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Inclusive design and human factors: designing mobile phones for older users

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ABSTRACT

This paper reviews the human factors requirements of mobile phones in order to facilitate inclusive design and provide older users with technological support that enhances their day-to-day lives. Particular emphasis is placed on whether human factors requirements are fully considered and meet the needs of older users. The scope of this review is necessarily wide including: human factors, gerontology, inclusive design, technology and design research methodologies. Initial consideration is given to understanding what it means to be an older user and the changes that occur with the aging process. Older user requirements are examined in relation to achieving inclusive design solutions and the way in which human factors methodology can be used to support inclusive design goals. From this standpoint, attention is given to the design of mobile phones, considering how human factors issues are reflected in product design and context of use beyond the phone handset to the wider interaction environment. This paper does not propose specific direction from primary research findings but argues for a 'state of the union' with regard to the current approaches designers and manufacturers adopt and the effects that design decisions have on potential end users. This paper argues that when effective and flexible human factors methodology and inclusive design ethos is integrated into the product development process global benefits to a wide user population can maximise inclusion as opposed to exclusion via technological advances.

Keywords: *Human factors, inclusive design, older users, mobile phones, cell of exclusion*

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1. Introduction

With approximately 25 million mobile phones in use by one in three of the UK population, mobile phones have developed at a considerable pace over the past 20 years within the UK and throughout the world (The Stewart Report, 2000). With the increasing number of older users as a demographic group, this should mean that they

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present a large-scale user group of such technology. However, this is not the case as mobile phone design is skewed towards younger users. This may be due, in part, to techno-phobia which is an anxiety associated with using advanced technologies (Elder, Gardner, and Ruth, 1987; Hone, Graham, Maguire, Baber, and Johnson, 1998). Techno-phobia is correlated with age illustrating that older users are more reluctant to use new technology than younger users and could arise through poor user requirements capture where the design solutions do not meet the specific needs of older users.

In a highly competitive marketplace, development of mobile phones is driven by consumer spending and problems can develop where the main consumer base becomes the main design focus because it is the main revenue platform. As a result, there is a danger that the development of mobile phones has not grown to support different users and that niche user groups have to ‘make do’ with what is generally available. This would seem to be the case for older users. However as the older population increases, so too does their power as a consumer group as they move out of being a niche user group and into being their own mainstream market sector (Lee and Kim, 2003).

2. Older users: a growing consumer group

Over the last 150 years the combination of reduced infant mortality and increased life expectancy has led to a restructuring of population demographics in the UK and across the developed world (Coleman, 2001). Population projections suggest that following the two post-war baby booms of the 20th Century, the older population will continue to expand during the first quarter of the 21st Century from 400 million to 1.3 billion by 2050 (Summers, 2001).

As users grow older and their requirements change, designers should be sensitive to their changing user needs as well as designing for the users they might eventually become themselves (Coleman and Pullinger, 1993).

Older users may have a substantial command of income, with children grown up and with mortgages paid off, they can control a significant portion of the country’s wealth, saving and spending power (Lee and Kim, 2003). However, many older users are poor and struggle financially and/or physically in an environment that can enforce disability out of impairment[1]. Disability through impairment can refer to those at a disadvantage

[1](http://www.ricability.org.uk/reports/report-design/guidelinesforproductdesign/contacts.htm#4)

through a lack of resources and support. That users can be 'disabled' through poor design highlights the idea that users are often stifled by a restrictive, rather than de-restrictive, environment that surrounds them (Fisk, 1993). With various needs, technology should be designed to support older users through independent living and interaction rather than being alienated because they cannot use a mobile phone, access the internet or understand the latest graphic user interfaces (Mikkonen, Vayrynen, Ikonen, and Heikkila, 2002). Since the early 1990s this has been a fundamental concept in design education philosophies applied by leading authorities in the UK and across Europe such as the Helen Hamlyn Research Centre at the Royal College of Art, The Design Council, The Danish Centre for Assistive Technology, as well as leading research groups such as COST 219 investigating accessibility for all users to services and terminals for next generation networks.

