Mobile Phones for the Elderly: a design framework

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Abstract

Globally people are living longer. The elderly, defined as people over 65 for the purpose of this study, have recognised physical and cognitive limitations which can lead to their marginalisation as far as information and communication technology is concerned. To enable the aging population to live productively and independently, their technological needs, expectations and limitations warrant intervention. The elderly living in rural areas of Southern Africa rely on private mobile phone access as their main and often only means of participating in the activities of the global village. The academic literature provides a variety of guidelines to support the design and evaluation of mobile phones, and guidelines to inform the process of technology design for the elderly. Yet, no frameworks to guide the specific evaluation and design of mobile phones for the elderly in developing countries are evident. This paper presents a comprehensive framework called RoADMaP (fRAmework for Design of Mobile Phones for seniors) which integrates the existing literature related to the design and evaluation of mobile phone models for the elderly and then uses data gathered in two separate locations (South Africa and Scotland) to augment and verify existing guidelines. We demonstrate the validity of this framework by applying it to a four-year longitudinal mobile phone usage pattern comparison for the period 2009 to 2012. The value of the framework lies in the potential to

Steyn, J., Van der Vyver, A.G. (eds.). (2013). Public and private access to ICTs in developing regions. Proceedings of the 7th International Development Informatics Association Conference, held in Bangkok, Thailand. ISBN: 978-0-620-58040-3
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support private communication access and services for the elderly in developing countries where there may not be any public access.

Keywords

Elderly, Mobile phones, design

1. Introduction

Projections suggest that the over-65 population will grow to 1.3 billion by 2040 compared to 506 million in 2008 (Kinsella and He, 2009). This is an increase from 7% of the global population in 2008 to an anticipated 14% in 2040. Such a growing 'grey' market warrants attention in terms of understanding their technological needs, expectations and limitations. Researchers from diverse fields such as human computer interaction, health science, robotics and ubiquitous computing, are investigating and developing tools and applications to enable the elderly to lead independent and productive lives. For example, information appliances, such as personal digital assistants (PDAs) and mobile phones, have, for some time now, been used as assistive technologies for older people (Helal, Giraldo, Kaddoura and Lee, 2003; Carmien, DePaula, Gorman, and Kintsch, 2004; Donnely, 2010).

Older people are sometimes stereotyped as technophobes, but current research provides evidence that over-60s (who we will interchangeably refer to as seniors, the elderly and older adults) do use technology, provided the physical and virtual interfaces are designed to meet their special needs. A 2006 United Kingdom report reveals that 49% of older adults own a mobile phone (for adults older than 75 it is 36%), and of that group, 82% make one or more calls per week (OfCom, 2006). A significant number of older adults are using information technology, but at the same time they encounter problems due to the physical, mental and social constraints associated with aging (O'Connell, 2007). In 2006, Jones and Marsden wrote about the device size impacting on the readability and interface complexity of phones (Jones and Marsden, 2006). The physical constraints of aging, namely impaired vision, reduced dexterity, and memory loss, are exacerbated by mobile phone size. In the years since 2006 there has been a change in terms of size. For some time phones became smaller and smaller, yet the most popular phones in 2013 are smart phones with large screens, so size may not be as much of a problem as it was in 2006. Other age-relevant issues are leisure time (this group has more), disposable income (they usually have less, though in some cases considerably more), and age-specific key concerns (e.g., family, health and security) (Jones and Marsden, 2006).

According to Rogers' (2003) innovation diffusion model, technology follows an adoption cycle that moves through the following phases: appropriation (the process of acquisition of the artefact); objectification (the process of determining roles the product will play); incorporation (the process of interacting with a product) to conversion (the process of converting to intended future use or interaction). Research has shown that despite older users being keen to use their phones, they sometimes do not move beyond incorporation and hence do not adopt the technology (Conci, Pianesi & Zancanaro, 2009; Gelderblom, Van Dyk and Van Biljon, 2010). Results from recent studies on the adoption of mobile phones for older people provide evidence that there is still room for improvement (Pedlow, Kasnitz, & Shuttleworth 2010, Conci, et al., 2009). Siek (2008:625) warns against technology complacency, i.e. assuming that simply giving an older person a new technology artifact is enough. One cannot assume that they will be able to interact with the device without further assistance.

Warschauer (2003) argues that a set of guidelines is needed to help inform the design and development of future technologies for older people and thereby avoid the problems associated with technology determinism referred to above. Design and selection checklists and descriptive behavioural models have been published to explain mobile phone adoption and use and also suggested some design guidelines (Renaud and Van Biljon, 2008; Van Biljon, Van Dyk, and Gelderblom, 2010). Other researchers have published similar guidelines (Hoober and Berkman, 2012; Siek 2008; O'Connell, 2007). It would be helpful if these published results were synthesised and organised into a format which makes the existing dispersed knowledge coherent, comprehensive and useful.

Such a framework should be made available in a format that can easily support mobile phone designers. They undeniably need this information, since they do not have the time to search for, and consolidate, all the research literature themselves. The purpose of our research is thus to propose such a framework which incorporates the full range of existing guidelines to inform ‘senior’ mobile phone design. Our aim in conducting this research was to determine how we could organise a range of existing knowledge pertaining to the design of mobile phones for the elderly into a coherent and useful framework to support designers. The elderly are considered a marginalised group. Given the infrastructural information and communication limitations of developing countries, the elderly in developing countries are even more marginalised and hence this study lies in the field of ICT4D which deals with the ICT needs of marginalised groups.

