements of deaf people regarding the use of mobile phones. We extracted and constructed needs from deaf users and translated them into user requirements. The identified requirements were then compared with the functions and features of the mobile phones used by the participants to identify insufficiencies in the phones' development and design.

QUALITATIVE RESEARCH

This work applies qualitative research to develop a contextual and detailed understanding of the needs of deaf mobile phone users in their daily life. Three reasons exist for our applying qualitative methods, as follows. First, we wanted to understand the breadth of the issue, namely its range and scope, rather than the frequency of such opinions (Glaser, 1992; Strauss & Corbin, 1998). Furthermore, qualitative methods can be successfully applied to collect the views of insiders (the participants being studied), thus yielding valid descriptions of how the participants perceive various phenomena (Cresswell, 2002; Patton, 1990). Second, qualitative methods are superior to quantitative methods

for probing information regarding complex behaviors and in sensitive contexts (Smith-Jackson, Nussbaum, & Mooney, 2003). Third, qualitative methods are appropriate in situations involving low frequency of respondents or when seeking targeted perspectives (Hartley & Muhit, 2003). The low prevalence of deafness in Taiwan made qualitative methods well suited for this research.

Qualitative data can be gathered by observations, interviews, focus groups, and open-ended surveys; collecting public and private documents and e-mails; and through audiovisual materials such as photographs and videos. Participants should be selected according to the emerging data, with a data analysis then performed to identify further participants for additional interviews (Yun-Hee, 2004). Accordingly, data collection continues until saturation. Rifkin and Pridmore (2001) provide a useful text regarding these data collection techniques.

Using qualitative methods, we performed semistructured interviews and task observations to extract and construct deaf mobile phone users' needs. Figure 1 demonstrates the qualitative research methods, which comprise three phases. Phase 1 is user recruitment. Phase 2 is data collection, which consists of three steps: pre-interview, task observation, and post-interview. Finally, Phase 3, the data analysis, comprises four steps: context coding, extraction of user needs, translation of user requirements, and identification of gaps in feature-function requirements. Data collection continues until saturation is achieved. Consequently, on completion of each interview, user needs were analyzed and a comparison made with the initial interviews until it was determined that further interviews were not adding to the findings. User requirements were translated from user needs and then compared with the functions of the participants' mobile phones.

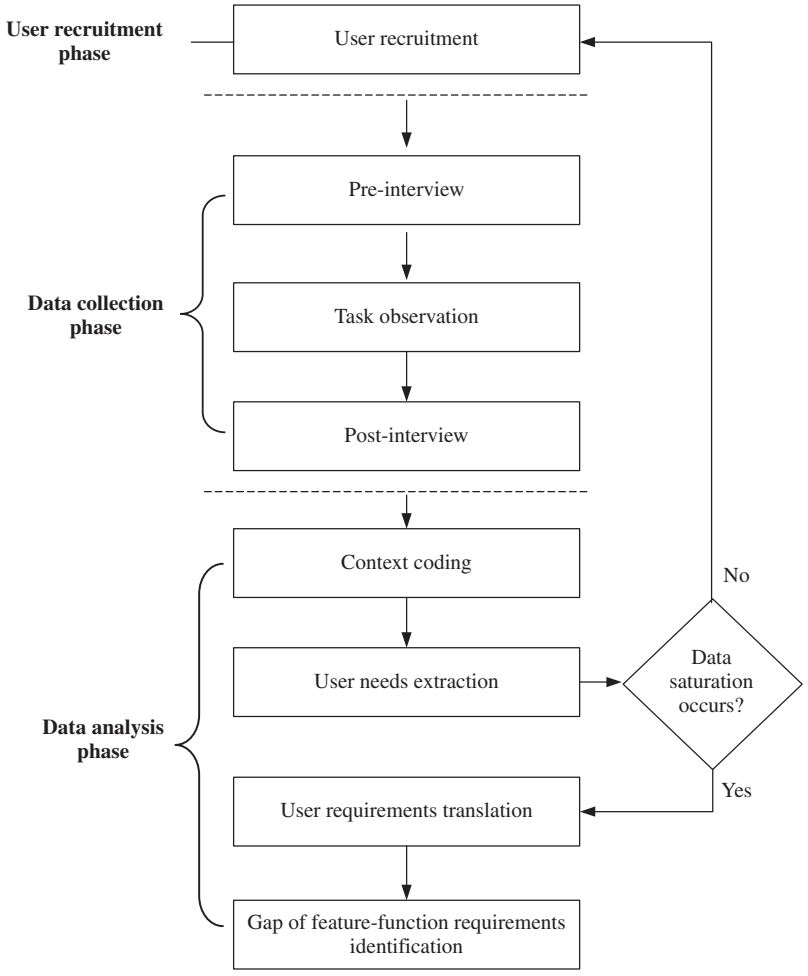

FIGURE 1 Qualitative research process applied in the study.

USER NEEDS AND REQUIREMENTS

User Recruitment Phase

The sample of participants comprised those invited to visit the Chinese National Association of the Deaf (CNAD) for occupational counseling between January and May 2008. Purposive sampling was employed to select deaf individuals who were active mobile phone users and who were not physically or psychologically disabled. Recruitment continued until the point of theme saturation. Twelve members of CNAD volunteered to participate in the study and were interviewed. Three of these members were students, nine were employed, and all were between 18 and 45 years old. Table 1 lists participant profiles by gender, experience, and mobile phone model.

