Possible implications of aging for interface designers

D. Hawthorn*

Department of Information Systems and Computing, Unitec, Private bag Mt Albert, Auckland, New Zealand

Received 1 December 1998; received in revised form 29 July 1999; accepted 24 September 1999

Abstract

The populations of the developed countries are becoming older while computer use is affecting increasingly wide aspects of life. Thus it is increasingly important that interface designs make software accessible to older adults. However there is almost no research on what makes an interface usable for older adults. As a stopgap measure this paper reviews the findings on the effects of age on relevant abilities and uses this information to provide suggestions to consider when designing interfaces for older users. The paper concludes with indications of the needed research in the area of interface design for older users. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Computer use; Interface designs; Aging

1. Introduction

We have a rapidly graying population and increasingly ubiquitous computing. More and more, people will need to handle some variety of computer interface not just at work but for convenient access to banking services, communication and information search. It seems likely that in the future this will extend to access to entertainment, social contact, purchasing and government services. At the same time there has been a marked change in the population structure of developed countries as people live much longer.

As can be seen in Fig. 1 (from Ref. [74]) we are in the middle of an extraordinary shift from a triangular population structure in which old age was unusual to a nearly rectangular distribution of ages through the population. Shifting age ratios combined with the spread of computing mean that the importance of older users and the importance of interfaces for older people in general has increased considerably.

This paper is concerned with the 45 year old plus group. The effects of age become noticeable from the mid forties onward. So this is not just about design for yet another minority group, the one we call senior citizens. This paper is concerned with design for the

* Fax: + 64-9-849-4180.
E-mail address: dhawthorn@unitec.ac.nz (D. Hawthorn).

0953-5438/00/$ - see front matter © 2000 Elsevier Science B.V. All rights reserved.
PII: S0953-5438(99)00021-1
Second half of our own lives and for a group that will shortly be nearly half the workforce and over half of the adult population. With the shift in population structure we have a rapid rise of older people in increasingly computerized work for which, I suggest, we are unprepared. There are only a few papers on computer use by older adults. Worse, I can find is almost no published research on interface design for older users, this is supported by Czaja [26]. It will take time to fill this gap. As an interim measure this paper reviews findings on how aging affects ability in general and considers on the implications of these findings for interface design.

2. Methodological issues

A number of factors suggest caution when applying findings on aging obtained from the literature of the psychology of aging. For discussions of methodological issues in aging research see Rybash et al. [90] and Hertzog [45]. Older people vary—a lot. Spiriduso and MacRae [109] point out that descriptions of average behavior become less accurate as the age of the group being described increases. Further, much research on the abilities of older people relies on volunteers taking part in laboratory studies; as an exercise in population sampling such groups are problematic. The two main methods used in the study of aging give different results. Cross-sectional studies involve comparing today’s old people with today’s young people. The problem is that members of an age group will have a shared social history which influences their test scores and this shared history will differ for each age group studied. Longitudinal studies attempt to get around this by following the same individuals over time and testing them at repeated intervals. Typically longitudinal studies show less decline in ability than cross-sectional studies but here we should consider that there is some training in test taking and that those individuals who are most impaired by age are those most likely to drop out of the study. Ability levels of old people also change with training or disuse. Thus a study which reports that X ability declines by 30% at age 75 does not give us hard and fast information about the ability of 75 year olds to produce behaviors based on X if they are highly motivated, see Baltes and Willis [3]. Most of the findings on ability from the psychology of aging are based on studies of artificial behavior in laboratory situations. Presumably much of this work will generalize to real life situations but one would expect exceptions. The majority of studies contrast a young group
with one or more very old groups, it is not certain where the abilities of say, 55–60 year olds, fall between the abilities of 20 and 70 year olds, it is not safe to assume that decline from 20 to 70 is linear. Studies of the ability of older people should also be checked for the controls provided in the design. It is currently recommended that studies include controls for education, eyesight, medication and training effects. Training effects are important as older people are much slower to reach asymptotic behavior than younger subjects.

3. Psychological findings on aging and ability

This paper will now review some findings from the extensive literature on the psychology of aging and consider possible interface design implications. In what follows findings for a single area of ability are presented followed by a short section looking at the implications of impairment in that ability for interface design. Of course in actual use of an interface the user brings several abilities into play at once and so for older users several sources of impairment may interact or competence with one set of abilities may compensate for impairment on another set. Older users in particular have a limit to how much cognitive activity they can engage in simultaneously. The question for designers is how much of that capacity must be used coping with the interface and how much is available to apply to the users’ real task. The concern in this paper is that interface features and changes that young designers take for granted as effortless may in fact make significant inroads upon older users’ cognitive capacity.