3. Older users: the performance continuum and aspects of aging

Older users by definition have lived longer than younger users and therefore represent one of the most heterogeneous groups in society (Bullock and Smith, 1987). Assuming that people generally start at a similar point, born with similar functions and abilities, by the time they become older users they will have gathered many different experiences, perceptions and mental models of the world, as well as possibly suffered the rigours of physical and mental demise in various forms. From a similar starting point older users will have travelled and deviated further than other user groups and therefore be further away from design homogeneity.

A performance continuum exists as a function of age in terms of vision, hearing, motor function and cognition.

3.1. Vision

Visual impairment takes many forms, from partial loss of vision through to complete blindness. Aging can be seen to affect older adults in many ways briefly highlighted below:

- *Decreasing Visual acuity* (the ability of the eye to discriminate detail) diminishes especially after 50 years of age (Haigh, 1993; Steenbekkers, Dirken, and Van Beijsterveldt, 1998). The average 60 year old requires three times more light than the average 20 year old to see the same level of detail (Haigh, 1993).

- *Decreased contrast sensitivity* (the ability to distinguish between light and dark) diminishes from the age of 20 years to 80 years with the main decline beginning around 40 to 50 years.
- *Worsening light accommodation* (the ability to focus on near and far objects) decreases from the age of 8 to 50 years by roughly 50-55%, at which point the decline generally levels off. The decreased elasticity in the lens leads to a reduction in the accommodation and an average near point of 50cm for a 50 year old, compared to 12.5cm for a 30 year old (Haigh, 1993, Ishihara, Ishihara, Nagamachi, and Osaki, 2002).
- *Difficulties with glare* (which arises from harsh light leading to discomfort and/or disability). The scattering of light in the eye due to increasing lens opacity increases the effect of glare. With three times more light required (in relation to visual acuity), the increased likelihood of glare needs accounting for in design solutions for older users (Haigh, 1993).

3.2. Hearing

As with vision, changes to or the gradual loss of hearing are most commonly associated with aging. The process is affected by many factors such as work exposure, diet and genetic influences, but by the age of 50 there is often sufficient loss of hearing to cause impairment (Takeda, Morioka, Miyashita, Okumura, Yoshida, and Matsumoto, 1992). Aging has also been shown to have an effect on the ability to interpret and respond to complex auditory information. The ability to discriminate frequency also deteriorates in a linear fashion between 25 to 55 years of age, after which a greater differential is required especially for the higher frequencies (Takeda et al., 1992).

3.3. Motor Function

Age related changes in hand/motor function appear to occur as a decrease in strength, dexterity and range (Steenbekkers et al., 1998). There is a decrease in grip strength and endurance with age, with force exerted deteriorating from the mid to late twenties (40% decline in strength from 30 to 80 years old) and the average 65 year old user having only 75% maximal strength (Sato and Fukuba, 2000).

3.4. Cognitive aspects of aging

In general, working memory appears not to decline in relation to storage capacity, but rather processing efficiency declines over time (Norris, Smith and Peebles, 2000).

Processing speed declines but recall stays within Miller's 7 plus/minus 2 chunks (Miller, 1956). Long-term memory declines with age in relation to episodic memory, however, semantic memory is maintained and deficits are rare (Bowles, 1993). In relation to procedural memory, decline is elevated with the complexity of task and reaction time has been shown to decline with age. Therefore memory retention for prior known faces and places can appear to be good if supported by contextual knowledge but new complex tasks can be problematic for older people. Total knowledge increases with age and so a larger database is available for older rather than younger people although speed of retrieval slows down. Older people maintain the ability to learn, with evidence of neural plasticity, however, the process takes more time, especially with complex material (Kandel, Schwartz, and Jessell, 2000). This could help explain techno-phobia if there is little or no prior context for older users to use in learning how to use new technologies or new technologies are not developed which support the mental models of older users.

Skills such as vocabulary and language use are maintained unimpaired until late in life whereas skills that depend on rapid processing, accurate logical thought and spatial ability are markedly affected as people become older (Haigh, 1993). Evidence supports the theory that older people cope poorly with divided attention tasks and whilst problem-solving increases in capacity until the ages of 40 - 50 years, after this period an experiential related decline occurs (Norris et al., 2000).