We obtained ethnical approval from CNAD. Written consent was sought from all participants to ensure their rights and confidentiality. One-to-one interviews were performed following occupational counseling at CNAD. At the beginning of each interview, the interviewer (first author) explained the purpose of the study and informed the participant that the interview data would be kept in a secure place during the study and erased afterward, and that pseudonyms would be used to maintain participant anonymity with regard to the interview results.

Data Collection Phase

The data collection phase consisted of three steps, namely pre-interview, task observation, and post-interview. The pre-interview step was designed to gain detailed information about the contexts of users' daily life and mobile phone use. It was conducted as a semi-structured interview. The interview questions were designed to encompass the participant's daily activities, perception of mobile phones, and patterns and main functions of mobile phone use. Appendix A presents the interview questions.

The task-observation step attempted to observe the deaf individuals using their mobile phones in order to identify the explicit and implicit problems of using mobile phones. Since SMS via mobile is an essential communication method for the deaf community (M. R. Power et al., 2007) and video communication and Internet access are both becoming increasingly popular via mobile phones (Cherniavsky et al., 2008; Manduchi & Coughlan, 2008), participants were asked to perform three relevant tasks: sending a message to a friend for a date, making a mobile video sign language communication with a friend, and accessing the Internet via a mobile phone. The explicit problems observed when each participant performed the tasks were recorded.

The aims of the post-interview step were (a) to verify the explicit problems recorded when performing the tasks and (b) to elicit implicit problems encountered when performing the tasks. The post-interview questions (Appendix B) were designed to achieve this purpose.

Questions in both interviews contained general probes to elicit detailed information from participants. Probes, which are follow-on questions that are employed to clarify statements made by participants during the course of the interview, help researchers apply follow-up questions to new issues raised in the interview process. More explications, elaborations, and representations of experiences and phenomena relevant to mobile phone users' needs and accessibility issues can be obtained. Table 2 shows an example of a participant's responses to questions, subsequent probes, and responses to probes. Because the participants were deaf, both interview questions from the researchers and responses from participants were written down on paper or typed on the computer.

TABLE 1 Profiles of participants' gender, experience, and mobile phone model

Sub.	Gender	Experience (yrs)	Mobile phone model	Sub.	Gender	Experience (yrs)	Mobile phone model
S1	F	2	BenQSiemens-EL71	S7	M	3	Nokia-N81
S2	F	5	Nokia-N95	S8	M	3	Nokia-N82
S3	F	10	Nokia-N73	S9	M	5	Motorola-V3
S4	F	10	Nokia-1650	S10	M	8	Nokia-N80
S5	F	Over 10	Nokia-N81	S11	M	8	Nokia-3500
S6	M	3	Nokia-6151	S12	M	10	Dopod-577W

TABLE 2 **Sample raw data of interview questions, subsequent probes, and responses**

	Sample text
Interview:	How do you get help in an emergency situation?
Response:	Screaming, sending messages via a mobile phone, or using video communication by mobile phone with my family or friends to ask them to come to help me.
Probe:	Can you get help after you scream?
Response:	Usually not. Most people do not like to take too much time to "read" our problem since we write on the paper or type on the mobile phone display.
Probe:	Can you get help if you send messages via a mobile phone?
Response:	Yes, but the help always comes too late for an emergency situation.
Probe:	How do you hold your mobile phone if you have to use sign language to interpret an emergency situation through video communication?
Response:	This is a problem. Another problem is that photography may be strictly prohibited in many places. But the most serious problem is that I do not like people turning their gaze on to me.
Probe:	Is privacy the most important issue to you?
Response:	Yes, it is. I do not want people to treat me like a "weird person" or to keep a close watch on what I am sending to whom in sign language.

Data Analysis Phase

The data analysis phase is the core of the process and comprises four steps: (a) context coding, (b) extraction of user needs, (c) translation of user requirements, and (d) identification of gaps in feature-function requirements.

In the content coding process, each statement or perception was considered as an element or observation for the content analysis. Additionally, the data were analyzed with matrices. Detailed patterns in the data emerged at this level, leading to initial explanations of user needs. Qualitative code information was further utilized to support user needs and develop requirements.

All of the data obtained in last phase shown on the paper or computer were first coded by Nvivo7.0, a computer program for analyzing qualitative data. The researcher performed the code assignments subjectively. For instance, the first two answers to the first two questions presented in Figure 2 were both coded as "personal safety." Table 3 summarizes the 20 different answers that were coded as "personal safety." "Personal safety" was thus coded 20 times, giving it a frequency

