Optimizing the Usability of Mobile Phones for Individuals Who Are Deaf

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ABSTRACT Mobile phones are employed as an assistive platform to improve the living quality of individuals who are deaf. However, deaf individuals experience difficulties using existing functions on mobile phones. This study identifies the functions that are inadequate and insufficient for deaf individuals using existing mobile phones. Analytical results were referenced by designers to optimize mobile phone functions for the deaf community. A simulated mobile phone interface, the PeacePHONE, was designed to evaluate functions. Functions were developed based on the conceptual design of a multifunction mobile phone. This conceptual design was based on the daily life requirements of individuals who are deaf. Peace-PHONE usability was tested by 18 deaf individuals. Five factors were assessed: user experience profile, user perceived usability, functions on existing mobile phones that should be retained, new functions that should be added to existing mobile phones, and functions that are most useful to individuals who are deaf. Positive and negative feedback on the PeacePHONE is presented as well.

KEYWORDS conceptual design, daily living requirements, individuals who are deaf, multifunction mobile phones, usability testing, user-centered design

INTRODUCTION

Mobile phones provide many functions to improve people's daily lives, including voice call, video call, e-mail and Instant Message (IM), organizers, global positioning system (GPS) route displays, and multimedia messaging services (MMS). These functions enable communication, announcements, entertainment, or even mobile-electronic commerce (m-commerce). The portability of mobile phones enables these functions to be employed conveniently. Hence, mobile phones have become an integral part of people's daily lives (Leysia, 2002). Similarly, mobile phones can be adopted as an assistive platform to improve the quality of daily life of individuals who are deaf.

The most frequently employed function on mobile phones by people who are deaf is the short messaging service (SMS) (Pilling & Barrett, 2007; D. Power, Power, & Rehling, 2007; M. R. Power & Power, 2004; M. R. Power,

Power, & Horstmanshof, 2007). According to a usage survey of mobile phones among people who are deaf, 96% of them employ SMS on mobile phones for interpersonal communication (D. Power et al., 2007). Additionally, some of them employ other functions like video phones, Internet search, or e-mail/IM on the mobile Internet (Cavender, Vanam, Barney, Ladner, & Riskin, 2008; D. Power et al., 2007; Dunnewijk & Hulten, 2007; Henderson-Summet, Grinter, Carroll, & Starner, 2007). For instance, the Sidekick, a mobile phone marketed in the U.S. by the service provider T-Mobile, has had success in the deaf community for e-mail, IM, and Internet search (Henderson-Summet et al., 2007). Another survey has found that many people who are deaf prefer the BlackBerry to standard mobile phones owing to its wider range of functions, including e-mail, text messaging, and Web browsing (M. R. Power et al., 2007).

Although existing multifunctional mobile phones were designed for general users, not users who are deaf, most are used by deaf individuals. However, deaf individuals experience difficulties using existing functions on mobile phones. For instance, they cannot call 911 and communicate verbally; instead, they must key in an emergency sentence word for word and send it to their hearing friends or a special police line. Additionally, individuals who are deaf cannot hear such important environmental sounds as fire alarms or doorbells. If their mobile phone could receive these environment sounds and output this information via a non-sound channel (e.g., through visual display or vibration), their daily lives could be improved significantly.

Notably, people who are deaf can only use functions provided by non-sound channels (such as visual, vibrating, handwriting, and video). Since deaf individuals cannot use sound-based functions, the functions of off-the-shelf mobile phones are inadequate for them. According to Ornella and Stephanie (2006), the functions provided via non-sound channels are also suitable for the general public. Therefore, if mobile phone designs considered the service requirements of individuals who are deaf, existing mobile phones could be significantly improved without adversely affecting use by the general public.

Although Fuse (2008) and Vodafone (2008) attempted to upgrade existing mobile phones based on feedback from deaf consumers, such as implementing a high resolution screen and camera, strengthening the IM interface, and modifying emergency text messages, no comprehensive study has considered the service requirements of individuals who are deaf. This study identifies functions that are inadequate and insufficient for deaf individuals using existing mobile phones. Analytical results can be referenced by designers to optimize mobile phone functions for the deaf community and assist deaf individuals in daily life.

A simulated mobile phone interface, the PeacePHONE, was designed to evaluate functions that were developed based on the conceptual design of a multifunction mobile phone. This conceptual design was based on the daily life requirements of deaf individuals (Chiu, Liu, Hsien, & Li, 2010). PeacePHONE usability was tested by 18 deaf individuals. Usability test results identified the functions on existing mobile phones that should be retained, the functions that should be added to existing mobile phones, and the functions that are most useful to individuals who are deaf. Positive and negative feedback on multifunction mobile phones is presented as well.