In relation to the performance continuum and the effects of aging, decline occurs throughout adult life. Most areas of decline vary greatly between individuals due to the heterogeneous nature of aging itself and the multitude of factors (such as such as lifestyle, health, nutrition, individual differences, work and exercise) that can impact on everyone growing older. In relation to mobile phone design the performance continuum is linked to human interaction with complex systems. On one level a mobile phone is a single device used by an individual interacting with a keypad, screen and simple interface. On another level a complex set of combined cognitive and physical interactions are linked to changing contexts of use and environments in which these mobile devices are used. The management of these interactions underpin how successful and accessible these mobile technologies are. The challenge for designers is that there is no typical older user to design for. What is required is a clear philosophy (such as inclusive design) and an approach (such as human factors) in order to develop user-centred solutions that meet older user needs. If this is achieved then designers can target the design for a specific user group and provide an inclusive design solution.

4. Inclusive design: incorporating the needs of older users

Inclusive design aims to cater for as many users as possible and therefore incorporate diverse user requirements – it is more of a design philosophy than an end product. The underlying premise of this philosophy is that it should enable rather than exclude different users (Gyi, Porter, and Case, 2000). However, the aim is not necessarily to achieve a 'universal' solution but to be more pragmatic, supporting different users by forming generic design solutions that suit specific needs. A model of inclusive design is illustrated below in Figure 1 (adapted from Keates and Clarkson, 2004).

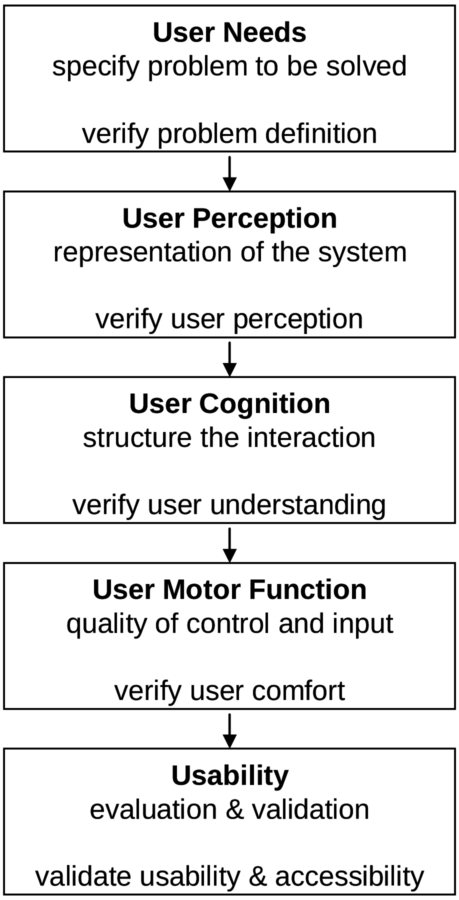

Figure 1. Model of inclusive design (adapted from Keates and Clarkson, 2004)

The model highlights the complexity of inclusive design from analysing user needs through to evaluating and validating the usability of design solutions. In order to achieve this, user needs have to be understood in terms of:

- the representation of the design problem (taking user perception as a basis for the design);
- the structure of the interaction between the user and design solution (understanding that this will be different for different user requirements);
- the quality of control and input (as a basis of user comfort).

If these aspects are addressed then the design solution should be accessible to users and therefore inclusive in its nature. If inclusive design is implemented at the start of the overall design process, design options can be evaluated in an iterative manner. For older users this could mean that specific user requirements are identified. By incorporating human factors methods, involving users and designers, to help develop and sustain inclusion throughout the design process this should also support the uptake and usability of actual products and services.