4. Vision and aging

Progressive visual impairment is one of the more clear-cut areas of decline in performance with aging. See Kline and Scialfa [59] for a recent review. Fozard [40] suggests that problems with vision tend to appear in the early forties. At this stage people begin to notice difficulty in adjusting focus for near vision and as a separate issue, visual acuity, the ability to see fine detail, declines. Hence this age group is likely to consider bifocals. Contrast sensitivity is an aspect of visual acuity, it is typically measured by the ability of individuals to detect differences in illumination levels, usually in lines forming gratings of differing fineness. Owsley et al. [78] reported a significant decline in contrast sensitivity comparing 50 year olds to 20 year olds and the decline increases again by age 80. There is also reduced sensitivity to color, especially in the blue–green range, Helve and Krause [43]. Older adults are also sensitive to glare and less able to adapt to rapid shifts in brightness. See Kline and Scialfa [59] for other studies confirming these findings.

Later problems emerge from around age 60 when older adults may show a reduction in the width of the visual field. This means that peripheral stimuli must be stronger and/or closer to the center of the visual field to be detected, Cerella [16]. A reduced ability to detect flicker, particularly in the peripheral visual field also appears at this age, Casson et al. [15]. A related phenomenon reported by McFarland et al. [73] is persistence, the sensation of continued presence of the stimulus after presentation of the stimulus has ceased. Persistence has been found to be more prolonged in elderly people. Older people appear to be less able to detect minimal motion by objects they are observing and may give
more cautious estimates of speed of real life objects, Kline and Scialfa [59]. According to Bell et al. [5] there is only a slight decline in the ability of older people to make accurate estimates of depth up to 40 years but after this there is rapid decline through to age 70 which corresponds to the oldest subjects in the group studied.

Processing of visual information appears to be slower with age, Kline and Szafian [60], Fozard [40]. There are declines in several of a person’s abilities to make sense of what is seen. The ability to recognize figures that are embedded within other figures is reduced, Capitani et al. [13]. There is a decline in the ability to recognize objects that are fragmented or incomplete, Salthouse and Prill [96], Frazier and Hoyer [41]. Older people do not perform as well on location tasks when trying to locate a target figure in a field of distractors, Plude and Hoyer [82]. However if the target location is constant there is little or no difference due to age, Farkas and Hoyer [35], Carlson et al. [14]. Older people appear to benefit more than younger people when presented with advance cues indicating the future location of a visual search target, Kline and Scialfa [59]. However older people appear to learn visual searches at the level of the specific targets presented and unlike young people they do not show transfer of learning to new searches where the specific examples have changed but the categories have not, Fisk et al. [39].

The level of individual impairment varies a lot; Rybash et al. [90] quote American figures to the effect that 10% of over 80 year olds are legally blind while 10% retain 20/20 vision under good lighting conditions. However Kline and Scialfa [59, p. 32] cite findings indicating that the reduction in acuity with age significantly worsens in dim light even among older subjects who were visually equivalent to younger subjects in the well-lit conditions used in standard eye tests.

5. Vision in older people and implications for HCI design

We need designs that help older users to find items easily and to keep their attention focussed on them. Problems with partial or embedded figure recognition may mean that multiple overlapping windows disadvantage older users and also support simplicity of icon design. The findings on visual search support current design recommendations emphasizing layout simplicity, clarity and consistency, we should also perhaps provide extra, bolder search cues. Text in itself provides a complex background and within text older users may have target acquisition problems when locating the typical carets used in word processing applications. This could be made more difficult if the blink rate for a caret gets close to the lowered critical flicker frequency for older adults or the caret lies at the edge of the reduced visual field. Perhaps the insertion point caret can be customized. A slow blinking, red caret for example?

The distance from eye to screen typically falls into the range which bifocals leave blurred. Tri-focals or graduated lenses are expensive, not all older users will be able to afford them. We can thus expect that some older users will be squinting at perpetually fuzzy screens. This is tiring and may increase the cognitive effort needed to follow text. Work by Charness et al. [19], shows reading performance for older adults declines with a move from black text on white background to colored text and colored backgrounds. Younger adults did not show such differences. Morrell and Echt [75] review a number
of studies on text preferences of older readers and cautiously suggest that older adults may benefit from sans-serif fonts that are in the 12–14 point range, short line lengths and left justified text. These recommendations are for printed text so it is of interest to see if they hold for on-screen displays. My own informal observations suggest that fancy fonts and patterned backgrounds make reading noticeably harder for older adults. The work of Kosnik et al. [62] suggests that we avoid moving text and take care to allow older readers ample time to read any text presented. Work reviewed on attention later in this paper indicates older users’ inability to shut out distracting detail. This implies that our designs should use only simple, highly relevant graphics and avoid decorative animation and pictures, wallpaper patterns and flashing text, distractions increasingly found on the Web.

We should avoid glare and rapid changes in brightness as users move between screens. We should not ask older users to make rapid shifts in focal distance as in moving one’s gaze from screen to paper. Designs which use depth perception to convey information should provide additional cues in the case of older users. Color shadings that convey information should be distinct and avoid blue–green tones. We should not expect older users to detect small movements and so should find more obvious ways of indicating changes. Older users with their narrowing of the visual field are likely to have to work harder to compare screen objects that are widely separated. Customization of display fonts and colors will help the middle aged but may be hard for the very old to do. In addition really large fonts may require splitting the design into more parts which older users may find hard to integrate.