CONCEPTUAL DESIGN AND DEVELOPMENT

The proposed mobile phone for individuals who are deaf was designed to be multifunctional. The multifunctional ideas were adopted from a study on requirements of people who are deaf (Chiu et al., 2010). In this requirements study, in-depth interviews were performed with 12 individuals who were deaf or hard of hearing to determine their usage difficulties and needs with respect to mobile phones in daily life. The usage difficulties and needs of the participants were compiled into tables, and the votes received for different needs were counted and categorized as logically as possible. The researchers provided different thoughts and concepts to enhance the accessibility of mobile phones to people who are deaf during the classification process. Table 1 presents the detailed thoughts and ideas. These ideas were then grouped into three conceptual designs (communication, announcement, and m-commerce) to determine whether the conceptions of the researchers fitted with the daily living

TABLE 1   Needs of deaf users, along with service requirements as categorized by the researchers

	Percentage responding affirmatively	Researchers' thoughts and ideas
I generally spend a long time keying in texts when writing a text message.	67	Simplify the text input by adding a touch screen and handwriting recognition system
I sometimes use sign language on a videophone.	78	Improve the efficacy of the videophone by incorporating a 2.8-inch screen, high-quality screen and camera, and kickstand
Placing the mobile phone on the table while using sign language on the videophone is a nuisance.	44	
The video image is often unclear owing to the small display.	33	
I frequently communicate with my friends via MSN Messenger and e-mail, but I find these inconvenient to use on a stationary computer.	100	Improve the efficacy of complementary telecommunications by setting up the mobile phone as an Internet platform and adding simple entry portals onto the main page
Asking strangers for directions when I am lost is difficult.	67	Add a feature to search for directions by browsing the Internet on a mobile phone
Approaching an information center or passersby is difficult, so I always search for a route in detail before leaving home.	56	
I feel confused when I have trouble understanding the information about goods, because asking the sales clerk is difficult.	33	Search for shopping information by Internet browsing on a mobile phone
I cannot call for help on a mobile phone immediately.	89	Hot key for sending SMS and MMS emergency announcement messages
I am not aware of the doorbell or telephone ringing when I stay in a part of the house where I cannot see the flashing light.	100	Embed the doorbell announce function on the mobile phone
There are no visual notices for fire announcements in my home.	100	Display fire announcements on the mobile phone
I cannot pay additional visual attention to reading and checking the deduction and remainder functions clearly on the display when passing quickly through gates in a mass transit system.	33	Display mobile fare card information on the mobile phone
I cannot perceive dangerous sounds and always feel unsafe when I go out alone.	56	Incorporate electronic cash into the mobile phone

requirements of people who are deaf (Benyon, Turner, & Turner, 2005).

Communication Conceptual Design

Communication conceptual design refers to ideas for all complementary telecommunication systems in which deaf individuals are helped in expressing or exchanging their thoughts, opinions, or information. Complementary telecommunication systems, such as MSN Messenger (Windows Live Messenger), SMS, and videophone, were arranged into the simple entry portals on the main page so that deaf individuals could use them easily. Figure 1 depicts three common daily communication activities practiced by deaf mobile phone users: a user props a mobile phone on a table with a kickstand and touches the "videophone portal" graphic on the mobile phone to make sign language video calls conveniently (Figure 1a); a user going out for a walk sits on a park bench and touches the "MSN Messenger portal" graphic on the mobile phone to communicate with a friend (Figure 1b); and a user who is lost touches the "GPS portal" graphic to find his location and then possibly touches the "Internet
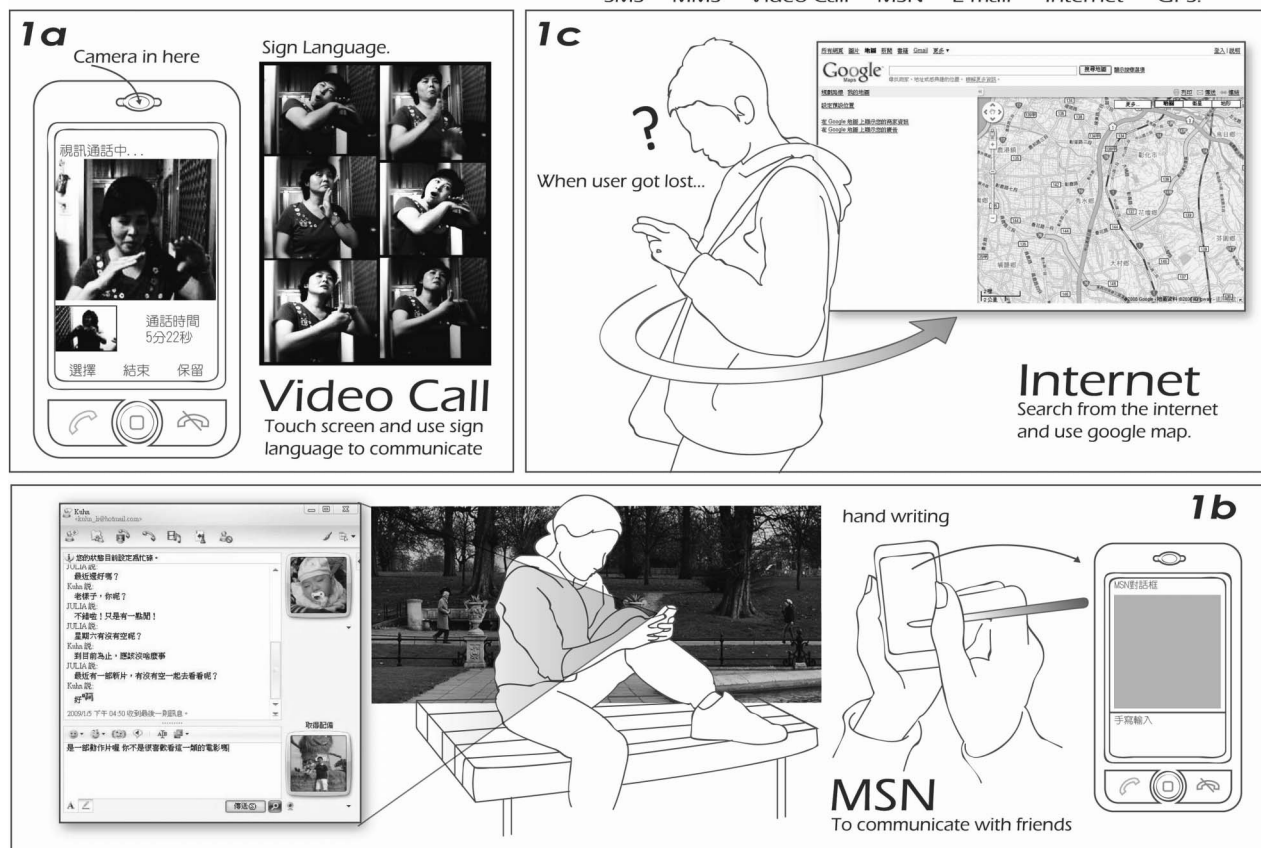
FIGURE 1 Three common daily communication activities (video call, MSN Messenger, and Internet) of mobile phone users who are deaf.