5. Human Factors in Design research supporting inclusive design

Human factors offers a 'user-centred' approach which ensures fit between the design and the users needs and requirements. For decades, various task analysis techniques (eg. Kirwan and Ainsworth, 1993; Militello and Hutton, 1998) have allowed human factors experts to describe the interactions between users, technologies and their environments at a level of detail that can be used to inform the design solution. Recognition of this has recently been formalised by the publication of International Standard ISO 13407, Human-Centred Design Processes for Interactive Systems (Earthy, Sherwood Jones, and Bevan, 2001) which specifies four general principles of user-centred design:

- ensure active involvement of users and a clear understanding of user and task requirements (including context of use and how users might work with future products);
- allocate functions between users and technology (recognising that today's technology, rather than de-skilling users, can actually extend their capabilities into new applications and skill domains);
- ensure iteration of design solutions (by involving users in as many stages of the design process and implementation cycle as is practical);

- ensure the design is the result of a multidisciplinary input (emphasising the importance of user feedback, but also stressing the need for input from such disciplines as design, marketing, ergonomics, software engineering, technical authors, etc).

Without such a standard there is a risk of specifying or designing solutions that fail to support the users' understanding of the target application (Stone, 2001). Advances in applied methodologies have increased the level of exposure between designers and end users. Techniques such as video ethnography (Hughes, O'Brien, Rodden, Rouncefield and Blythin, 1997) and audio/video diaries (Palen and Salman, 2002) prove very powerful tools to a design team or client in developing solutions based on user understanding, requirements and ultimately real use. Beyond the 'exploration and understanding' phase, older users can act as powerful participants in the design process. These individuals can often provide an innovative contribution to design thinking and solution creation via articulation of real needs and real experiences which the design team can use to develop conceptual solutions (Woodhuysen, 1993).

Implementing human factors methods and data can be difficult or can be seen to stifle individual designer creativity. Good design features can sometimes occur by chance, or design teams are not able to involve users until near the end of the project (Etchell and Yelding, 2004). Designers often have to follow a strict design specification from their clients and can find anthropometric data difficult to implement due to its format being non-design centric (Gyi, Porter, and Case, 2000). Furthermore, holistic end user analyses are required in usability testing to achieve designs that really meet the needs of target user groups and these are not always factored into the design process (Tuomainen and Haapanen, 2003).

Human factors specialists involved in the design process must seek to supply knowledge to designers to maximise assistance and education whilst minimising information overload by disseminating knowledge based on shared mental models (Hitchcock, et al., 2001). One such model is defined as the 'Cell of Exclusion' (Mitchell and Chesters, 2004). The cell is based on a cube metaphor with each face of the cube highlighting design boundaries and barriers to use. Indeed, it has also been referred to as the 'inclusive design cube' because by taking account of these barriers a more inclusive framework can be established (Keates and Clarkson, 2004). The cell of exclusion reflects the design dilemma based on both the user's and society's expectations which could be altered through inclusive design initiatives.