We begin, in section 2, with a description of our research design. Following that, in section 3, we report on related research. In section 4 we describe the refinement of the SMAC checklist based on an analysis of newly acquired data, and we synthesize the results into the integrated framework. In Section 5 the application and validation of the framework is discussed and in Section 6 the paper is concluded.

2. Research Design

The research philosophy is interpretive, the research approach is inductive, the research strategies include a literature investigation, surveys and interviews, with a structured questionnaire as data capturing tool. We conducted our research in three distinct phases.

Phase 1: A literature study into the design of mobile phones and the design of technology for the elderly was conducted. These two fields were then narrowed to the design of mobile phones for the elderly. We reviewed mobile phone adoption to critique existing models and frameworks to ascertain their applicability to design for the elderly.

Phase 2: Survey data related to mobile phone usage from elderly mobile phone users was collected over an initial period of 12 months in (mostly) South Africa and also Scotland. The Senior Mobile Phone Adoption Checklist (SMAC) (Van Biljon, et al., 2010) was then later expanded and verified based on the captured data.

Phase 3: A design framework was constructed which incorporates findings reported by Heo, et al. (2009) and Ham, et al. (2008). The framework also integrates the findings from literature study, the survey data and the extended senior mobile phone adoption checklist (ESMAC). The integrated framework provides guidance to support the design and evaluation of mobile phones for the elderly in an accessible and easy to use format.

Steyn, J., Van der Vyver, A.G. (eds.). (2013). Public and private access to ICTs in developing regions. Proceedings of the 7th International Development Informatics Association Conference, held in Bangkok, Thailand. ISBN: 978-0-620-58040-3 Pages 85-102

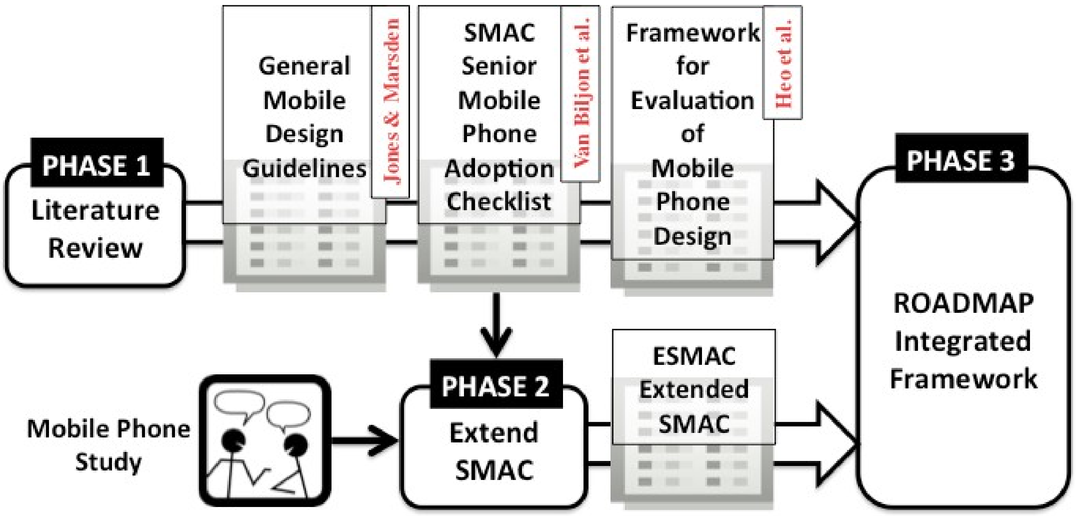

Figure 1: Research Design

Phase 1
Data collection involved a literature search for design and evaluation guidelines published in the last decade. A multitude of publications reported on small to medium-scale studies relating to various selected aspects of general technology and mobile phone use by the elderly, as well as by other user groups. Many of these include recommendations for the design of such technologies. We concentrated our search on publications that included already assimilated sets of guidelines, and those that present well-structured design or evaluation frameworks or models. See Section 3 for the literature review.

Phase 2
The data for phase 2 (refinement of the SMAC checklist) was collected by a class of post-graduate students in human-computer interaction (HCI) who served as field workers to collect data on older people's use of mobile phones. Using a questionnaire as starting point, they interviewed respondents and then studied the respondents' interaction with their cellular phones. Students had to identify a function on the cell phone that the elderly participant had never used, and then teach him or her how to use that function. Together with the completed questionnaire and notes from the interviews, the students submitted a detailed report on their observations of each participant while using the cell phone. The responses included interviews with 147 mobile phone users (60 male, 87 female) between the ages of 60 and 89. The majority (123) of respondents lived in South Africa, with 24 living in Scotland.

Phase 3
Heo and Ham (2009) present a comprehensive framework for the evaluation of mobile phones. They focus on the evaluation of generic mobile phone design. Here we focus on the evaluation of mobile phone design for the elderly, the seniors in our populations. We view their framework as a particularly apt foundation for grounding the development of our own "senior" framework. Heo et al.'s (2009) framework is summarised in Table A.2 (Appendix). We tailored their framework, incorporating the findings from our own research, to produce the consolidated framework.