6. Speech and hearing in older people

Overall hearing declines with age, about 20% of those between 45 and 54 have some hearing impairment, this rises to 75% for those between 75 and 79 years of age, Fozard [40], Kline and Scialfa [59]. There is a loss in the ability to detect tones over all frequencies, particularly for high pitched sounds; Rockstein and Sussman [85], Schieber [101]. Older adults miss attention getting sounds with peaks over 2500 Hz. Commercially available telephone bells and smoke alarms tend to have intensity peaks around 4000 Hz which are effective for younger users but these sounds are missed by older users, Berkowitz and Casali [6], Huey et al. [51]. Since some consonants in English are high pitched (such as f, s, t, z,), selective loss of high frequencies (presbycusis) means that parts of speech are not heard and the impaired listener needs to guess at meanings. Feldman and Reger [36] reported that by age 80 people may miss 25% of the words in a conversation. Older individuals may find female voices harder to follow than male voices because of the overall higher pitch.

Older adults also show reduced ability to localize sound and this is more pronounced in individuals with presbycusis, Kline and Scialfa [59]. There are problems for older people when dealing with background noise as evidenced by the typical complaint about being unable to follow conversations in noisy groups of people. Corso [23] also reports that sentences which are meaningful under test conditions are lost when words within the sentences overlap or are interrupted and that, for older people, the ability to obtain meaning from spoken information declines under conditions of stress.
Speech becomes less distinct with age, possibly due to reduced motor control of tongue and lips, possibly due to impaired ability to hear and correct oneself or to compare oneself to others. In addition a proportion of the elderly have speech impairment due to strokes. Speech slows with age both from the insertion of more and longer pauses into spoken material and due to word lengthening, Balota and Duchek [2]. The ability to produce words which correspond precisely to experimenter defined constraints declines and the time taken to produce words to precise requirements increases with age, Mackay and Abrams [69]. Older adults speak less fluently with more evidence of language planning deficits such as false starts, hesitations and filled pauses such as um and er or word repetitions, Kemper [57]. They are also more subject to tip of the tongue episodes where a familiar, but infrequently used, word eludes the speaker, Burke et al. [12].

7. Speech and hearing in older people and HCI design

Interfaces that use sound to get the users attention will need to use lower frequency sounds for older users. Huey et al. [51] found that a beep that swept a range of frequencies including the 500–1000 range was reasonably effective.

Hearing is less relevant to current interfaces but problems with hearing among the older population may affect attempts to design speech based interfaces to compensate for problems with sight or with lack of keyboard skills. Recorded voice should make use of speakers with low pitched voices. Computer generated speech as output for older people may be a problem. Smither [106,107] found poorer performance for older adults with remembering and understanding computer generated speech and attributed this to short term memory demands. It has also been claimed that part of the understanding of speech shown by elderly people may be due to unconscious lip reading and other contextual clues. If so designers could find that speech from a mechanical source was less intelligible for older users. The slowness of speech compared to reading and the lack of user control over the delivery may lead to problems in remembering content since older people are more likely to suffer from interference effects where a stream of facts makes it hard to remember earlier information. However brief spoken messages might be useful as optional replacements for the current provision of fly-over hints to give brief names or explanations of buttons and other features. It is possible that interfaces of this sort could extend the number of years during which users were able to make use of applications.

Speech as a control mode for interfaces may also meet problems when attempted by the elderly. In part there is the problem with reduced articulation among some elderly as well as the disrupted speech of stroke victims. Speech recognition software may also need to cope with slower speech from older users, more hesitations, interruptions and filled pauses as well as more audible breathing. Czaja and co-workers are currently starting work on this problem. It can be expected that some older people will have less control over their speech production (see Morris and Brown [76], Ryan and Burk [89]) and so may be less able to adapt to the sensitivities of speech recognition software. It seems reasonable that that elderly people are more subject to respiratory infection and so have more periods during which their voice is significantly different from the voice the interface is adapted to. It may also be that extended periods of speech are difficult for some elderly people. In the light
of the material on difficulty in speech planning, word retrieval and conforming to a precise vocabulary, use of a verbal command language is likely to be more difficult for older users.

8. Psychomotor abilities and older people

For a wide-ranging review of changes in movement skills with age see Vercruyssen [112]. With age comes lengthening of response times on more complex motor tasks, Spiriduso [108], Light and Spiriduso [65]. Older adults are less able to cope with demands for repetitive speed. However training and the amount of recent practice can provide improvement in skills such as finger tapping speed, see Krampe and Ericsson [64]. There is little evidence for age-related decline on simple discrete actions which can be planned in advance, Welford [116], or on real-life, well practiced non-laboratory tasks such as typing, Salthouse [91]. However Bosman [9] showed that there is no generalization of the faster speeds found for typing movements in skilled older typists to speed improvements in other finger and keyboard tasks. Salthouse and Bosman both found that in compensation for their reduced finger speed older skilled typists scanned further ahead and prepared in advance for the keystrokes to come.

The degree of choice required also affects response time and highly predictable responses may show little age differential. Vercruyssen [112] notes that the standard finding that incompatibility between stimulus and response slows response time (the Stroop effect) is accentuated with age.