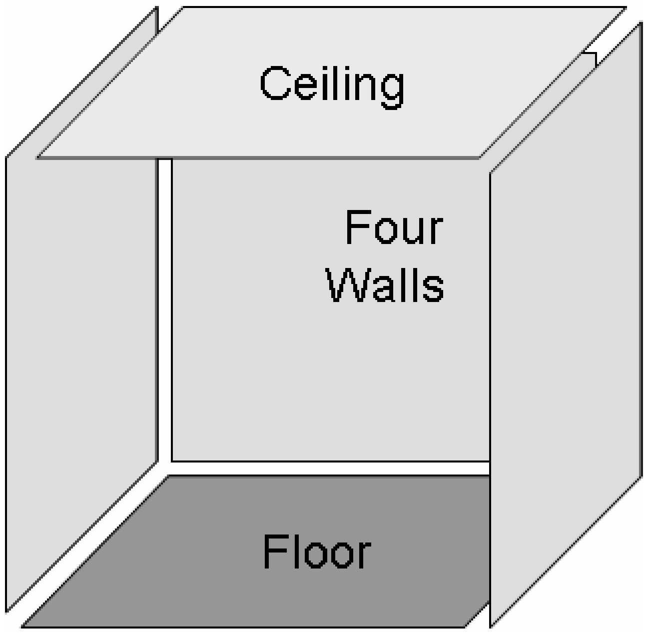

Figure 2. The ‘Cell of Exclusion’ (adapted from Mitchell and Chesters, 2004

The four sides of the cube, or walls of the cell, are defined as: (1) a non-inclusive design process (which ignores the needs of specific users), (2) ignorance about barriers (which ignores the user requirements), (3) ignorance about the penalties of exclusion (design blindness to the effects of alienating user groups), and (4) absence of disability expertise in the design process (limited or non-existent specialist knowledge). The ceiling of the cell refers to society’s low expectation of the older user and the floor of the cell refers to the low expectations of the users themselves (perpetuated through the society’s lack of consideration for their needs). The ceiling and floor of the cell help explain techno-phobia as society has expectations for niche users to adapt to mainstream technologies whilst users may have severe doubts about how easy it is to learn to use new technologies.

Relating this to mobile phone design, non-inclusive design factors refer to the implicit performance specifications based on the ability to see the screen, use the keypad with dexterity and conduct tasks within specific time limits (Mitchell and Chesters, 2004). Based on this, it should be relatively simple to design out such barriers based on a better understanding of inclusive design principles rather than penalising users based on their sometimes limited abilities (Mitchell and Chesters, 2004).

6. Mobile phones: 'user-centred' solutions for older users

Mobile phone designs have evolved with younger users in mind, but access to mobile phone technology can offer the older user the opportunity to maintain their quality of life (see note 1) . Furthermore, as mobile and wearable technologies evolve they also offer tools for monitoring health (Dishman, 2004) and maintain social inclusion and community connectivity via networks such as the 'message center' (Wiley, Sung, and Abowd, 2006) Such communication solutions designed specifically for adults can integrate carers, older and younger user and sustaining independent lifestyles. However, as technology advances and becomes increasingly complex, older users are exposed to products and services which they are unfamiliar with and which can actually further isolate them if they are not designed to support their needs.

Older users have identified a number of problems with mobile phones such as displays that are too small; buttons and keypads that are too difficult to use; too many functions; battery life too short; poor sound quality; and a preference for speech input (see http: www.nttdocomo.com/pr/2004/001207.html). All these issues can be directly mapped to the performance continuum effects discussed earlier. These issues of functional improvement may apply to all users to some degree and serve to highlight the importance of inclusive design in meeting not only older user needs but also assisting other users.

The screen display of a mobile phone to many older users (or any other visually impaired user) presents a barrier to use with many phone handsets. Mobile phones are used in all environments and varied levels of illumination must be accommodated by screen and display design. Older users may suffer a deteriorating capacity to use miniature screens as optical accommodation rates weaken.

Poor vision can be supported by tactile feedback such as the raised '5' key, use of contrasting textures, and clear and consistent key pad layout. Alongside this, audible feedback can be provided from an audible 'beep' through to fully functioning speaking phones, such as the 'Owasys 22C' which provides audible text, numbers and phone functions (see note 1).

Phone use in public areas can be susceptible to background noise which interferes with auditory input. The inability to distinguish complex sounds can often make communication increasingly difficult for older users and hearing aids can also affect mobile phones usage, causing audible interference which can range from being annoying to masking communication. Hearing deficits can also be supported in mobile phones with the use of text, vibration warning and visual ringing, all providing non-audible feedback. The text phone or videophone offers solutions for the hard of hearing but can be exclusive due to the high price of such products (see note 1).

The trend for miniaturisation of mobile phones has impacted on keypad size which has diminished significantly, resulting in a smaller physical interface (with smaller key pads and spacing). For the older user, coupled with impeded dexterity, the interface can restrict them, making it difficult view the keys or move between them easily. These factors can be further compounded in older users by muscular tremors or joint rigidity which impact on motor control. Inclusive design principles have assisted users with regard to hand function in fixed phone technology, by user-centred developments such as the 'Big Button' telephone by British Telecom which bases its design solution on the ease of use of large keys which are easy to read and use.