3. Phase 1: Related Research

Our aim is to produce an integrated framework incorporating the findings of related studies. Hence the literature review will address the following questions:

1. What guidelines exist for the design of technology for the elderly?

2. What can we learn about mobile phone design for the elderly?

3. What guidelines exist for mobile phone design and, specifically, evaluation of senior "mobile phones?

3.1 Designing Technology for the Elderly

Siek (2008) reviewed a number of studies that examined the ability of the elderly to use computer input devices. These studies found that the elderly were slower in completing motor-muscle-based tasks (compared to younger users) and that when comparing control keys, mouse, and light-pen input devices, the elderly preferred the (light) pen. They further found that older people made more mistakes compared to younger users, and they have difficulty with fine motor control tasks such as double clicking. Older people performed point and click and click and drag manipulations slower than younger people, but completed it with the same accuracy. The likely reason for this is that the elderly may exhibit reduced fine motor control, muscle strength, and pincer strength, all of which are typically associated with old age. We should, however, keep in mind that they have probably had less experience using these input devices than younger users and may improve with time.

O'Connell (2007) emphasises that although the senior technology user has some characteristics in common with disabled users, they also have a unique set of characteristics that should be catered for in the design of interactive products. She reasons that the single most important usability aspect when designing for the elderly is related to reliability and the reliable delivery of functionality - and this may be achieved through robustness, reducing, recovering from, and explaining errors, consistency, and operability. Other important factors mentioned are personalisation (making them feel as if the product had been designed for them, and also to accommodate their unique needs), helpfulness, trustworthiness and confidence building, reducing their cognitive load, letting them feel in control (provide sufficient time for inputs, and provide for multiple undo levels), eliminate barriers to functionality, and enhanced feedback, enhanced discernability (through increased legibility, contrast, effective colour usage, clear and simple presentation and layout), and a focus on multimodal interaction.

3.2 Mobile Phones for the Elderly

In designing mobile phones for the elderly, it is important to know exactly what purposes they use mobile phones for. Ten years ago, Maguire and Osman (2003) found that older people primarily considered mobile phones as a way to assist in emergencies, whereas younger people used mobile phones mostly to interact socially. Older people's needs were related to maintaining independence. For example, older women were interested in finding the nearest retail shop that met their needs with location aware systems, whereas older men wanted to know how to get to places with various forms of transportation. Abascal and Civit (2001) also found that older adults liked the safety and increased autonomy mobile phones gave them.

Recent studies show that many older people now also use mobile phones as a social interaction tool (Gelderblom, et al., 2010; Conci, et al., 2009), but that its safety value is still an important motivation for using it and even more so for women (Kurniawan 2006). Keeping in touch with children and grandchildren is cited as a primary advantage of having a mobile phone, but apart from communication they also use the phone for organisational tasks (van Biljon and Renaud, 2008). In developing world contexts the usual aspects of communication and organisation remain, but the importance of the device for communication is more pronounced for rural users who do not have access to landline telephones (Van den Berg et al., 2008).

Preferred mobile phone characteristics

Findings of research about the requirements of older mobile phone users often relate to size - e.g., screen size, font size and icon size. Maguire and Osman (2003) found that older people want small phones with large buttons and location aware systems. They typically prefer larger fonts (e.g., 12-point font) (Darroch et al, 2005; Kurniawan, 2006) and bigger icons (e.g., 25mm) (Siek et al., 2008), even if they are able to read smaller fonts and icons. Kurniawan (2006) found that, unlike their younger counterparts, older women wanted brightly coloured, bulkier phones that they could easily locate in a cluttered handbag.

Renaud and Van Biljon (2010) describe older people's mobile phone requirements noting their need for autonomy, relatedness and competence as basis for their needs. Their results confirm many of the requirements already mentioned, such as bigger buttons, bigger font size on the buttons, good spacing between the buttons, and simple, consistent menu structures. In addition, they found that older users did not want any buttons on the side of the phone that could be activated accidentally, and that the number of buttons should, in general, be minimised. Older users in their study disliked slide-out keyboards.

In Van Biljon, et al.'s (2010) study involving 46 respondents over the age of 60, the following features were the most prominent requirements mentioned: bigger buttons, bigger text on the buttons, easier to remember menu paths, bigger text on screen, audio facilities including voice input/output and text-to-speech functionality, better colour contrast, fewer functions, larger screen size, and buttons that are further apart

Mobile phone adoption by the elderly

As mentioned in the introduction, technology adoption models such as that of Rogers (2005) are based on the idea that users either adopt or reject the technology and that adoption involves progression through phases such as appropriation (the process of possession or ownership of the artefact), objectification (the process of determining roles product will play, incorporation (the process of interacting with a product) and, finally, conversion (the process of converting to intended future use or interaction).