Older adults show poorer performance when asked to track a target, Jagacinski et al. [53]. Vercruyssen notes that reduced ability to inhibit interference from neural noise is one possible reason for problems with control of fine movement. Walker et al. [114] confirmed earlier studies showing that older people made more sub movements and were slower in capturing a target with a mouse. Charness and Bosman [19] report that older adults have some problems with cursor positioning if the target is the size of letters or spaces in text. Older people are more cautious/error aversive in their movement strategies. This is reasonable given that the inaccuracy (distance from target) of fast movements climbs more sharply with peak acceleration for older subjects. Walker et al. [114] see older subjects producing a movement strategy which compensates to an extent for both their reduced ability to produce acceleration force without neural noise and their slower perceptual speed. Both older and younger people took more time to verify that they had captured the target as target size decreased but this effect was stronger for the older group. Vercruyssen [112] reports that older people also slow more following an error than do young subjects.

Older adults are reported as having less ability to control and modulate the forces they apply, Siedler and Stelmach [102]. This is consistent with Dixon et al. [30] who found that handwriting quality declines in older people. It has been reported that older people are less accurate in reporting body position in relation to surroundings, Vercruyssen [112]. In addition, older people may have difficulty in receiving new information during the execution of movements. There is conflicting evidence on the effect of age on touch sensitivity but it appears that there is a degree of loss of sensitivity to light pressure on the palms.
evident in the sixties, Kenshalo [58] and there is a small loss of sensitivity to high frequency vibration in the hands, Skre [103], Verillo [113].

Szlyk et al. [111] looked at driving performance with age. They found that older adults drove more slowly and made more eye movements, compensatory actions which translated into a lower real world accident rate for the older drivers in spite of the younger groups’ faster responses. Workplace studies cited in Vercruyssen [112, p. 70–71] suggest that older workers in machine paced jobs have higher accident rates, also that younger workers tended to make errors indicating misreading of the situation while older workers tended to correctly read the situation but fail to produce responses with sufficient speed.

9. Psychomotor abilities in older people and HCI design

Older people can be expected to be slower in use of a mouse and to require larger targets to be comfortable. It is probable that we should revisit standards for target size and timing of actions such as double clicks. Welford [115] has recommended adding an age correction factor to Fitts’ law governing target acquisition. We should ask ourselves to what extent does our interface depend on speed? Common examples occur with double clicks or in mouse movement from a menu item to a sub-menu item which moves briefly outside the boundaries of both items yet does not drop the sub-menu. Expecting a completed response within a given time may also run counter to the fact that older users slow down more after making errors. Any move towards interaction that is machine paced rather than self paced may cause problems for older users. It should be possible for applications to detect the speed and certainty of a user’s mouse movement and/or typing and to adapt the application’s speed requirements accordingly.

Because of problems with inhibition of neural motor noise older users may have more problems with basic mouse actions such as holding the mouse still while clicking or controlling dragging on scrollbars. My own informal observations suggest that older users’ problems with control of fine movement may rule out some pointing devices such as button or touch-pad mice which map greater screen movement to smaller hand movements than a traditional mouse. Older users are more disrupted by errors, they may benefit if we compensate for less accurate movement and slower recognition of target capture by providing redundant confirmation of target capture and easily available undo/redo.

Text input should allow older users to shift to larger fonts to accommodate difficulties in point and click manipulation of small text. Many of the current generation of older (male) users will have limited typing skills which can be a barrier to using many applications. Conversely it is worth asking if skilled older typists are more disrupted by switching between keyboard and mouse. It is worth considering the timing of complex physical tasks, do they occur in the midst of other more cognitive activity, such as composing a letter, or do they occur after creative effort has paused? For example scrolling during work may have more potential to disrupt thought than clicking a minute exit button after work has ended. Again forewarning older users of required movements should be beneficial. We should ask how complex are the movements required and are they movements that are likely to be well practiced in other applications or are they novel? It is important to
consider how easily older people learn new motor sequences in general and how well they handle learning sequences that conflict with previously well-established sequences. There are findings which indicate that older adults will move more slowly when there are many choices, Vercruyssen [112]. This leads to questions such as whether older users are comparable to younger users in the ease with which they pick up new, richly expressive idioms such as circular menus? Again we might ask how well older users learn and use gesture as an interface idiom where there is little visible feedback to distinguish the correct movement? Adapting to immersive environments and tools such as data gloves is likely to be difficult for some older users, given the frequency of the following problems in the older population:- balance problems, difficulties with accurate depth perception, problems with accurately reporting body position, problems with tracking and capturing moving targets, problems with perceiving and applying forces and difficulty in receiving new information during the execution of movement. Finally handwriting recognition software may have problems coping with older users’ shakier writing.

10. Attention, automated responses and aging

Attention is basically the ability to focus on the items needed for the performance of a task. Vercruyssen [112] states that older adults have problems maintaining attention over long periods of time. He suggests (p. 66) that tasks requiring rapid or continuous scanning are particularly fatiguing for older adults. However note findings cited by Kline and Scialfa [59, p. 37], in the same handbook, which reported no age difference in a vigilance task involving detecting infrequent double jumps on a chronometer display over very long time intervals.