search portal" graphic to discover a detailed route to his intended destination on Google Map (Figure 1c).

Announcement Conceptual Design

Announcement conceptual design refers to ideas for all visual and vibrating notices via mobile phone that help individuals who are deaf deliver or receive important information. Figure 2 illustrates four announcement activities (SMS, MMS, doorbell, and fire) stipulated by mobile phone users who are deaf. Except for the doorbell, these are emergency announcements. Sample scenarios are as follows.

SMS Emergency Announcement

When a deaf user needs emergency help, he or she just needs to hold down the upper hot key for 2 seconds. The GPS navigation system is activated

automatically, and the current location of the user is then discovered. The location information is edited and spliced together into a prewritten message. "Help, I am in danger at a (GPS searched location)" is then transmitted to the two preselected numbers (Figure 2a).

MMS Emergency Announcement

A deaf user who needs emergency help can hold down the lower hot key for 2 seconds to initiate the camera function. The camera then captures the caller's sign-language message and/or accident video. The user then holds down the hot key again to switch the camera off. This video and the SMS emergency announcement message are transmitted directly to the preselected numbers. The message recipients understand the accident situation through the digital video (Figure 2b).
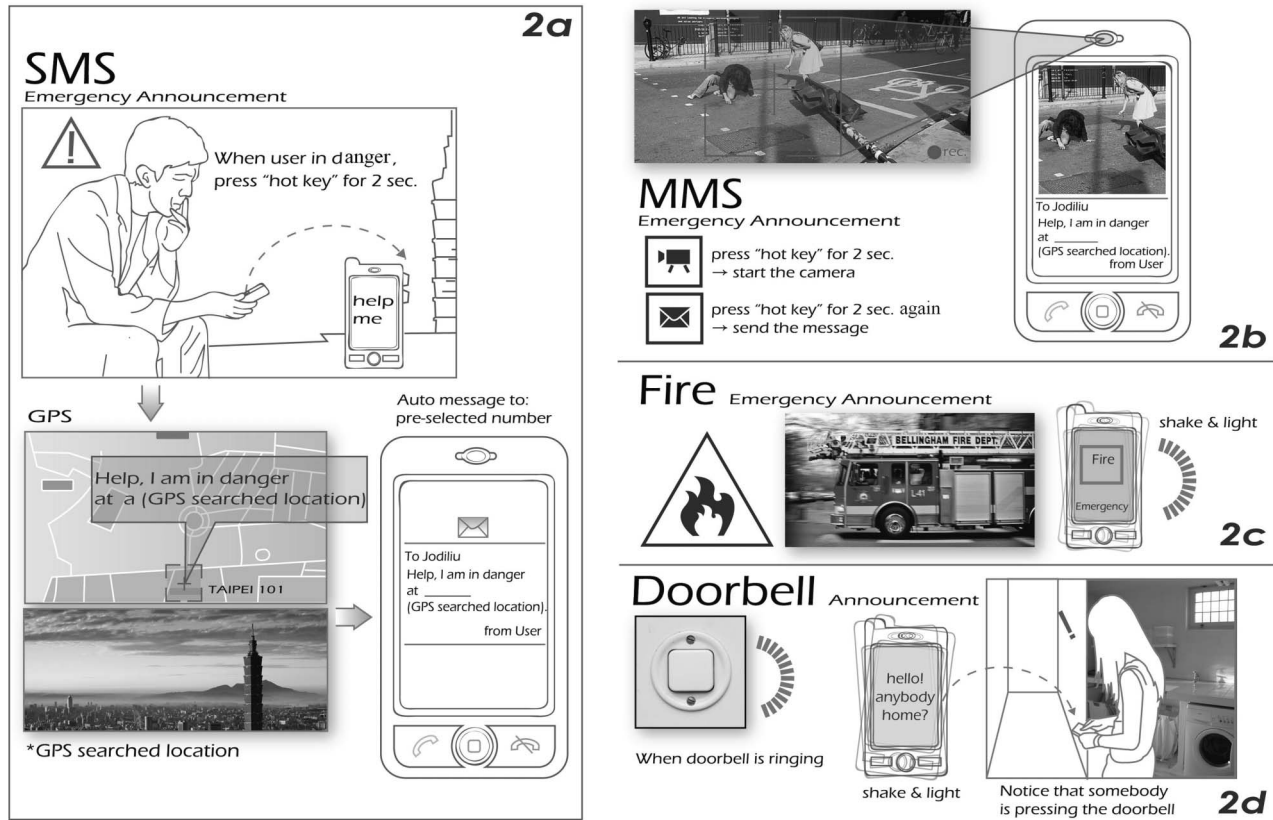
FIGURE 2 Four announcement activities (SMS, MMS, doorbell, and fire) stipulated by mobile phone users who are deaf.