Renaud and Van Biljon's (2008) senior technology adoption model (STAM) argues that many older people do not go through the appropriation phase since older people often receive their phones from children or grandchildren and do not purchase it themselves. Another finding is that although older people might well use their mobile phones, they do not fully adopt them. This is echoed by Conci et al. (2009) who found that many older people do not go beyond their initial approach to the mobile phone, even after years of frequent usage. In a more recent study by Gelderblom, et al. (2010) it was found that users could be divided in three groups with regard to the rejection or acceptance of mobile phones: one group rejects the technology (some strongly and some weakly), one group accepts the technology (also, either strongly or weakly) and the third group has a neutral attitude towards the phone. The sizes of the three groups were comparable (28%, 37% and 35% respectively). Therefore more than a third of the sample of older mobile phone users stagnated in a phase of limited use where they had no inclination either fully to adopt or reject the technology. The fact that they continue to use the phone does not necessarily imply adoption. This non-adoption is indicated by low usage frequency, a minimal number of functions used, and expressed rejection.

Their intention to use was clearly influenced by social pressure from children, peers and grandchildren. There is a lack of experimentation and exploration that is partly a consequence of the fact that the perceived usefulness is somewhat transitive, since it is motivated by social influence rather than intrinsic motivation. In order to support seniors in making optimal use of their mobile phones we have to understand their actual needs, requirements and limitations. The SMAC checklist presented in the next section is one possible way of creating an awareness of the needs of the elderly towards encouraging full adoption.

3.2 Existing guidelines and evaluation frameworks for mobile phone design

Various sets of generic guidelines exist for the design and evaluation of mobile phones. In this study we refer to three prominent sets or frameworks which we believe capture the essence of mobile phone design, namely the guidelines proposed by Jones and Marsden (2006), the SMAC checklist proposed by Van Biljon, et al. (2010) and the evaluation framework of Heo, et al. (2009). Jones and Marsden (2006) provide mobile device design tips arranged into one of three categories namely physical characteristics, complexity and features (abbreviated as PCF). Table A.1 (Appendix) is a synthesis of the guidelines presented by Jones and Marsden (2006). Many of the guidelines have attributes that indicate that they could belong to more than one of these three categories. We placed them under the most obvious category and indicate, in the first column of the table, when they belong to any other category (with P=Physical, C=Complexity and F=Features). The same classification has been used for a set of mobile phone guidelines for the elderly proposed by Van Biljon, et al. (2010). Some of the items presented in Table A.1 require an additional explanation and these explanations are included after Table A.1 (Appendix).

In addition to the guidelines, Jones and Marsden (2006) make specific recommendations for mobile applications designed for use in the developing world. They specifically note that "using the visual language of cellular handsets is a good starting point. For Africa at least, be wary of interfaces that rely on users understanding hierarchically classified data (such as hierarchical menus) - we have found that hierarchies are not a common way of thinking across all cultures. For highly visual cultures, we have shown that iconic interfaces can be effective" (Jones and Marsden 2006:334).

More recently Hoober and Berkman (2012) published a comprehensive and detailed set of guidelines for mobile design. Their work is valuable when detailed choices has to be made between interface (soft and hard) objects, as they provide advantages (patterns) and disadvantages (anti-patterns) for virtually every interface element that is present on mobile devices. They do not, however, pay specific attention to the needs of the elderly. It should also be noted (and as use in both tables 1 and 2), that touch interfaces became popular since the publication of Jones and Marsden (2006), and are discussed in more detail by Ginsburg (2011) and Hoober and Berkman (2012).

4. Phase 2: Extending the Senior Mobile Phone Adoption Checklist (SMAC)

Van Biljon et al. (2010) presented an extensive requirements checklist for senior mobile phones. The 2010 SMAC checklist is presented in a simplified format in Table A.3 (Appendix). It is the synthesis of the reviewed characteristics of commercially available phones, phone requirements that were deemed a desirable feature or property from the 2010 findings, and the additional characteristics as identified in Van Biljon et.al (2010). Some phone characteristics that were deemed unsupported by the research findings, or are considered unimportant in the selection of a mobile phone for the elderly, have been omitted.

Three essential categories of characteristics emerge from this checklist:

1. Physical characteristics: It must have large, easy to understand keypad buttons that give good tactile feedback when pressed. It must have a large, high contrast screen with options for increasing the font size. It must have an extra loud loudspeaker.

2. Complexity characteristics: It must be easy to add talk-time to the phone. The menu structures must be flattened and simplified using self-explanatory terminology. Each keypad button should, at most, control one extra function.

3. Features: The phone must have the two essential functions (making and receiving phone calls). Non-essential, but desirable, functions include (in order of priority): Emergency (speed dial) function, alarm and scheduling functions, emergency button, voice input and output, and text messaging (SMS).

Previous findings by Renaud and Van Biljon (2008), Gelderblom et al. (2010) and Van Biljon et.al (2010) indicate that most current mobile phones do not address these limitations nor do they meet the needs and expectations of older adult users. The situation is made worse by the fact that many older people do not choose their own mobile phones and, because of cost implications, the tradition of passing phones to older relatives when a new mobile phone is purchased or a phone is upgraded, will probably continue. Therefore these relatives, friends and salespeople of mobile phones should be educated to know what older users need and what support and training is required to successfully adapt to a new or first, phone. A checklist such as SMAC may be useful in providing the required knowledge in a succinct form.