Complex cognitive processes are increasingly required with multi-functional phones which do more than just allow the user to make mobile phone calls. The combination of memory and dexterity issues can often exclude users in timed responses systems where limited dial time is allowed to make the call and/or where the phone interface is difficult to use. The decreased reaction times of older users may leave them unable to exploit this technology to the full, unless it is designed with them in mind.

One major problem for the older user is the lack of standardisation in interfaces which is an essential component in designing transferable usability across mobile phones. Technological change has been rapid and the increased complexity of new phones with less intuitive interfaces may require previous experience of earlier generation products in order to understand current designs. However, older users may not possess the requisite specialised prior knowledge where as younger users can rely on the mental models they have built up from using previous generations of technology. This is apparent not only when considering the move to using mobile phones rather than land-lines, but also with the difficulties experienced in changing from one brand of mobile phone to another. Brand specific differentiation causes barriers to use as users find it difficult to learn new operating procedures from the ones they are familiar with.

The general effects of the aging process are summarised in Table 1 below and provide a basis for evaluating how current phones meet the needs of older users.

Factor	General effect on older users	Potential design solution
Vision	• more light required • ability to focus deteriorates • ability to deal with glare diminishes	• improve illumination • provide user interface options • if a display is required, use anti-glare coatings to display
Hearing	• loss of sensitivity to higher frequencies • general threshold deteriorates • complex sounds more difficult to process	• do not use high frequency audio feedback • couple auditory feedback with visual or tactile feedback • keep auditory feedback as simple as possible
Hand function	• general weakness (strength and grip) • dexterity often impaired • range of movement is more limited	• design casings that are easy to hold and keys so they are easy to press (oversized and/or easy press). • group keys by use and function.
Cognitive processes	• processing time – with working memory • long term memory (episodic) • reaction time • learning time required • problem solving capacity	• keep menu structures intuitive and consistent • make user interfaces as simple as possible

Table 1. The effects of the aging and potential design solutions

7. Mobile phones: design solutions for older users

Whilst many mainstream phones do not cater for the older user, models are emerging that are designed with the older user in mind (even if not all of them are commercially available yet).

The Design Business Association challenge winning ‘Ello’ phone minimised functions by providing a screen-free, large tactile button, ‘clam’ style handset that afforded clear visual contrast and graphics. As a concept phone it has not been produced commercially, but adopted simple to use memory functions, and programming with audio and visual feedback to provide a design solution based on inclusive design principles that produced a simple handset that affords ease of use.

The ‘Mobi-Click’ phone, released in 2004 by Orange, affords ease of use (answering and hearing) with an integrated loud-speaker. As with the ‘Ello’ handset, this phone does not have a display and offers a very simple design with only three keys. However, although the interfaces is a simple and intuitive in design, it resembles a pendant alarm system for older users (such as the ‘Benefon Seraph’ which also has only three buttons), which places it at risk of falling into the specialist disabled equipment category rather than a standard phone with wider market appeal. By ignoring the 'inclusive' principle of non-specialist requirements, the design does not cater for younger users who require a display and texting facilities.

Another similar design is the 'SilverPhone' which has been designed to be more usable by older users than conventional mobile phones. Along with the 'Ello' and 'Mobi-Click', this phone does not have a screen and uses a limited set of three buttons. It is bought pre-programmed in order to make it ready to use and easy to begin using than many conventional mobiles, store 3 most important numbers and uses one touch input for simpler interactions. It has an in-built loud-speaker and can be used by blind or partially sighted users also. However, this phone has the aesthetic of a remote control handset not a contemporary phone and might have been simplified too much in trying to make technology 'simple to use' rather than 'easy to use'.

One of the smaller phone producers in Japan, Kyocera, have targeted older users with considerable success by releasing the 'Tu–Ka S' phone. The handset is modelled on a standard handset very much like a wireless landline handset (and therefore fits with a common mental model of a standard phone which older users are more comfortable with). Like the other phones, it does not have a display and therefore has a long battery life. The keys are large with simple colour coding and good contrast. In emphasising the product slogan 'no manual needed', all aspects have a simple, intuitive, functional design that affords ease of use. Due to mapping onto a common mental model of a standard phone, this handset should be usable by a range of users with varying abilities and therefore could have wider appeal than just the older user market. Similar trends have seen to the move towards mapping contemporary technology with traditional interface design with the contemporary version of the old fashioned Roberts radio (RD50 DAB/FM radio) being a good example of new technology packaged within an older mental model underpinning the context of use.