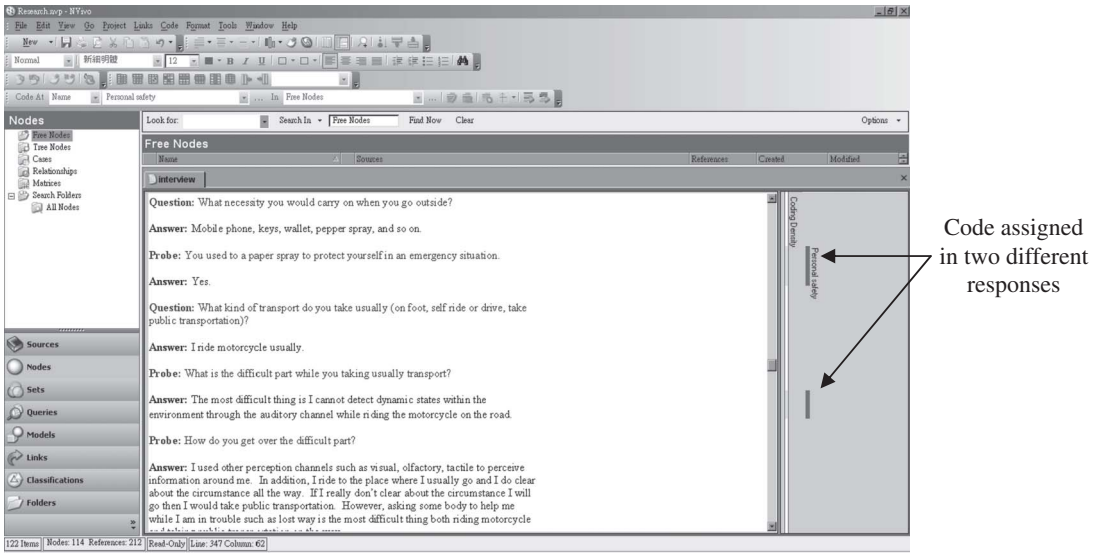

FIGURE 2 **Example of a participant's response and code assignment.**

TABLE 3 Sample raw data from mobile phone interviews supporting the qualitative codes

Qualitative code	Raw qualitative data
Personal safety	1. I always carry an emergency whistle with me. 2. The smoke detector in our home was rebuilt with a loud electronic horn and flashing light signal to alert me to a potential fire. 3. I confronted three gangsters on my way home after a date. 4. Gas and smoke detectors in my house have flashing light signals. 5. I had a traffic incident because I did not hear the car horn. 6. The robber got away because I could not shout for help. 7. I would send a text message to my family after arriving at my destination. 8. Taking public transportation is safe and convenient. 9. I go with my family or friends if I am going to a strange place. 10. I feel depressed that I cannot shout clearly for help when I get into trouble. 11. I carry pepper spray with me when I go outside. 12. A smoke detector should have both electronic horns and flashing lights. 13. People give me the cold shoulder when I need help. 14. I can do nothing when I am robbed. 15. The gas detector can be used as a flashlight, but is dangerous to leave on while sleeping. 16. It is always too late to send text message via mobile phone to get help. 17. I usually cannot get help immediately when in danger. 18. I cannot detect the status dynamically through the auditory channel. 19. I would send the taxi telephone number to my family when taking the taxi. 20. I used to go outside with my friends.

of 20. Although the study involved only 12 participants, the "personal safety" code had a frequency higher than 12 because each participant gave the same response for different questions or probes. However, some codes may have frequencies lower than 12, because some participants gave no response to some questions or probes because they had no opinion or lacked knowledge of the questions or probes.

User Needs Extraction

After all of the data were coded, they were then grouped subjectively based on their attributes. Six groups of codes were identified, each assigned with a unique need name: social needs, communication needs, consumption needs, entertainment needs, transportation needs, and safety needs (as shown in Table 4). Social needs originate with the need of peo-

TABLE 4 Summary table of user needs in daily life identified from interviews (n = 12)

User needs	Statements
Social needs	Maintaining and expanding social networks is important. Social activities could enrich the lives of participants.
Communication needs	Participants communicated with many objects for several reasons. They adopted various communication methods. Efficient and successful communications are essential.
Transportation needs	Participants took diverse forms of transportation. Transportation information is helpful for itinerary planning.
Consumption needs	Consumption behavior includes searching, selecting, and using goods and services. Participants spend a lot of time on surveying the good or service, since they cannot ask or listen to the salesman.
Entertainment needs	Participants participated passively in several forms of entertainment. Technology changes not only entertainment instruments such as mobile phones, but also the manner of processing entertainment.
Safety needs	Safety and security is a critical issue for all needs. Effective and efficient devices and services for emergency situations are fundamental.

ple to feel a sense of belonging and acceptance (Maslow, 1954). Communication needs involve people transmitting their thoughts, ideas, and feelings to other members of their social groups via various media. Consumption, entertainment, and transportation are the parts of daily activities associated with satisfying or supporting the life of others. Safety is positively related to all other needs and is concerned with people's daily life. Personal safety, internet security, payment security, and computer security were grouped together because they had the same attribute "safety or security." The six needs categories were supported by all of the interviewers and at least 28 references for each (Figure 3).

Since each user need category was linked closely with other need categories, they were organized as shown in Figure 4. Social needs are the most critical user needs for deaf people (and are thus in the center of the framework), because people cannot withdraw from society and live in obscurity (M. Power, 1997). Communication and transportation supporting social needs are very important in daily life. Consumption and entertainment are common human behaviors in all societies and in all periods in history when production and labor have occurred (Bauman, 1992; Wachtel, 1989). The linking relationships among the categories of needs were identified by reviewing the results of the interview test. For example, the following example pre-interview transcript demonstrates the participant's user needs.

> I like to go to *shopping with my friends* (social need/entertainment need/consumption need) on the weekend. I always *send text messages to my friends* (communication need) to make and confirm our appointments. I usually *take the public transportation system* (transportation need) to go to keep an appointment. *Driving by myself is too dangerous* (safety need) to me because I cannot detect the status dynamically through the auditory channel.