4.1 Extending SMAC

In order to extend the research reported in Van Biljon, et al (2010), student researchers collected additional data to bring the total to 147 seniors. Whereas the 2010 study included only South African respondents, we now also had 24 respondents resident in Scotland and this data was used to refine and extend SMAC.

Using data gathered by student field workers in the way described above is open to rater bias and unmeasured rating differences, but it has a number of significant advantages, namely:

1. Each field worker only had to interview one respondent, thus there was no restriction on how long they could spend with the subject.

2. Most of the students selected a family member (e.g. mother, father, mother-in-law,

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grandmother) which means the respondent trusted, and was comfortable with the interviewer.

3. Doing the study with only one participant made it possible for the field workers to report in great detail on their findings, providing us with a rich set of data to analyse.

Table 1 What elderly participants would like to change about their phones.

Proposed changes	Number of mentions
Bigger keys/buttons	53 (a)
Bigger text on screen	29 (b)
Larger screen size	29 (b)
Bigger text on the keys/buttons	26 (a)
Easier to remember menu paths	20 (c)
Fewer functions	16 (c)
Buttons further apart	12 (a)
More colour contrast	9 (b)
Audio input/output/voice prompts/text-to-speech/speech to text	8
Easier way to adjust speaker's volume/ring volume	6
Loud ringtones	5
Easier to understand terminology	5 (c)
Bigger phone	4
Add camera	4
Raised buttons	3 (a)
Better battery life	3
Keypad tones/tactile click	3 (a)
Touch screen	3
Lighting on screen shouldn't fade too quickly, Separate keyboards for text and numbers, Easier to load air time, Earpiece/hearing aid compatibility, Support different languages	All of these mentioned twice
Better grip, Add GPS functionality, Clearer battery status indicator, Joystick less sensitive, Clearer indication of new message/missed call, Keys too sensitive, Web access, Loudspeaker setting, Top/bottom distinction, More memory, Stylus to press buttons, No battery operation, Buttons must be soft, Log onto Internet by itself, Torch, Better quality photos, Switch on faster, More robust (drop proof), Automatic key locking function, Make it easy to set to Silent	All of these mentioned once
Note that *a* represents the references to the keypad, *b* the references to screen and display and *c* the references to reducing complexity	

The data extracted from the student assignments were organised into a spreadsheet under the following headings: Age, Gender, Occupation/previous occupation, Highest qualification/school grade, Place of residence, How long owned phone, How was phone acquired, How often used, Which functions used, Make/model of phone, Do you like the phone?, What would you change?, Makes life easier/difficult?, Task learnt, and Additional information. The interview and observation reports were combined in a separate document in such a way that each discussion could be linked to the corresponding row in the spreadsheet. Complete anonymity has been ensured: neither the respondents nor the student field workers can be identified in any of our reports.

Table 1 presents a "wish list" of changes proposed by the respondents in our study. The second column gives the number of times the feature was mentioned by the participants. The item 'fewer functions' mentioned by 16 of the respondents is also related to menu complexity, as well as reduced features.

Our questionnaire reflects the interpretivist nature of the research since it asked participants about their needs, giving them the freedom to respond and contribute rather than providing a fixed set of needs. The disadvantage of this approach is that it is more complex to gauge the importance of a need or feature. The fact that a participant did not mention a particular feature does not mean that they do not find it important; they may not have thought about it at the time or other, more important features, were uppermost in their minds. It was therefore important to triangulate our data with mobile phone design guidelines from the literature.

Table 2 Extended senior mobile phone adoption checklist (ESMAC)

1. Physical characteristics		
Type	Identifier	Details
Keys	1	Large size keys.
	2	Touch screen (can provide larger keys but less tactile feedback).
	3	Key buttons should provide for clear tactile feedback when pressed.
	4	Key buttons should provide for audible feedback when pressed. (Key tones should also be adjustable via the phone settings).
	5	Backlit keypad is preferred especially for use in low-light conditions.
	6	Keypad inscriptions should use a suitable large font with high contrast colours.
	7	Raised buttons
	8	The phone should have a big "Answer" button and a big "End Call" button.
	9	A keypad lock/unlock switch on the side of the phone is preferable to the normal two key press function.
	10	Separate keyboards for text and numbers.
	11	Easy key-lock function (physical and via software).
	12	Stylus for key-press and stylus clasp provided.
	13	Soft (rubber) buttons.
	14	Wide spacing between the keys.
	15	Keypad buttons are not too sensitive (prevent accidental key presses).
	16	Large emergency button in a prominent place (programmable function).
Display	17	Option to make the (power saving) display backlight timeout function extra long before it dims or switches the backlight off.
	18	Display should be larger than normal
	19	Screen font should be large.
	20	Screen font should be high-contrast.
	21	Display should have adjustable brightness and contrast.
	22	Display should have different colour schemes.
	23	Provide magnification and zoom options for enlarging the screen characters.
Case	24	The phone surface should be easy to grip.
	25	Overall size of the phone should not be too small.
	26	The phone must not be too heavy.
	27	Rubberized corners may protect the phone during a fall.
	28	The case design of the phone should be hearing aid compatible.
	29	The case should have phone neck-loop compatibility.
	30	Phone must have easily visible and identifiable speaker and microphone positions.
	31	Phone must have an obvious top and bottom.
Extras	32	It should have a flashlight LED external on the phone body that is easily controlled via a single button.
	33	The phone volume should have additional amplification with an extra-loud loudspeaker. It should have a speakerphone facility, and a headphone jack.
Battery	34	Longer battery life.
	35	It should be easy to recharge via a cradle rather than a plug.