Fire Emergency Announcement

Users who are deaf receive fire emergency announcements, comprising simultaneous flash fire photo displays and vibration, to warn of a fire emergency when they are indoors alone (Figure 2c).

Doorbell Announcement

Individuals who are deaf can receive doorbell announcements, comprising simultaneous flash doorbell photo displays and vibration, to tell them that someone is coming (Figure 2d).

M-commerce Conceptual Design

M-commerce conceptual design refers to ideas for all transactions initiated and/or completed by using mobile access. Figure 3 displays two m-commerce activities (e-money and fare card) practiced by mobile phone users who are deaf. They can pay with e-money embedded in mobile phones when shopping in a supermarket or grocery store, and an informative summary of the charge and remaining balance is displayed on their mobile phone (Figure 3a). They can pass through the ticket gate of a mass transit system via a fare card embedded in a mobile phone and recheck "deduction" and "remainder" anytime and anywhere (Figure 3b).

PeacePHONE PROTOTYPE DEVELOPMENT

To test the usability of different functions, a prototype mobile phone, the PeacePHONE, was designed. The PeacePHONE is merely a simulated interface that displays functions (e.g., a 3-D model physically displays the kickstand, such that testers can determine how to open and close). Thus, testers can view the functions displayed on the PeacePHONE but cannot actually perform tasks. The PeacePHONE has 16 functions.
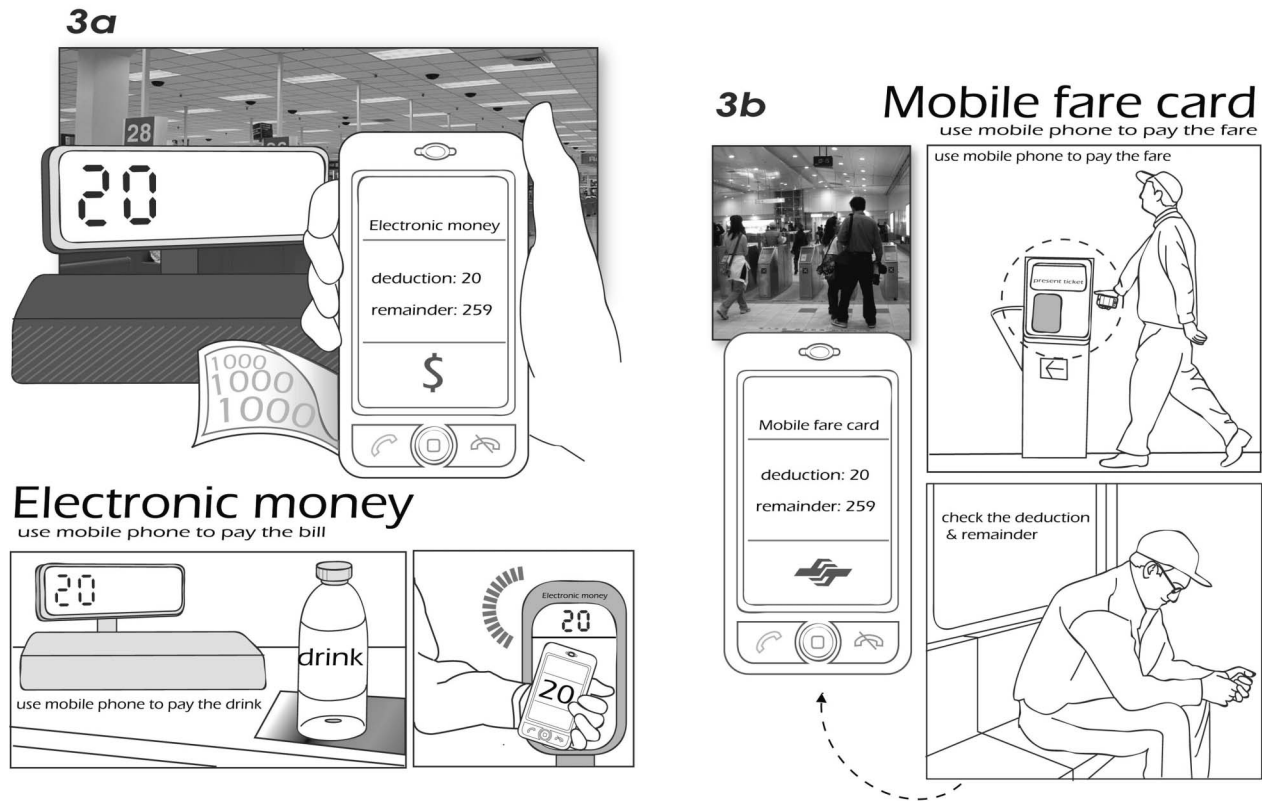
Optimizing Mobile Phones for Individuals Who Are Deaf

FIGURE 3   Two m-commerce activities (e-money and fare card) of mobile phone users who are deaf.

Functions 1–10 are communication functions; functions 11–14 are announcement functions; and functions 15–16 are m-commerce functions. These functions were designed for individuals who are deaf. Therefore, the ideas, attitudes, opinions, and suggestions of deaf users for each PeacePHONE function were elicited. Figure 4 shows the PeacePHONE, and the 16 functions are described in the sections to follow.