The linking relationship among user needs could also have been determined post-interview, and the following example illustrates a participant's responses to problems in accessing the Internet via mobile phone.

> I could access the Internet via my mobile phone to download *video games* (entertainment need) and *share those games with my friends* (social need). Using a mobile phone to access the Internet is very convenient, but the *connect fee is too expensive* (consumption need) and sometimes service is suspended for illegal *downloads* (safety need).

User Requirement Translation

Most individuals are unsure of what they want (Adams, 1996) and lack the professional skills to define their requirements (Kujala, 2008). Moreover, potential user requirements must be presented in a format that is easy for users to understand so that they can provide feedback. As Kyng (1995) stated, it is impossible to gather user feedback using traditional approaches such as requirement specifications. Users believe in prototypes and mock-ups, concrete forms of presenting requirement specifications that are well suited for hands-on exploration. However, prototypes are focused on interface issues, which present difficulties for

B36 Name

	B	C	D	E	F	G	H	I	J	K	L	M	N
36	Name		Sources	References	Created	Modified							
37	Users' needs		12	70	2008-03	2009-01							
38													
39		Name		Sources	References	Created	Modified						
40		Communication needs		12	41	2008-03	2009-01						
41		Consuption needs		12	28	2008-03	2009-01						
42		Entertainment needs		12	32	2008-03	2009-01						
43		Safety needs		12	45	2008-03	2009-01						
44													
45			Name		Sources	References	Created	Modified					
46			Computer security		3	3	2008-03	2009-01					
47			Internet security		9	12	2008-03	2009-01					
48			Payment security		6	8	2008-03	2009-01					
49			Personal safety		12	20	2008-03	2009-01					
50													
51		Sociality needs		12	39	2008-03	2009-01						
52		Transportation needs		12	42	2008-03	2009-01						
57													
58													

Tree Nodes

FIGURE 3 **Example of users' need code list generated from the responses.**

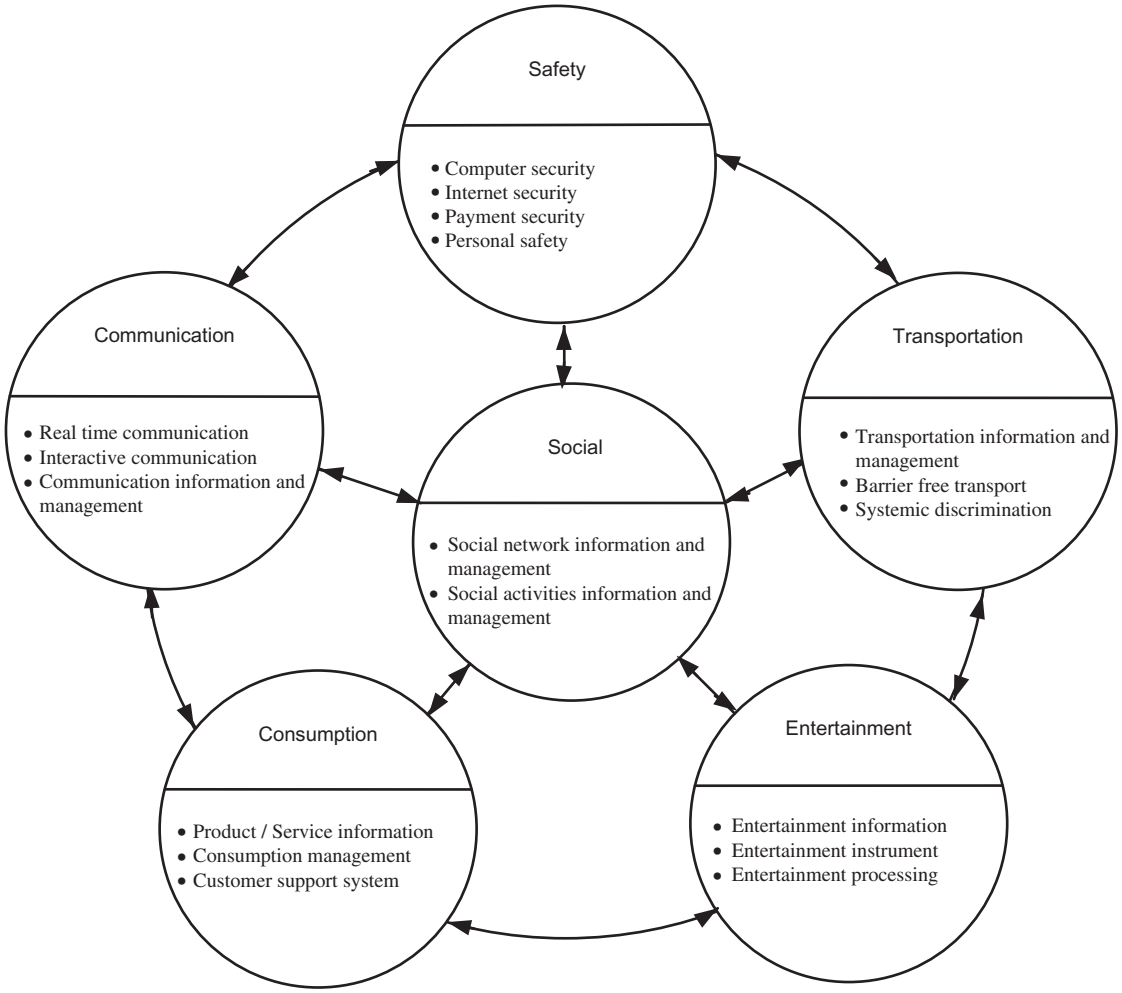

FIGURE 4 **Framework of deaf users' needs in daily life.**

users. Hence, this study infers user requirements from interviews rather than directly asking participants their user requirements, and participants confirm their requirements.