2. Complexity		
Keys	36 37	Each key should preferably control only one function (not always possible on a limited size device), but at the same time, the number of key buttons should be minimized. Avoid button overload (dedicated function buttons). Recognisable function names on buttons to facilitate recognition rather than recall.
Menu	38	Simplified menu structures to minimize nesting of functionality
Indicators	39 40 41	Clear indication of battery charge remaining. Clear indication of a missed call and message received Easy to understand terminology and markings.
Tasks	42	An easy way to load talk (air) time.
3. Features		
Calls and SMS	43 44 45 46	Essential functions such as receiving and making a call, text messaging (SMS). Pre-programmed emergency speed dialling. Flashing and vibrating alert for incoming calls. Remote management of the phonebook (such as via SMS).
Caretaking	47 48 49	A big programmable, emergency button in a prominent place is desirable. Alarm and reminder functions (such as for wake-up and medication). Remote monitoring (i.e. constant one-way communication).
Communicate	50 51	Support additional languages in addition to English. Voice output of displayed information could also be useful, as is voice input (easily trained and effective voice recognition), used for example in voice dialling.
Features	52 53 54	Reduce the number of non-essential phone functions. Add a camera. Add internet access.

We can now extend and refine the SMAC checklist to incorporate the newly acquired data. The improvements included in ESMAC (the extended senior mobile adoption checklist) are mostly related to the following aspects:

(a) the keypad, with buttons mentioned by the majority of the respondents (97 = 53 + 26 + 12 + 3 + 3),

(b) screen and display improvements (67 = 29 + 29 + 9), and

(c) reduced complexity through a better menu structure and/or fewer functions (41 = 20 + 16 + 5).

The ESMAC model is presented in Table 2.

We applied the categories from Heo et al.'s (2009) design guidelines namely logical, graphical, physical and hardware to Jones and Marsden's (2006) general mobile device guidelines.

Table A.4 (Appendix) presents the integrated set of the ROADMAP guidelines.

1. The ESMAC identifier in Table A.4 refers to column 2 of Table 2 (ESMAC).

2. The shaded columns in table A.4 (#1 and #2) represent the count totals for the (1) general guidelines and (2) the ESMAC identifiers.

Table 3 is a summary of ROADMAP where columns are created as follows:

1. the ESMAC identifier counts are presented in the first column,

2. the design indicator based on Heo et al (Table A.2) in the second column, and

3. the supporting evidence as presented in the general guidelines column in Table A.4. (originally from Jones and Marsden as presented in Table A.1) in the third column (counts of 0 to 6).

The reasoning is that the important design indicators (specifically for mobile phones for the elderly), are reflected in Table 3 as a high count value (10 to 21), and optionally also supported by a significant general guideline tally. Similarly, medium priority design guidelines will be presented by tally values in the 4 to 9 range, but their priority can be strengthened or weakened by the general guideline tally (0 to 6).

(a) High priority design features: These include designing for error prevention, providing extensive user guidance and ensuring minimal memory load, design for informativeness, function existence, provide extensive visual cues, limit functions (but include required functions i.e. function existence such as a camera function), take note of special needs for keyboard and display design aspects. Function existence is moved to the high priority group because of its strong support from the general guidelines (6).

(b) Medium priority design features: These include flexibility, function and task automation, task support, adaptability and personalisation, hardware needs (earphones and amplification), and minimalism. Task support is moved from the low priority group to the medium priority group because of its strong support from the general guidelines (5).

(c) Low priority design features: These include aspects such as alternative input methods, adaptability and task support. Although indicated to be low priority features some of these such as task support to have strong general guidelines support.

Figure 2 depicts the development process and contribution of the different tables to the development of the ROADMAP framework.