Communication Functions

Functions 1–7 were SMS, MSN Messenger, Internet search, MMS, videophone, GPS, and e-mail, respectively. All of these functions were through the simple entry portals and arranged on the main page of the PeacePHONE. After a tester touched each simple entry portal on the main page, the PeacePHONE showed how to implement this function. For example, after a tester touched the "videophone portal" graphic, the prototype displayed the interface for selecting a receiver and connecting to him, along with two fictitious people who use sign language videophone

communication on the PeacePHONE. Figure 5 shows a simulated interface of this videophone function.

Functions 8–10 were touch screen, handwriting recognition, and kickstand, respectively. Different views of the PeacePHONE physical appearance were constructed using a 3-D model to visualize the ideas of designers. For instance, the designers provided different front, side, and back views to show how to operate the kickstand (Figure 4).

Announcement Functions

Functions 11 and 12 were SMS and MMS emergency service functions, respectively. For instance, the physical appearance of the PeacePHONE first appears on the simulated interface, and the hot keys are displayed on the screen of the PeacePHONE. After the SMS hot key is touched, a simulated interface is presented, the GPS navigational system is activated automatically, and the user's current location is identified. The location information is edited and combined into a prewritten message that is then transmitted to the two preselected numbers.
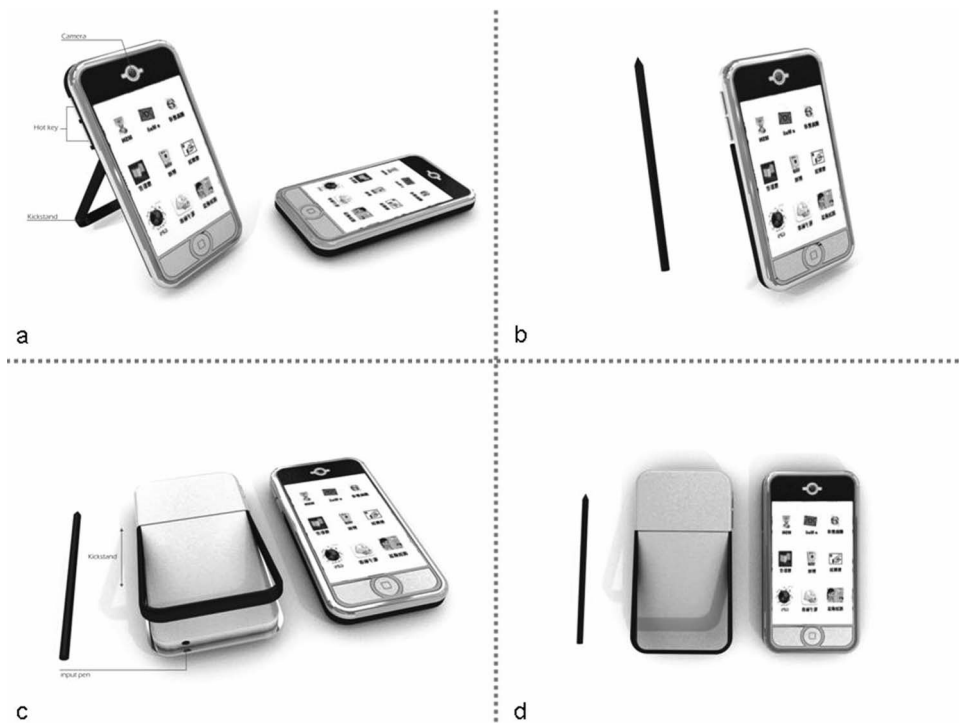
FIGURE 4   Different views of the PeacePHONE.

to touch videophone   to select receiver   connecting   Two fictions persons
entry portal   communicate with sign
                                                                          language videophone
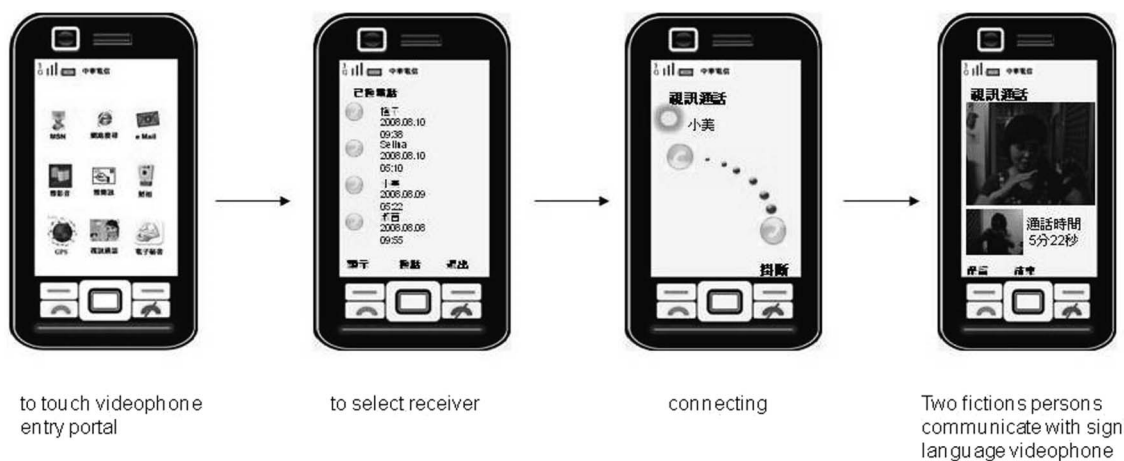
FIGURE 5   Part of the simulated interface of the videophone function.