A requirement is a feature (hard or soft), function, or other property of a product that fulfills user needs (Kujala, 2003). Therefore, users' needs and points of view should be stated explicitly in requirement definition as the input to the product design phase. According to the definition of user requirements and the user needs framework shown in Figure 3, the six need categories were translated into three user requirements, namely specific feature-function requirements, general feature-function requirements, and common requirements. The specific feature-function requirements were the mobile phone features or functions that support an individual need category (Table 5). For instance, GPS is a specific mobile phone feature-function that supports transportation and safety needs, allowing deaf users to identify their location and plan their itinerary effectively and efficiently, and thus avoid losing their way. The general feature-function requirements are the recommended default features or functions of a mobile phone for deaf users (Table 6). Among the general feature function requirements, all of the participants emphasized the significance of visual and tactile functions. The common requirements identified across participants are not features or functions of the mobile phone itself, but instead relate to usage (Table 7). Furthermore, needs and requirements have the following relationship: A need requires one or more requirements to fulfill, and conversely a requirement can fulfill several needs.

Additionally, participants are not only concerned about features and functions of mobile phones, but also about other issues including fees, privacy, and safety. For example, video communication is very convenient for deaf people, but the connection fee for 3G

TABLE 5 List of specific feature-function requirements

User needs	Specific feature-function requirements	Design justifications
Social needs	"Online" social information and activity	The device can expand social networks and activity.
	Calendar/phone book	An organizer such as a calendar and phone book could help users to make arrangements for social information and activities.
	Clock	The clock on a mobile phone replaces a watch.
	Digital camera	The digital camera records images of social activities.
Communication needs	Messaging/mobile e-mail/MSN/video communication	Users can use various communication methods in different situations.
	Phone book	The device can easily organize personal or business phone numbers, reducing the load on memory.
	Phone record	The system supports call records and management.
Transportation needs	"Online" transportation information	Information such as timetables, routes, and maps is easy to obtain.
	GPS/map	The system helps to plan, identify, and find the itinerary.
Consumption needs	Calculator	The system can calculate payments.
	Online store and information	The device provides various types and forms for consumption and product information.
	Mobile cash	The system provides convenience when paying a bill (e.g., fare).
Entertainment needs	Built-in game/media player	The system provides convenience when paying a bill (e.g., fare).
	"Online" entertainment	The system provides various types and forms of entertainment.
	Entertainment manager	The device can organize various types and forms of entertainment.
Safety needs	Identification	The system allows possible embezzlement of mobile phone and mobile cash.
	GPS	The device can identify user locality while in an emergency situation (e.g., traffic accident).
	Emergency hot key	Users can obtain help effectively and efficiently.
	Fire/gas/doorbell alarm	The device can easily identify abnormal situations anywhere when it is used in the house.

communication via mobile phone is very expensive (Tihanyi, 2007), and privacy concerns cause anxiety while making a mobile video sign language communication with others. Participants have taken necessary precautions to protect their phones against unauthorized usage by activating the phone lock or SIM lock function.

Feature-Function Requirement Identification Gaps

The extracted user requirements were compared with the mobile phones used by the interviewers, with the former as a base. The comparison results indicate that the designers of the phones did not understand the deaf users' needs or represent them as user requirements. For example, deaf users do not need to look for set-up facilities if the mobile phone holder is embedded into the device, and text-to-speech and speech-to-text systems enable deaf people to communicate normally with hearing people. Table 8 shows the feature and function gaps discovered in this study. These feature-function gaps can be classified into five categories, as follows:

- Immoderation–the features or functions of the current mobile phone do not suit the user.
- Intolerability–the features or functions of the current mobile phone break down frequently.
- Incompleteness–the features or functions of the current mobile phone do not develop completely.

TABLE 6 List of general feature-function requirements

Requirements	Design justifications
Touch screen	The device is easier to operate than a keypad.
Handwriting recognition	Input on a keypad takes more time.
QWERTY keyboard	A QWERTY keyboard is the keypad layout that users have used most often; a general mobile phone keypad makes text input complicated.
Cameras and display on the same side	This approach obviously would not work for filming oneself, as in a sign language conversation.
Visual present	A big screen with a big font size would prevent loss of information at the screen margins.
Tactile present	Longer and powerful vibration can be avoided, ignoring vibrating alerts, especially while the participant is using two hands to present sign language and the whole body is shaking, and therefore the participant cannot recognize the vibrating alerts from the mobile phone in the pocket.
WiFi	Information is exchanged efficiently.
Wireless network	Information is obtained efficiency.
Text-to-speech	A text-to-speech system can support reading aloud any text input or written down on the mobile phone display to improve interaction with others.
Speech-to-text	A speech-to-text system can support recognizing and presenting the content of speech by other people, thus helping users interact with nondisabled people.