At the high end of the market NTT DoCoMo released the 'Foma Raku-Raku' phone aimed at users unfamiliar with mobile phone technology. This phone uses image-based instructions for task 'walkthrough' and a read aloud element for a wide variety of functions in order to make the learning process as easy as possible. As with the 'Ello' handset, it is a 'clam' style phone with good battery life however visually it is problematically styled in non-contrasting silver perhaps making it difficult to identify specific keys.

Tu–Ka also present the TS41 'Bone Phone' based on technology that transmits sound via the skull, thus increasing the efficiency of sound transmission. Previously this technology has only been used for fixed lines with older users in mind but is now proving popular to young businessmen who are working outside whilst they talk, illustrating how different design solutions can migrate across different user groups, broadening the market share and fulfilling many user requirements.

These phones seek to address issues faced by the older user with varying degrees of success and emphasis on inclusive design. In so doing, many design solutions focus on the immediate physical design of the handset (incorporating different aspects of visual, auditory, dexterity and tactile based limitations).

Focus on designing for context of use and wider environments or settings prove more of a challenge. Speed of processing skills, memory abilities and reaction time limitations can impact on the notion of the 'cell of exclusion' which designers need to be aware of. A consideration of users in context may reveal that older users find themselves using phone technologies in more complex changing environments and usage scenarios than their use of phones in static settings 10 years ago. It is important to consider mobile phone design as part of a holistic system and the Human Factors and Ergonomics Society (HFES) have developed standards to provide in-depth requirements to the design and usability of such systems (HFES, 2001). From the standards, the function of 'dial-ahead' designs (the ability to fast track through voice responses) and handling 'time out' (time periods allowed prior to stopping the function) are of interest. Older users vary in their ability to access such systems due to varying cognitive abilities, which along with younger user frustration at the time restrictions and lack of, or unclear, short cuts identify an area of design where the technology, engineering or the design itself has not afforded inclusive principles. In targeting an inclusive design it is essential to consider the system capability to speed up or slow down the response time and give control to individual users. An example of this could be the use of time prompts between each response tailored by the user via the keypad, with the aim being to empower the user in the use of such systems.

Developing more inclusive mobile networks is something that the COST programme has been investigating for more than 30 years as part of an inter-Governmental framework for European cooperation. It has published guidelines for mobile phones ranging from the design of instruction books, physical characteristics, operation, display and keypad design, as well as audio output and the use of wireless interface technologies. Much of the guidance is generic and therefore provides an inclusive approach to designing for older users whilst also supporting younger users, but perhaps with a greater acknowledgement of older user limitations (based on an understanding of the performance continuum) would enable designers to develop solutions that are more sympathetic to older user requirements.

8. Conclusions

An aging society of consumers has a variety of specific user needs which need to be incorporated into the design of mobile phones. Inclusive design is a philosophy that can enable users and more specifically the older population to take a more active role in society through design solutions that support their needs. However, all too often, especially with rapidly developing technologies, this group is excluded making disabilities out of impairments.

The advantages of inclusive design and user-centred approaches and standards, have been cited along with the requirements older users have, with a broad description of the performance continuum and changes that occur with ageing. The failure to include the needs of older users is due to a number of factors which construct a ‘cell of exclusion’ not only in the expectations of design but those of older users themselves and society also. The notion of the ‘cell of exclusion’ illustrates that there is more development required before the mobile phone is providing full access to older users.

Trends for the miniaturisation of screen and keys have further excluded the older user and isolated an increasing market sector. Probably through financial motivation, phone companies are beginning to respond to the developing market of older users. However, whilst manufacturers and service providers may be addressing some issues in relation to handset design (micro-design) there are still many barriers that exist when considering wider systems use of the technology (macro-design). Older users may be willing to use mobile services as long as they truly facilitate independent living.

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