In selective attention tasks the subject must extract relevant information from distracting detail, here there is agreement in the literature that the ability to pay attention to relevant information in the presence of distracting information declines with age, Connelly and Hasher [22], Kotary and Hoyer [63]. In a series of papers dating from 1988, Hasher, Zacks and co-workers have argued that this is because older adults are less able to inhibit response to the presence of distractor items, see Kane et al. [54] for a summary.

Divided attention is where the subject must pay attention to more than one task at the same time. This is applicable to tasks such as word processing where attention must be split between composing the document and manipulating the interface. There is less agreement on the effect of age on the ability to maintain divided attention Researchers such as Hartley [42] and McDowd and Craik [72] have reported declines in performance with age on divided attention tasks. However divided attention problems with age appear to occur only in complex tasks rather than simple or nearly automatic tasks. Perhaps the apparent attention deficit may be a result of overall task complexity rather than due to divided attention as such, see McDowd and Craik [72], Salthouse and Somberg [97]. Work by Plude and Hoyer [83] and Fisk and Rogers [38] indicates that there are reductions in the capacity of older individuals to direct attention to support complex tasks but that this does not apply to tasks, which, through training, have become automated.

Korteling [61], in an interesting paper, showed that old people initially performed as well as a younger group on dual tasks on a driving simulator, keeping to the center and
maintaining a following distance. However when the accelerator was reversed so that faster became up, the older group had trouble, not with the distance task involving the accelerator but with the steering task. Korteling interprets this to mean that while coping with the reversed accelerator was possible, to do so markedly reduced the cognitive resources available for the second task.

An automated response (AR) is a response to other stimuli which occurs without conscious effort or control. An AR can occur in parallel with other activity and is seen as allowing actions which do not contribute to cognitive load. Examples are typically taken from visual search where features learnt as relevant “jump out” from the display, or from motor activity such as braking or gear changing while driving, see Bargh [4]. Such responses need to be learnt before they become automated. Once learnt there is difficulty in unlearning the automated response since it is not under conscious control. A group of studies done by Rogers, Fisk and co-workers claims that most older adults are unable to form an AR, at least in visual search, see Rogers, Fisk et al. [87]. The suggestion taken from this is that, while older adults are able to learn new sets of associations, what they learn remains attention demanding and thus contributes to cognitive load. Where older adults do possess automated responses a study by Rogers and Fisk [86] found that these automated responses led to higher levels of disruption for an older group on new tasks that made the automated response inappropriate. On the other hand Kelley [55] showed that for subjects trained on an experimental word processor, young expert users (20–35) showed more disruption than older expert users (50–65) when learning a version which contained a non-standard sequence of actions for selecting and changing an object. However it is not clear if Kelley’s older subjects had automated their standard responses.

11. Attention and automated responses in older people—HCI design issues

We can expect that older users will be more easily distracted by extraneous design detail or background noise. For older users graphics need to be carefully selected for relevance rather than decoration. Multi-media approaches and the more flamboyant Web pages may disadvantage older users. One might paraphrase Don Norman to the effect that “If it won a design or art award, older users will probably hate it”.

When researching the usability of a new interface feature, Korteling’s paper referred to above indicates that increase in difficulty may not show up in performance on the novel feature itself. Instead poorer performance due to the new feature may appear on other tasks performed at the same time. Our interface research designs should reflect this.

Automated behavior is a major source of reduction in effort in use of applications, we should therefore be very concerned about findings that indicate that automated responses are unlikely to be formed by older people. This implies that behavior, learned for the first time in old age, continues to take cognitive effort and hence that it is harder to make applications transparent for older users. We should also be concerned about the effects on changing to new applications. Remember that Fisk and co-workers claim, that where automated responses exist, older people may find extinguishing them harder. If this is so, then automated actions, that are highly useful in a known application, may hamper older users when learning new, competing, responses. Hence new versions of designs...
should include careful consideration of backward compatibility with those previous actions that may have been automated, such as hot key and menu choices and menu, tool button and input locations.

The ability to cope with change is obviously extremely important in our consideration of older users. However the definitions of automated behavior are not clear-cut, see Bargh [4] and the work by Fisk and Roger’s team is in areas which are not closely linked to dealing with interfaces. A research priority should be to clarify the role of automated responses in the way that older users handle interface change.

12. Memory and learning in older people

Structural theories of memory view memory as comprising a number of distinct abilities which are brought into play in different tasks. Normal aging (excluding pathological conditions such as Alzheimer’s disease), produces differing degrees of impairment on the different forms of memory. See Smith [105] and Howard and Howard [49] for reviews. Short term memory is used to hold the events of the immediate past. Information stored in short term memory is displaced by new information coming in and so is lost rapidly over time unless transferred to long term memory. Working memory covers simultaneously holding and using short term information, Rybash et al. [90], and as such it is central to effective conscious action. Age gives only a slight decline in the number of items which can be held in short term memory, an average of around 6.5 items can be held from the 20s through to the 50s but this then drops to around 5.5 for the 60s and 70s, Botwinick and Storandt [11]. However tests of working memory show that there is a stronger decline in the ability to process items in short term memory as distinct from simply recalling them, Salthouse [92], Dobbs and Rule [31]. Light [66] suggests that decline in working memory underlies older peoples’ problems in text comprehension. Processing of visual information in short term memory also slows with age, Hoyer and Rybash [50]. Howard and Howard [49] suggest that we will only see effects with age when tasks impose significant load on working memory.