Functions 13 and 14 were doorbell and fire emergency announcements. The PeacePHONE uses a flash interface and vibration. Testers saw how the PeacePHONE presents this information

M-commerce Functions

Functions 15 and 16 were fare card and e-money functions, respectively. Vibrations were used to notify users that deduction information was received, and

the "deduction" and "remainder" information appeared on PeacePHONE interface.

FUNCTION ASSESSMENT EXPERIMENT
Participant Recruitment

Eighteen deaf or hard-of-hearing subjects (9 females and 9 males) were recruited through the Chinese National Association of the Deaf, Republic of China,

Optimizing Mobile Phones for Individuals Who Are Deaf

and the Sheng-Hui Association of Hsinchu in Taiwan. These subjects were different from the participants in the conceptual design session. Their mean age was 37.4 years ($SD = 11.2$ years). Seven participants reported having impaired hearing from birth. Five of the participants employed hearing aids during the experiment. All participants utilized sign language as their first language. All participants were active mobile phone users, with average usage experience of 3.8 years ($SD = 1.9$ years).

Questionnaire Design

Although several questionnaires are available in usability testing of human-computer interactions, none are specific enough to examine usability problems of mobile devices for individuals who are deaf (Bailey & Pearson, 1983; Chin, Diehl, & Norman, 1988; Davis, 1989; Davis, Bagozzi, & Warshaw, 1989; Lewis, 1995; Nysveen, Pedersen, & Thorbjonsen, 2005; Ryu & Smith-Jackon, 2006). Therefore, a pretest and post-test questionnaire was specifically designed and formulated for this study.

The pre-test questionnaire was designed to determine users' experiences with 16 functions. A user experience profile was generated from the pre-test questionnaire results to acquire data on participants' use experiences in real life.

The post-test questionnaire had three parts. The first part assessed PeacePHONE usability using 18 items (16 items related to functions and 2 items related to impressions of the PeacePHONE interface and its physical appearance). This part was undertaken by adopting quantitative measures reflecting the four usability attributes (namely ease of use, usefulness, learnability, and user's attitude) defined in user-centered design (Rubin, 1994; Shackel & Richardson, 1991). Since each item had four usability attributes, the questionnaire had 72 items in total.

Subjective perceptions were assessed on a 5-point Likert scale where 1 signified "strongly disagree" and 5 signified "strongly agree." Table 2 lists examples of the usability questions with the SMS function. In the second section, 16 functions were selected in order to resolve three issues: (a) identifying the functions in existing mobile phones that should be retained, (b) deciding which new functions to add to existing mobile phones, and (c) identifying the functions that users wished to arrange in the simple entry portals on

TABLE 2 Examples of usability questions related to the SMS function

Attribute	Description	Score
Ease of use	I find that SMS on the PeacePHONE is clear, understandable, and easy to interact with.	1 2 3 4 5
Usefulness	Using SMS on the PeacePHONE would improve my efficiency and would be useful to me.	1 2 3 4 5
Learnability	I find using SMS on the PeacePHONE easy to learn.	1 2 3 4 5
Attitude	I find that using SMS on the PeacePHONE has a positive impact on me.	1 2 3 4 5

their main pages. The final part was post-task semistructured interviews. The users were asked which functions they wished to use, their preferred designs, and their opinions on using this simulated mobile phone.

Experimental Procedure

The experiment had four stages. First, participants received the concise instructions for evaluating the PeacePHONE by writing conversations or typing on a computer. Second, participants filled out the pre-test questionnaires. Third, participants performed the 16 functions on the PeacePHONE. The participants did not perform tasks physically; they only viewed the function on the simulated interface of the PeacePHONE. For example, to perform the first function, the SMS function, participants touched the SMS entry portal on the PeacePHONE interface, which was displayed on a 17-inch touch screen. This interface activates to create the assigned sentence, and sends it to a fictitious friend. If participants did not understand this function, they could touch the entry portal again or ask an examiner. The examiner responded to all questions in detail. Finally, participants filled out the post-test questionnaire once the 16 functions were completed. The experimental procedure for each participant lasted approximately 40–50 minutes.

RESULTS

The usability questionnaire results were analyzed in a quantitative data analysis. The questionnaire was

analyzed with a reliability test to ensure internal consistency. A descriptive analysis was then performed to analyze the usability perceptions of users. The results from the semistructured interview were then analyzed using a qualitative analysis. Next they were compiled into tables, and the different responses were counted and categorized as logically as possible into groups. The qualitative analysis was undertaken by one of the researchers and reanalyzed by another for double checking, and consensus was reached on the final responses.

User Experience Profile

The user experience profile was ascertained by the usage frequency and the tools used for each function (see Table 3). Analytical findings indicated that all participants used SMS on mobile devices (mobile phones and PDAs), while 32% owned a touch screen and 22% owned a handwriting recognition system. Many participants had used a personal computer to send and receive e-mail (66%), communicate with friends via MSN Messenger (72%), and browse the Internet (77%). Many participants had used SMS (66%) and MMS (50%) via a mobile phone to notify family or friends of an emergency. In addition, the majority used a flashing light to indicate when the doorbell in their home was activated (66%). Many participants also used fare cards (72%) and electronic money (55%). However, none used a mobile phone with a kickstand.