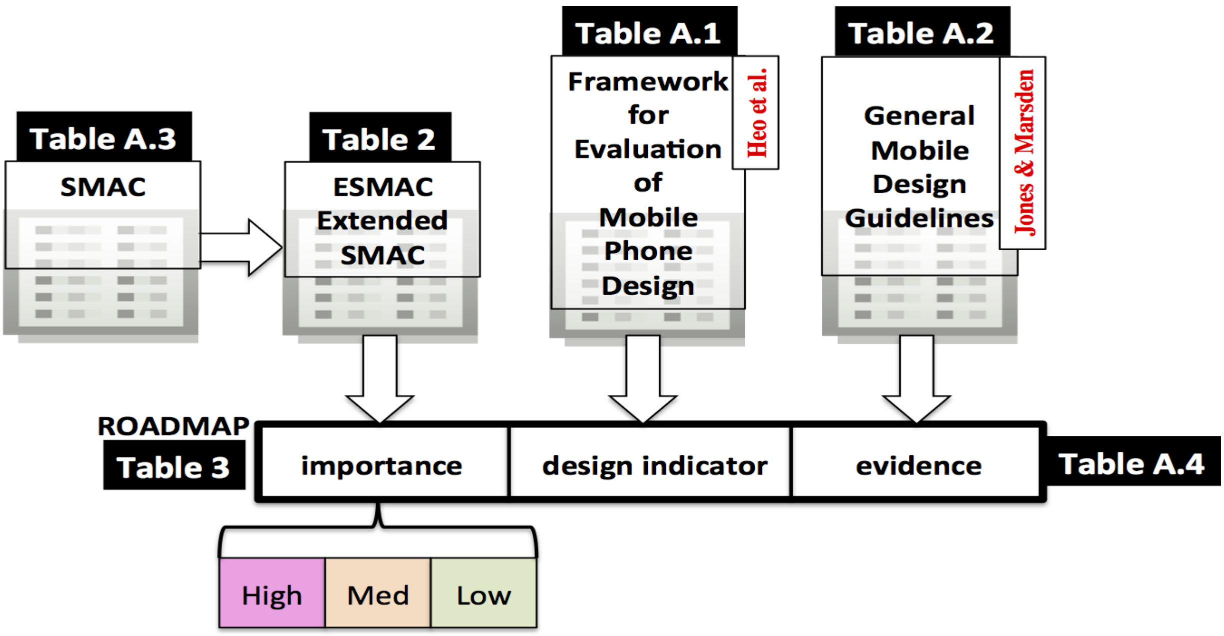

Figure 2: Development process of the ROADMAP design framework

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Table 3: ROADMAP: A Prioritised Design Framework.

Priority Number	Design Indicator Heo et al. (2009)	ESMAC Count	General guidelines supported: (0-6) Jones & Marsden (2006)
High Priority Design Features: Count 10 to 21			
1	Error prevention	21	0
2	Minimal memory load	12	2
	Alphanumeric (QWERTY) keys		1
3	User guidance	10	2
	Informativeness		0
Medium Priority Design Features: Count 4 to 9			
4	Visual cue	9	1
	Physical Interface/HW shape (9+9)		2+2
5	Function existence	8	6
6	Physical size (7+7)	7	1+1
	Front screen		1
7	Task automation	6	0
	Key mapping (6+6)		0+0
8	Flexibility	5	1
9	Minimalism	4	3
	Indicators		3
	Navigation (Menu)		2
	Physical Screen Colour (4+4)		1+1
Low Priority Design Features: Count 2 and 3			
10	Input method, Function automation, Adaptability, GUI naming/labelling, Task support	3	Some support 0-5 (5 is Task support)
11	LUI naming/labelling, Menu content, Consistency, Head set/jack, Special side keys Earpiece buzzer, GUI colour	2	Some support 0-2

5. Discussion

The construction of the ESMAC design framework entailed the decomposition of the framework described by Heo, et al. (2009) and Ham, et al. (2008), for the evaluation of mobile phones and the integration of the results of the literature study with the extended senior mobile phone adoption checklist (ESMAC). Finally the findings were organised into a framework for the design and evaluation of mobile phones for the elderly as presented in Figure 3. The framework is based on Heo et al.'s (2009) graphical user interface (GUI), physical user interface (PUI), logical user interface (LUI) and hardware (Device) categories, is the theoretical contribution of this study. Comparing the findings to the prioritised design features as presented in Table 1, it is evident that there are similarities, and not surprisingly these are related to the three most obvious customisation requirements for the elderly namely finger and hand dexterity, visual deterioration, and cognitive re-alignments requirements.

Our findings agree with those of O'Connell (2007), that the single most important usability aspect when designing for the elderly is related to reliability and the reliable delivery of functionality which may be achieved through robustness, reducing, recovering from, and explaining errors, consistency, and operability, it is clear that all of these aspects are indicated to be high and medium priority design characteristics from Table 3. Error prevention is the highest count feature in Table 3. Other important factors such as personalisation are also present in Table 3 as flexibility and adaptability, whilst aspects such as accommodating their unique needs, helpfulness, and reducing their cognitive load, have been discussed comprehensively. Reducing complexity has also been discussed and addresses O'Connell's (2007) concerns regarding multiple undo levels, eliminating barriers to functionality, enhanced feedback and discernability (through increased legibility, contrast, effective colour usage, clear and simple presentation and layout). The following issues pertaining to the use of mobile phones for the elderly are highlighted.

- Keyboard characteristics: The requests are for larger, widely spaced keyboard buttons with clear markings which is supported as medium priority features as physical size and interface (counts of 7 and 9 respectively). In addition there is also some support for this from the general guidelines (2 and 1). We can therefore conclude that keyboard design aspects (the detail of which is revealed in section 1: Keys of table 2) are of paramount importance.
- Complexity reduction: It is immediately noticeable from Table 3 that this is the one design aspect that should be given priority treatment above all else. Aspects such as user guidance, minimal memory load, visual cues, minimalism and informativeness, are all aspects that that ameliorate the impact of complex interfacing with high-technology products for the elderly, and are well represented in the high and medium priority sections in table 3. These aspects also receive some (mostly 1 or 2) support from the general guidelines section in table 3 and are consistently in the high request section of table 1 with request counts of 20, 16 and 5. Table A.1 has valuable indicators in its second section (complexity) for managing and reducing the level of complexity for mobile phones.
- Display characteristics: Table 3 indicates that the (front) screen, visual cues and indicators, and physical size all show that screen size and arrangement are important design aspects. This view get support from table 1 (29 + 29 + 9 requests for screen and text size and contrast), and also receives some support from the general guidelines in table 3. Table A.1 presents a summary of the more detailed design guidelines for mobile device screen that can be found in Jones and Marsden (2006).
- Features: Because function existence is the only medium priority characteristic evident in table 3, and fewer function is a highly requested feature from table 1, the results from table 2 do indicate that there are some functions, mostly aimed at caretaking and reducing the complexity of required tasks, that are essential additional functions in a mobile phone aimed at the elderly. The availability of needed functions is also strongly supported by the general guidelines count of 6 in table 3.