Long term memory is involved in information storage for periods over 60 s. Long term memory involves several components, episodic memory for specific events, procedural memory for holding knowledge of the way in which tasks are carried out and semantic memory which holds information about meaning of the components of ones world. Different long term memory tasks show different impairment with age. Howard and Howard [49] state that findings of age-related deficits in episodic and procedural memory are common but there is generally little age-related decline in semantic memory until extreme old age. Studies typically show little decline in the ability to perform on memory tasks simply involving recognition that some items are familiar from previous exposure, but significant declines in the ability to recall content, Rybash et al. [90], Ratner et al. [84]. This is subject to the complexity of the tasks. When learning material contained in stories, interviews or text, age-related declines are also found in recognition tasks, Hultsch et al. [52], Hertzog and Rogers [44] and Stine and Wingfield [110].

It has been shown that older adults tend not to adopt strategies for organizing material to be remembered unless prompted to do so, Ratner et al. [84]. However if adults are
provided with semantic categories to organize learning and as cues to aid recall the differences between young, middle aged and elderly essentially vanish, Smith [104], Craik and Jennings [24], Perlmutter and Mitchell [81].

One potentially important point is that memory for sequences of finger movements appears to depend on separate systems to those involved in verbal memory and memory for motor sequences does not appear to deteriorate with age, Rybash et al. [90]. However Krampe and Ericsson [64] indicate that the amount of practice becomes important for maintaining skill at expert levels in older professional pianists.

Older adults appear to perform worse on spatial memory tasks, for example remembering which quadrant a word appeared in, Denny et al. [28] or replacing items correctly in a model, Cherry et al. [20]. Older adults tend to have poorer memory for non-verbal items such as faces, Crooke and Larrabee [25], or map routes, Lipman and Caplan [68]. Prospective memory is the ability to remember to remember, to remind oneself to keep appointments, take out the rubbish or take one’s medicine. Prospective memory seems to be reduced in elderly people only where there are complex tasks involved, McDaniel and Einstein [71], Einstein et al. [34], Maylor [70]. Age differences were also seen with tasks which require subjects to perform an action every so many minutes without providing reminders, McDaniel and Einstein [71].

13. Memory and learning in older people and HCI design

We should find special payoffs for older people in reducing interface demands on working memory. Where possible our interfaces should provide opportunities for users to off-load memory requirements to the program. Since we know that time delays lead to short term memory losses our interfaces for older users should avoid delays in the flow of the task as well as emphasizing simplicity and avoiding distractions and undue manipulation. We should also allow users to process concrete representations of items rather than relying solely on working memory.

Our applications should provide cues to support recognition rather than unassisted recall—labels, menus and captions already do this but as Kelley and Charness [56] point out, function keys do not. The context in which an item is encountered while being memorized is important as a cue to later remembering. However older adults appear to have problems in making use of contextual cues if either the context is only loosely related to the target item or there is competing cognitive load during the memory task, Craik and Jennings [24], Park et al. [80]. Icons seem to provide some cues for recall but it seems worthwhile to ask if older users get the same level of benefit from icons as younger users. More generally research needs to identify what are useful ways of providing “knowledge in the program” to make affordances visible and recallable for older users?

Our older users are likely to find lists easier to work with than paragraphs. As an example, the emerging use of “cue tips” Help screens replacing full screen Help gives the user short relevant lists and brings them to the situation in which they are to be used. This relieves the user of the need to remember information while swapping from a full screen Help display to the application screen where the information is to be used.

Older users will have more erratic access to what they do know. This could affect use of
inflexible command languages. There is a decline with age in ability and speed in producing words that correspond precisely to constraints, Mackay and Abrams [69]. Older adults are also more subject to tip of the tongue episodes where a familiar, but infrequently used, word eludes the speaker, Burke et al. [12]. In attempting to recapture knowledge users may return to the source from which they originally acquired the material, be it books, Help systems or people. However older people have more trouble in remembering the location of information sources, Dywan and Jacoby [33], they may thus show special benefit from rich indexing of help sources. Older users may not “remember to remember”, we should therefore give reminders rather than relying on the users prospective memory.

Learning computer applications and their interfaces is possible but takes significantly longer and is harder for older people, see Baldi [1], Bosman and Charness [10], Kelley and Charness [56] for reviews of studies of computer training for older people. These reviewers found no clear agreement in the papers reviewed on the best forms of computer training for older adults. For the very old, learning to use new applications such as automatic teller machines (ATMs) is harder than we as designers are likely to expect. Rogers et al. [88] found that older adults made high levels of mistakes after training on a simulated ATM. Mistakes, including serious problems such as forgetting to take the card or the cash, occurred in over half the ATM transactions attempted. Real life learning has more significant penalties than laboratory experiments.