Perceived Overall Usability of the PeacePHONE

Perceived usability was assessed first by determining the reliability of the questionnaire. The Cronbach alpha coefficient was .97, indicating that the questionnaire had internal consistency. Average scores for each of the usability attributes (ease of use, usefulness, learnability, and attitude) were 4.6 ($SD = 0.6$), 4.6 ($SD = 0.6$), 4.6 ($SD = 0.7$), and 4.6 ($SD = 0.7$), respectively. All of these attributes indicated that participants perceived the usability to be excellent. (The average user-perceived usability score of all service functions was 4.6 [$SD = 0.6$], where rank 5 denotes strongly agree.)

Functions Embedded in Existing Mobile Phones That Should Be Retained

For communication functions, all of the participants thought that the functions that should be retained in existing mobile phones were SMS, videophone, GPS, and touch panel. The reasons can be seen in the results of the semistructured interviews. The users stated that SMS is the most convenient, useful, and inexpensive real-life communication channel. Videophone users stated that they could stay connected with sign language at any time and place through the PeacePHONE. The PeacePHONE display

TABLE 3 User experience profile (%)

Functions/equipment	Mobile phone	Personal computer	PDA	Flasher light in home	Card
SMS	94.44	16.67	5.56		
MSN Messenger	0.00	72.22	0.00		
Internet search	0.00	77.78	0.00		
MMS	50.00	16.67	16.67		
Videophone	50.00	33.33	0.00		
GPS	5.56	38.89	0.00		
E-mail	0.00	66.67	0.00		
Touch screen	27.78	0.00	5.56		
Handwriting recognition	16.67	5.56	5.56		
Kickstand	0.00	0.00	0.00		
SMS emergency	66.67	11.11	5.56		
MMS emergency	50.00	16.67	16.67		
Doorbell	0.00	0.00	0.00	66.67	
Fire emergency	0.00	0.00	0.00	0.00	
Fare card	0.00	0.00	0.00		72.22
E-money	0.00	16.67	0.00		55.56

was found to be big enough to communicate by sign language. Users could not only interact face to face in sign language but also express opinions instantly with the PeacePHONE. Users stated that the GPS map was a useful channel for obtaining information about unfamiliar locations. For touch panels, users stated that the "simple entry portal" together with the "touch screen" enabled them to access the PeacePHONE intuitively.

A total of 94% of the participants thought that MMS should be retained; they stated that they were accustomed to using MMS on a computer and would also be willing to use it on a portable device. Sixty-seven percent of the participants thought that MSN Messenger should be retained; they stated that they were accustomed to adopting MSN Messenger on a computer and were willing to use it on the PeacePHONE. Although 67% of participants thought that the handwriting recognition system should be retained as a convenient input method, they also frequently felt confused about how to adopt it to write the correct word. Users were accustomed to using the key-in button, but frequently felt confused about how to spell symbols phonetically. A total of 61% of the participants thought that Internet search should be retained; they were willing to search for required information via the PeacePHONE, enabling them to avoid approaching strangers when they were out alone. Only 33% of the participants thought that e-mail should be retained; most said that they rarely used e-mail on computers and had no interest in using it on the PeacePHONE.

For m-commence functions, 89% of the participants thought that fare cards should be retained. They stated that the ability to use the PeacePHONE to pay for things helped them avoid difficulties when they forgot their credit cards. Seventy-eight percent of the participants thought that e-money should be retained; they were satisfied with checking deductions and balances on the PeacePHONE, because they could not always check them on the gate display in time. Additionally, users stated that both fare cards and e-money were convenient on the PeacePHONE, because neither feature required additional operating action. However, users were concerned about issues of privacy and security for e-money and fare cards if their phones were lost or stolen.

New Functions That Should Be Added to Existing Mobile Phones

All of the participants reported that the following new functions should be added: kickstand, SMS emergency announcements, MMS emergency announcements, doorbell announcements, and fire announcements. Related results from the semistructured interviews were as follows. The kickstand was well received and found to be easy to fold, with stable support and an attractive appearance. For SMS emergency announcements, the users found that the hot key could conveniently deliver emergency information at the right place and time and could solve the problems of writing and sending text messages too late in emergencies. For MMS emergency announcement, users thought that the hot key design could solve the problem that creating multimedia messages in emergences would take several steps. Additionally, a multimedia message can provide evidence in a traffic accident. The users also thought that deaf individuals should not be charged for emergency announcements due to their dependence on video information. The doorbell announcement feature could make users aware that someone was visiting them at home anywhere and at any time owing to the portability of the mobile phone. Users also noted that they needed fire emergency announcements, particularly in public places, since they otherwise might not know that an emergency was occurring. Moreover, users thought that the doorbell and fire emergency announcements were convenient features that would enhance their life, because these features do not require any additional operating action.

The Most Useful Functions That Should Be Positioned in the Entry Portal

Users were also asked for the functions that they wished to place in the simple entry portals on their main pages. The preferred function was SMS (100%), followed by videophone (83%), MSN Messenger (78%), Internet search (78%), camera (67%), GPS (61%), MMS (61%), video (61%), and e-mail (33%). The camera and video functions proposed by some participants were not proposed in the initial creation sessions.

Positive and Negative Feedback on the PeacePHONE

The usability test results demonstrated that the PeacePHONE functions are suitable for deaf users. The results of the requirement study, user experience profiles, and usability testing were used to compile positive and negative feedback concerning the Peace-PHONE. This feedback will help designers upgrade multifunction mobile phones.