TABLE 7 List of common requirements

Requirements	Justifications by participants
User needs comprehension	Since mobile phones have become a necessity, the design and service of these phones should match the needs of users in their daily lives.
User capabilities and limitations	The design and service of mobile phones should consider the capabilities and limitations of users.
Standard and consistent design	Users desire a standard and consistent design for mobile phones to avoid having to learn and memorize related forms like meaning of icon, keypad layout, and the access process.
Built-in functions	Users prefer built-in functions without external components or extra cost.
Other issues	Beyond the features of mobile phones, users have strong concerns regarding other issues, including privacy, price, and connection fee.

- Inadequacy–the features or functions of the current mobile phone do not extend to all mobile phones.
- Redundancy–the features or functions of the current mobile phone are duplicated or unnecessary.

These gaps are generally considered during the development and design phases of the mobile phone, but only in terms of normal users, not users with disabilities (Smith-Jackson et al., 2003). The effects of inaccurate capturing of user needs not only influence user satisfaction but also increase development costs and time (El-Kiki & Lawrence, 2008; Kujala, 2003).

DISCUSSION

The six daily life needs of deaf mobile phone users identified from the interviews do not differ from the needs of normal mobile phone users. This phenomenon is unsurprising since the daily life of deaf people is no different from that of those with normal hearing. The only difference is how deaf people use mobile phones to fulfill their needs.

The six needs were translated into three user requirements (features, functions, or other properties of a product that fulfill user needs). The user requirements

TABLE 8 Feature-function requirement gaps in current mobile phone design

Gap category	Feature-function	Description
Immoderation	Phone size	Users could not easily sense the vibration from small and light phones.
	Display size	A bigger display would facilitate reading and watching the words and pictures. A small screen forced users to scroll pages incessantly using the keypad.
Intolerability	Keypad	The keypad broke down frequently due to the user keying in messages.
Incompleteness	Holder	Users did not need to find or prepare other devices on which to place the mobile phone when using sign language via video communication.
	Fire/gas/doorbell alarm	A portable device with a vibrate function can easily detect an abnormal situation (e.g., fire) anywhere in the house.
	Emergency hot key	Users could set content of contact such as contact object and phone number.
Inadequacy	Text-to-speech/speech-to-text	A device should enable users to interact with others, including people without disabilities, conveniently and efficiently.
	Mobile cash	A device should be able to pay a bill (e.g., fare) conveniently.
	Handwriting recognition	The input method should be simple and quick.
Redundancy	Stopwatch/countdown	Duplicate or unnecessary functions could be removed.

demonstrate that deaf individuals have special needs that existing mobile phones do not address. The gap in feature-function requirement identification also shows that the design of off-the-shelf mobile phones does not consider the limitations and needs of deaf users, and existing requirements of mobile phones do not fulfill the requirements of such users. Existing service functions suffer from inadequacies and insufficiencies associated with difficulties in usage. These difficulties arise because individuals with normal hearing can use service functions provided by existing mobile phones via sound channels, while individuals who are deaf can only use service functions provided by non-sound channels (including visual, vibrating, key in, handwriting, and video channels).

Since deaf individuals are excluded from service functions provided by sound channels, service functions in off-the-shelf mobile phones provided by sound channel only are inadequate for such individuals. However, user requirements provided by non-sound channels are also suitable for normal users, and can sometimes prove extremely useful to normal users with situational disabilities as well (Hannukainen, 2005). Therefore, if additional efforts could be made in mobile phone design to consider the user requirements of the deaf, deaf individuals' use of existing mobile phones could be significantly improved, while the general public would suffer no harm.

Although the characters and sign language in Taiwan differ from those used elsewhere, the communication methods used and information exchanged by the deaf via mobile phones are the same (SMS, e-mail, video communication, etc.). Additionally, the time delay involved in using SMS, video quality, and the small size of the mobile display were serious problems for deaf mobile phone users. Furthermore, mobile phones considerably impact the communication methods and culture of the deaf, and existing mobile phones clearly do not fulfill the needs and requirements of deaf users. However, several social issues have emerged and require further study. For example, SMS via mobile phone is an important medium for connecting with others, and can be used to keep in direct touch with both deaf and hearing communities, thus making it easier to communicate with an entire social network. Information and ideas flow more easily through this network and can give deaf users a feeling of belonging to a society or clearly defined group. Video communication via mobile phone is another medium that facilitates direct and immediate interaction with others, but deaf users are concerned about the high cost of this service as well as associated privacy issues. The government has to evaluate and modify the pricing of mobile telecommunication systems for minority groups such as the deaf community. Improvements are also necessary in

terms of education and guidance with respect to the privacy of others.

CONCLUSION

This study applied qualitative research to extract the needs of deaf mobile phone users in daily life. Both interviews and task observation were conducted to understand and discover the explicit and implicit needs or problems encountered by deaf people when using mobile phones. The coded needs were then sorted into six categories (social, communication, consumption, entertainment, transportation, and safety) and each user need category was linked closely with the other categories. The six categories were translated into three user requirements subjectively (specific feature-function requirements, general feature-function requirements, and common requirements). The specific feature-function requirements meet different user needs and support deaf users in performing their daily activities more efficiently. The general feature-function requirements focus on increasing the usability of mobile phone functions and services. The common requirements include basic concepts and social issues related to mobile phone design. Finally, the requirements were compared with the mobile phones used by the participants, from which five feature-function gaps were identified (immoderation, intolerability, incompleteness, inadequacy, and redundancy). The results revealed that current mobile phone designs do not fulfill deaf users' needs and requirements.