Successful learning for older users will involve a lot of practice. Older users also appear to prefer learning in the context of concrete tasks. This may make it harder for them to master application features that are useful but not frequent in typical work. Are older users more likely to learn a minimal or substandard set of skills? Additionally once a method has been learned there may be resistance to abandoning it to learn a more efficient alternative. Older users may be also be less likely to benefit from incidental learning of useful features through casual Help browsing or stumbling on unexpected application features.

A beginner’s first exposure to Windows and word processing involves learning a mass of factoids, my informal observations suggest that older novices (45 plus) seem less able to cope with this. They find themselves in the position of having learnt a number of isolated parts of the interface yet they are still missing details which are needed for them to make use of what they have learnt. At the same time they indicate that being given more details will overload them.

Some idioms appear slower to master and are less readily generalized. Charness [18] using informal observation of older users noted that older users had serious difficulty understanding the difference between the mouse position indicator and the insertion point indicator. My own informal observations of older users show considerable difficulty relating the partial view given by a scrolling window to the whole text or graphic. Where older users made large jumps with the scroll bar the result was often disorientation. In addition older novices who had learnt to use scrollbars in one application (MS Works), did not apply this learning in a second application that depended on the use of scrollbars, (MS Publisher).

Czaja and Sharit [27] found that the level of prior computer experience outweighed the effects of age when considering performance on training to use an application. However we need to ask how effective older people’s prior experience is across interface paradigm shifts. If it is true that part of the source of difficulty with older adults learning comes from
failure to effectively organise the material encountered, can we design interfaces which provide built in strategies for organizing learning?

14. Intelligence, expertise and aging

There is some decline in intellectual ability with age. Schaie [99] and Baltes and Willis [3] make the point that loss of intellectual ability is likely to be evident only in situations which are complex and challenging enough to require activation of an individual’s reserve capacities. Schaie [99] suggests that major decline in intellectual abilities is limited to late old age and probably mainly in abilities which were not central to the individual’s life experience.

The chart in Fig. 2 compares decline on reasoning ability from cross-sectional and longitudinal data from a large set of studies of both types by Schaie [98,99]. The longitudinal decline, based on composite data, shows individuals maintaining the ability they had in their 20s until their mid-60s. The cross-sectional data show that today’s older age groups do not score as well as today’s younger age groups and that the difference between them is significant and increases as the ages compared become more different. This demonstrates the Flynn effect, a well documented increase in the ability to score on intelligence tests for each generation this century, see Flynn [37]. Rybash et al. [90] suggest that to explain this improved performance in successive birth cohorts we should look at increased years of formal education, a greater cognitive orientation in work tasks and improvements in treatment of disease.

There is a suggestion from explanations of cohort effects that longer periods of earlier education and training facilitate later ability to learn as well as general retention of cognitive ability. Schaie [98] found that high levels of education predicted that individuals’ intellectual ability would decline more slowly. Dutta [32] and others cited in Schaie [99] provide evidence that high job status and work complexity indicate a likelihood of maintaining cognitive functioning into old age. This is relevant where the spread of computer use starts to impact a less educated sector of the older population.

Intelligence tests consist of sub-tests of different abilities: verbal, reasoning, spatial,
numeric, etc. Decline with age for an individual is likely to be on two or fewer abilities. Which abilities are affected and which are unimpaired appears to be almost random, Schaie and Willis [100]. This is not a population for which concentrating on a one or two specific problem areas will provide a widely applicable solution. However there is a general slowing of processing speed with age which correlates with the level of impairment over a wide range of abilities from vision to motor movement to memory and intelligence, see Salthouse [93], Salthouse, Hancock et al. [95] for reviews. Birren has maintained since 1951 that speed is an important factor in intellectual performance and that if a person is unable to think quickly then they are unable to think well, Birren and Fisher [8]. Older users in particular will suffer if their task directed thinking is slowed and diverted by dealing with crudities in interface design.

A different approach first developed by Horn [47] attempts to divide intelligence into crystallized intelligence and fluid intelligence, the first corresponding to performance based on life experience and cultural knowledge while the second measures skills of perception and abstract reasoning which are not directly incorporated in experience but are more directly related to the integrity of the central nervous system. Crystallized intelligence might be paraphrased as “reason your way through something the first few times, then remember how to do it”. Studies by Horn [46,47] and Horn and Donaldson [48] show that there are gains on crystallized intelligence up to the sixties which tend to compensate for the losses shown on measures of fluid intelligence so that overall intellectual performance declines only slightly. Park [79] and Welford [116] provide arguments that older adults have difficulty acquiring skills that require new schemata. See also Dittman-Kohli and Baltes [29] for views on older intellectual functioning.