Instant Interaction was an Important Communication Design Feature of the PeacePHONE

Only 33% of the participants preferred e-mail for communication via a mobile phone. Compared with other communication functions (MSN Messenger and Internet search), e-mail did not facilitate instant interactions with others. Although SMS cannot ensure instantaneous interaction, it is free for individuals who are deaf in Taiwan; thus, it was favored by the testers. The deaf users anticipated convenient and instant communication; therefore, such communication will be an important feature to develop. Such a function would be used widely and enhance the quality of life of deaf individuals.

Hot key Emergency Announcement Functions of the PeacePHONE Could Improve the Functionality of Existing Mobile Phones

The responses of participants demonstrated that they appreciated the designs of hot key emergency announcement functions. All participants stated that these functions were convenient for sending emergency information, and none worried about the risk of accidentally activating the hot keys.

The primary problems associated with emergency announcements were that users must key in words; this is often a slow process. The hot key emergency announcements eliminate the need to key in words and deliver correct emergency information to the two preselected numbers.

The Portable Doorbell and Fire Emergency Announcement Functions of the PeacePHONE Could Increase Usage of Existing Mobile Phones

Doorbell and fire emergency announcements were provided to overcome daily life difficulties. In total,

66% of the participants had a stationary doorbell light in their home, and all indicated that portable doorbell and fire emergency announcements would improve their daily lives. That is, portable doorbell and fire emergency announcements were appreciated by deaf users who could then access such information when they were unable to see the flashing doorbell light.

Notably, Matthews, Fong, and Mankoff (2005) and Matthews, Carter, Pai, Fong, and Mankoff (2006) tried to overcome this issue by recording all non-speech sounds in peripheral environments, transcribing these sounds, and then sending text messages to mobile devices. Their results indicated that deaf individuals are often confused about which information should be visualized. Actually, these popular environmental modifications can be modified and implemented to notify individuals who are deaf using state-of-the-art mobile techniques (Bluetooth, radio frequency identification, or WiFi) (Baker et al., 2007; Symonds, Parry, & Briggs, 2007). We hope future designers can tailor multifunctional mobile phones for individuals who are deaf.

M-Commerce Functions of the PeacePHONE did not Overcome Daily Living Difficulties

Although 89% of the participants approved of the e-money function, they were rarely concerned about the original concerns, thoughts, and ideas of the researchers (e.g., motorcycle theft in Taiwan). Additionally, 70% of the participants worried about privacy and security for e-money and fare card functions if their phones were lost. Therefore, m-commerce functions cannot overcome daily living difficulties experienced by deaf individuals. To address privacy and security concerns, the PeacePHONE should incorporate an e-lock. Molluzzo and Lawler (2008) noted that as knowledge of the functions of mobile computing devices increases, knowledge of privacy and security issues decreases (Molluzzo & Lawler, 2008). Therefore, deaf individuals should be encouraged to learn how to protect their devices.

The PeacePHONE Lacked Options that Would Allow Users to Choose their Preferred Input Method by Themselves

The results indicate that the handwriting recognition system was not well received by all users. Some

users often forgot how to write a word using the handwriting recognition system. However, other users stated that they frequently forgot how to spell the phonetic symbols with key-in buttons. Therefore, neither the key-in buttons nor the handwriting recognition system was well received. The PeacePHONE should provide options to enable users to choose their own preferred input methods.

The PeacePHONE Lacked Visual-Oriented Entertainment Functions

The participants suggested cameras and video as additional functions to be included in the entry portal. These recommendations reveal that visual-oriented entertainment functions are important in mobile phone design for deaf individuals. The mobile device had continuously provided upgraded phones, based on the feedback of the deaf community, most notably including a high resolution screen and camera, strengthened IM interface, and group chat capability (Fuse, 2008). Future work is needed to enhance visual-oriented entertainment functions in order to assist individuals who are deaf to access TV or movies on their mobile phones.

CONCLUSION

We have described a simulated mobile phone, the PeacePHONE, that can augment communication, announcement, and m-commerce activities among deaf individuals. The PeacePHONE is designed according to the daily living requirements of individuals who are deaf, thus not only enabling them to access mobile phones easily but also improving their quality of life.

Our usability testing results indicate that deaf individuals had positive perceptions of the PeacePHONE design ideas. Specifically, users perceived that (a) instant interaction was an important communication design feature, (b) hot key emergency announcement functions could increase the usage of existing mobile phones, and (c) the portable doorbell and fire emergency functions could improve the functionality of existing mobile phones. Three additional suggestions were also presented to enhance usability in the future design process: an added e-lock function, options to select the preferred input method, and enhanced entertainment functions.

Ideal products, especially those for users with special needs, will need to be designed through an iterative procedure (Gould & Lewis, 1985; Lopresti, Mihailidis, & Kirsch, 2004; Ma, 2007; Smith-Jackson, Nussbaum, & Mooney, 2003). This study completed the first cycle of usability testing of the PeacePHONE. Further research could redesign products according to feedback from usability testing. Additionally, the simulated interface was selected over the use of real products to test usability at this stage. A simulated interface is not affected by other technical issues (e.g., speed and reliability of Internet connection or interface usability of Internet browsing) that could influence the results. We obtained a complete specification of requirements from our analysis of users' needs. A usability test of functions was performed, and the sound and practical advice of users was obtained as well. Accordingly, to optimize the features of the multifunction mobile phone for individuals who are deaf, futher research is needed.

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Optimizing Mobile Phones for Individuals Who Are Deaf