This study focused on the needs and requirements of the deaf with regard to mobile phones. However, further testing and design is necessary in relation to user requirements (Boehm, 1988; Royce, 1987; Tanimura, Kanazawa, & Sudo, 2009), and further evidence is required to assist in developing design guidelines for mobile phones for the deaf. The additional testing and design can be achieved by (a) constructing and describing conceptual designs to present and map user requirements in terms of necessary functions and services; (b) designing and demonstrating the design prototypes, including how to improve upon inadequate existing functions and services for the deaf; and (c) performing usability testing involving deaf individuals to clarify their perceptions of usability and ultimately to improve the functionality or service level of mobile phone prototypes. In addition, to accomplish a universal mobile phone design, other groups of users including the elderly, children, and people with other disabilities should be further studied in the future.

ACKNOWLEDGMENTS

The authors would like to thank the Chinese National Association of the Deaf of Taiwan for making this research possible.

REFERENCES

Adams, S. (1996). *The Dilbert principle: A cubicle's-eye view of bosses, meetings, management fads & other workplace afflictions*. New York: Harper.

Armour, P. G. (2000). The five orders of ignorance. *Communications of the ACM*, *43*, 17–20.

Bakken, F. (2005). SMS use among deaf teens and young adults in Norway. In R. Harper, L. A. Palen, & A. S. Taylor (Eds.), *The inside text: Social, cultural and design perspectives on SMS* (pp. 161–174). Amsterdam: Springer.

Bauman, Z. (1992). *Intimations of postmodernity*: London: Routledge.

Boehm, B. W. (1988). A spiral model of software development and enhancement. *Computer*, *21*(5), 61–72.

Cavender, A., Vanam, R., Barney, D. K., Ladner, R. E., & Riskin, E. A. (2008). MobileASL: Intelligibility of sign language video over mobile phones. *Assistive Technology*, *3*, 93–105.

Cherniavsky, N., Ladner, R., & Riskin, E. (2008). *Activity detection in conversational sign language video for mobile telecommunication*. Paper presented at the IEEE International Conference on Automatic Face and Gesture Recognition, Amsterdam, the Netherlands.

Coble, J. M., Karat, J., & Kahn, M. G. (1997). *Maintaining a focus on user requirements throughout the development of clinical workstation software*. Paper presented at the SIGCHI Conference on Human Factors in Computing Systems, Atlanta, GA.

Cresswell, J. A. (2002). *Research design: Qualitative, quantitative and mixed methods approaches*. London: Sage.

El-Kiki, T., & Lawrence, E. (2008). *Mobile user needs: Efficient transactions*. Paper presented at the International Conference on Information Technology, Las Vegas, NV.

Gillard, P., Astbrink, G., & Bailey, J. (2007). Mobile communication in real time for the first time: User evaluation of non-voice terminal equipment for people with hearing and speech disabilities. In T. Sobh, K. Elleithy, A. Nahmood, & M. Karim (Eds.), *Innovative algorithms and techniques in automation, industrial electronics and telecommunications* (pp. 347–352). Amsterdam: Springer.

Glaser, B. G. (1992). *The basics of grounded theory*. Mill Valley, CA: Sociology Press.

Grudin, J. (1991). Interactive systems: Bridging the gaps between developers and users. *Computer*, *24*, 59–69.

Hannukainen, P. (2005). *Disabled persons as lead users in mobile user interface design*. Helsinki: Helsinki University of Technology.

Hartley, S., & Muhit, M. (2003). Using qualitative research methods for disability research in majority world countries. *Asia Pacific Disability Rehabilitation Journal*, *14*, 103–114.

Henderson-Summet, V., Grinter, R., Carroll, J., & Starner, T. (2008). Electronic communication: Themes from a case study of the deaf community. In C. Baranauskas, P. Palanque, J. Abascal, & S. Barbosa (Eds.), *Human-computer interaction* (pp. 347–360). Heidelberg: Springer.

Ichiro, N., & Hiroshi, M. (2000). A survey of current usage of telecommunication devices for young persons with hearing impairments in Japan. *Technology and Disability*, *12*, 41–51.