When we compare these conclusions with those from earlier (Van Biljon et al. 2010) results (as summarised in section 2 in terms of physical characteristics, features and complexity) we can state that all of the recommendations are supported by the evidence presented here, and that our findings indicate that the single most important design aspect that should be addressed when designed mobile phones for the elderly should be aimed at reducing complexity of use and interaction. As an example of the application of this framework we applied it to our four-year longitudinal mobile phone usage pattern comparison. This specific example focused on the trends in rural mobile phone use patterns for the period 2009 to 2012, shown in Table 4 and was derived from data collected as reported in previous studies (Gelderblom, Van Biljon, Van Dyk 2010; Van Biljon, Van Dyk and Gelderblom, 2010, Van Dyk, Renaud, Van Biljon 2012).

Table 4 A Longitudinal study on rural mobile phone use for the period 2009 versus 2012

Characteristic	Period	
	2009	2012
Average Age (years)	68.2	70.8
% Gift/(Gift + Bought)	12/(12+7) = 63%	6/(6+4) = 60%
% Liked = Y(/Y+N)	15/(15+2) = 88%	10/(10+0) = 100%
Functions used	35 functions total/19 users = 2	50 functions total/10 users = 5
Average usage	3.7 times a week	5.8 times a week
Changes requested	32 changes/19 = 1.7/user	14 changes/10 = 1.4/user
Note: Once a day and every day =7 times a week; Once a week or less = once a week		

This study confirmed previous findings (Van Biljon et al., 2010) that the:

(a) origin of ownership of the mobile phone seems to be a strong indicator of future use (in terms of frequency and depth of use), and
(b) frequency of phone usage is a good predictor of the depth and breadth of its use, and
(c) age of the mobile phone user correlates to the owner's attitude towards, and use of, the phone.

Table 4 demonstrates that the use of mobile phones have increased considerably (by 63%), over the period of 4 years, and that the user experience (using changes requested as an inverse proxy for this) has also improved (compare 1.4 requested changes per user in 2012 to 1.7 requested changes in 2009). Because (a) and (c) are effectively constant across the two comparison points (gift versus bought and the age of the user), we are confident that conclusion based on longitudinal trends observed for (b) are valid, and this is further supported by the data as presented in Table 4 where the average number of function used have also increased sharply from 2009 to 2012.

Table 3 lists as high priority design features: error prevention, minimal memory load, alphanumeric keys, user guidance, and informativeness. The detailed data on changes requested obtained from the 2012 study confirms that all of these design features remain a problem for elderly mobile phone users. For example, requests such as easier to reach and use, menu functions, easier keypad use (to prevent errors), and help in selecting functions are mentioned. This indicates that these areas are still problematic. Many of the medium priority design features are also still present in the 2012 study such as minimalism (users asked for fewer functions). Even though the usability of mobile phones for the average user have improved, this is not necessarily the case for the elderly, rural, mobile phone user and that supports the significance of this framework.

6. Conclusion

This paper motivated the need for a framework to guide the design of mobile phones for users over 65. We discussed the design and evaluation of mobile phones for the elderly, and then narrowed down existing guidelines by using mobile phone adoption models and their implications for mobile phone design. The initial research data was collected in (mostly) South Africa and also Scotland. This SMAC checklist (Van Biljon, et al., 2010) was expanded and verified based on the additional data captured for this study to synthesise a new set of guidelines namely the extended senior mobile phone adoption checklist (ESMAC). We consider the findings to be important, because previous findings indicate that almost all of the current range mobile phones (whether basic or smart) do not address the limitations or do not meet the needs and expectations of older adult users. The situation is worsened by the trend of passing older phones up the generation tree when a when a new mobile phone is purchased or upgraded. Therefore caretakers, relatives and friends of the elderly should be educated about the needs of older mobile phone users so that they understand that these users need support and training to successfully manage and use a newly acquired mobile phone, and that a phone which is perfectly suited to a younger user is not necessarily suitable for an older person. The ESMAC checklist is the primary practical contribution of this study. It is aimed at the needs of older people in general but even more applicable in developing countries where many older people rely solely on private mobile phone access for their communication needs.

7. Acknowledgement

This work is based on the research supported in part by the National Research Foundation of South Africa (Grant specific unique reference number (UID) 85667). The Grantholder acknowledges that the opinions, findings and conclusions or recommendations expresses in any publication generated by the NRF supported research are that of the author(s), and that the NRF accepts no liability whatsoever in this regard.

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