Kamphuis, H., Frowein, H., Rikken, E., & Spoor, J. (1999). *Mobile videotelephony for deaf people: The effect of video quality on the use of text telephony*. Paper presented at the Vehicular Technology Conference, Amsterdam, the Netherlands.
Kujala, S. (2003). User involvement: A review of the benefits and challenges. *Behaviour & Information Technology*, *22*, 1–16.
Kujala, S. (2008). Effective user involvement in product development by improving the analysis of user needs. *Behaviour & Information Technology*, *27*, 457–473.
Kyng, M. (1995). Making representations work. *Communications of the ACM*, *38*, 46–55.
Leung, L., & Wei, R. (2000). More than just talk on the move: Uses and gratifications of the cellular phone. *Journalism and Mass Communication Quarterly*, *77*, 308–320.
Leysia, P., & Marilyn, S. (2002). Beyond the handset: Designing for wireless communications usability. *ACM Transactions on Computer-Human Interaction*, *9*, 125–151.
Lidestam, B., Danielsson, H., & Lonnborg, T. (2006). Mobile phone video as an aid to speech understanding for persons with hearing impairment. *Technology and Disability*, *18*, 99–105.
Manduchi, R., & Coughlan, J. (2008). Portable and mobile systems in assistive technology. In M. Klaus, K. Joachim, Z. Wolfgang, & K. Arthur (Eds.), *Computers helping people with special needs* (pp. 1078–1080). Heidelberg: Springer Berlin.
Maslow, A. (1954). *Motivation and personality*. New York: Harper & Row.
Matthews, T., Carter, S., Pai, C., Fong, J., & Mankoff, J. (2006). Scribe4Me: Evaluating a mobile sound transcription tool for the deaf. In P. Dourish & A. Friday (Eds.), *UbiComp 2006: Ubiquitous computing* (pp. 159–176). Heidelberg: Springer.
Ornella, P., & Stephanie, B. (2006). *Universal design for mobile phones: A case study*. Paper presented at the Conference on Human Factors in Computing Systems, Montreal, Quebec, Canada.
Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.
Power, D., Power, M. R., & Rehling, B. (2007). German deaf people using text communication: Short message service, TTY, relay service, FAX, and e-mail. *American Annals of the Deaf*, *152*, 291–301.
Power, M. (1997). *The Audit Society: Rituals of verification*: Oxford, England: Oxford University Press.
Power, M. R., & Power, D. (2004). Everyone here speaks TXT: Deaf people using SMS in Australia and the rest of the world. *Journal of Deaf Studies and Deaf Education*, *9*, 333–343.
Power, M. R., Power, D., & Horstmanshof, L. (2007). Deaf people communicating via SMS, TTY, relay service, fax, and computers in Australia. *Journal of Deaf Studies and Deaf Education*, *12*, 80–92.
Rifkin, S. B., & Pridmore, P. (2001). *Partners in planning: Information participation and empowerment*. London: Macmillan.
Royce, W. W. (1987). *Managing the development of large software systems: Concepts and techniques*. Paper presented at the International Conference on Software Engineering, Monterey, CA.
Smith-Jackson, T., Nussbaum, M., & Mooney, A. (2003). Accessible cell phone design: Development and application of a needs analysis framework. *Disability & Rehabilitation*, *25*, 549–560.
Strauss, A. L., & Corbin, J. M. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage.
Tanimura, M., Kanazawa, M., & Sudo, T. (2009). Establishing human-centered design process in mobile phone development. *Fujitsu Scientific and Technical Journal*, *45*, 226–231.
Tihanyi, A. (2007). *Mobile multimedia application for deaf users*. Paper presented at the ELMAR International Symposium, Zadar, Croatia.
Tóth, B., & Németh, G. (2006). VoxAid 2006: Telephone communication for hearing and/or vocally impaired people. In M. Klaus, K. Joachim, Z. Wolfgang, & K. Arthur (Eds.), *Computers helping people with special needs* (pp. 651–658). Heidelberg: Springer Berlin.
Ulla-Christel, G., Jan, P., & Dick, J. (2004). A comparative study of text telephone and videophone relay services. *Technology and Disability*, *16*, 101–109.
Vincent, J. (2006). Emotional attachment and mobile phones. *Knowledge, Technology, & Policy*, *9*, 39–44.
Wachtel, P. (1989). *The poverty of affluence*: Philadelphia: New Society Publishers.
Yun-Hee, J. (2004). The application of grounded theory and symbolic interactionism. *Scandinavian Journal of Caring Sciences*, *18*, 249–256.

APPENDIX A: SELECT QUESTIONS USED IN THE MOBILE PHONE INTERVIEWS

Question: Please describe your daily activities, including work and rest.
Question: What transport do you take normally (foot, self ride or drive, public transportation)?
Question: What is the most difficult aspect of taking your normal mode of transport?
Question: What transportation information do you need (e.g., route, timetable, ticket price)?
Question: How do you obtain the information (e.g., asking friends or family, inquiring on the Internet)?
Question: Does the service or function of your mobile phone help you obtain the information?
Probe: If so, which services or functions do you use, and how do they help you obtain the information?
Question: What is your opinion on the service and function provided by your mobile phone?
Probe: Why do you have that opinion?

APPENDIX B: SELECT QUESTIONS USED IN THE MOBILE PHONE OBSERVATIONS

Sending a Message to a Friend for a Date

Question: What text entry system would be most useful to you (phonetic notation, Chang Jie, stroke count, Boshiamy, or others)?
Probe: Why would this text entry system be the most useful?
Question: Can you easily input text on the keypad layout of your mobile phone?
Probe: If not, why?
Question: What is your opinion on the keypad layout of your mobile phone?
Probe: Why do you have that opinion?

Making Mobile Video Sign Language Communications With a Friend

Question: How often do you use video communication via your mobile phone (never, occasionally, frequently)?

Probe for "never" response: Why do you avoid using video communication by a mobile phone?

Probe for other response: How do you place your mobile phone while sending sign language?

Question: What is your opinion on the service and design of your mobile phone for video communication?

Probe: Why do you have that opinion?

Accessing the Internet via a Mobile Phone

Question: How often do you access the Internet via your mobile phone (never, fewer, frequently)?

Probe for "never" response: Why do you avoid accessing the Internet via your mobile phone?

Probe for other response: When and why do you access the Internet via your mobile phone?

Question: What is your opinion on the service and design of your mobile phone for accessing the Internet?

Probe: Why do you have that opinion?