15. Expertise

It seems that expert performance is maintained only over narrowly specific areas as skilled people age. Older chess players, typists and medical technologists retained high levels of performance in skills narrowly specific to their area of expertise while showing normal declines in areas such as reaction time and figure identification which might be argued to underlie their specific skills, Charness [17], Salthouse [91], Clancy and Hoyer [21]. Similarly Lindenberger et al. [67] and Salthouse et al. [94] found that older architects and graphic designers continued to be acknowledged as experts but showed significant declines on measures of general visual thinking and imagery. Salthouse showed that, for expert older typists, the maintenance of typing skill depended on developing compensating strategies for reduced speed and reaction time.

Szlyk et al. [111] found that older adults showed poorer driving in a simulator than in their real world performance. This may suggest that older adults did not adapt as well to a generally familiar task (driving) in a new setting (the simulator). If this interpretation is valid it reinforces concern for the adaptability of older adults.

This raises the question of how such expertise in older workers survives paradigm shifts. Is it, for example, older programmers in particular who might find problems adapting to an object oriented paradigm? Do older computer aided design workers have more trouble adapting to new CAD packages? Anecdotal evidence exists that typists dislike shifting to
new versions of word processors, is this dislike correlated with age and is this a realistic reflection of possible age-related problems in adapting existing skills to new contexts?

16. Intelligence in older people and HCI design

Subtle shifts in intellectual functioning do not lead to obvious interface recommendations. Most normal and routine interface activity is likely to be largely unaffected by the losses of aging. For example Birdi et al. [7] found that older workers performing data entry tasks did not make more errors than young workers on routine work but were less accurate when the work became cognitively demanding. Hence older workers are more likely to benefit from interfaces that reduce the complexity of the task the user is attempting. However the variable nature of individuals’ loss of sub-classes of intellectual function means that one cannot successfully design for a specific pattern of reduced ability.

Interface designers should be aware of the increasing intellectual performance of younger users compared to the older group. The Flynn effect and the divergence of cross-sectional and longitudinal ability scores imply that while older users largely maintain their abilities, the younger group will still function at a higher ability level. Thus if we design interfaces which are only tested on younger users we run the risk of misjudging the capability of nearly half our future users.

The next area of concern is change. Reliance on crystallized intelligence and suggestions of problems with paradigm shifts imply that older users will function best in a stable well-known interface environment. Once more user tests showing that young subjects have a favorable response to some significant new interface development do not imply that older users will show similar ease of adaptation. I suggest that older adults are at risk in a computing environment where rapid change is part of the economic model. The possibility exists that continuing interface change, especially change involving paradigm shifts, may make older users less effective and reduce their access to work and services. This despite the fact that the changes may have been aimed at improving effectiveness (of young users). It would be of interest to ask how deeply older adults model applications since the level of abstraction reached should affect the ability to adjust to version changes.

Morrow and Leirer [77] reviewed studies of pilot performance. Older pilots were similar to younger pilots in response time on simulator tests except for “high workload conditions” such as a landing involving cross winds and turbulence. Older pilots made more mistakes in responding to and feeding back air traffic control communications in flight simulator tests and this effect worsened when the messages were made more complex. Age had more impact on communication tasks than on routine maneuvers. This is of potential interest to those looking at co-operative environments. It may be that older users have less ability to cope with the communication load and demands on working memory expected in a co-operative environment.

17. Research directions and conclusions

The whole area of computer use by older users offers considerable scope for research. There is a need for studies looking at: how much use older users make of computers and
for what ends, who are the non-users and late adopters among the older population and why? One could look at changes in sources of support and attitudinal/motivational changes as the older population becomes more involved with computing. One could also investigate the extent and effects of technical and economic isolation among the elderly.

When we look more specifically at research issues for interface design for older users we are considering applications in a variety of settings. As we shift towards a markedly older population the size of the 45–65 age group starts to approach half an increasingly computerized workforce. In addition automatic teller machines and the Web are precursors of a spread in the role and availability of computing and its interfaces which potentially benefits the older users who participate and penalizes those who do not, independently of their workforce status.

Each of the preceding sections on the implications of aging for HCI design in this paper has been deliberately speculative with only indirect support from research findings. The aim has been to suggest both a research agenda and a rough set of guidelines for best practice for software whose users are to include the older population. We now need research to evaluate specific design recommendations for older users such as the effect of font size, style, color, appropriate use of graphics, target sizes, level of complexity, memory demands, etc. In addition to this, research should look at how problems due to aging are distributed. The expectation of this paper is that older workers are affected but can this be supported or are significant problems found only for the 65 plus group?

The following research topics seem to me to be especially important to understanding design issues in this area. We need to look at the predicted vulnerability of older users to change. We need to consider what aspects of the interfaces we build support or challenge the transparency of the application for older users. We need to understand how older users learn new interfaces and as a related issue we need to consider how deeply older users model applications and complex documents. We can then ask how the interface can best make affordances apparent to older users and potentially build interfaces which help older users effectively model the application.

Research should look at older users who are successful in using interfaces and ask if they are using compensatory strategies which can be usefully shared with other older users and/or better supported by the interface. We need to look at how interface style interacts with the motivation of older users and how interface designs can support training that suits the older group. We can also ask for an exploration of how stress affects and is affected by interface use for older users.

We should check the assumption that current usability testing is biased towards younger subjects. It would also be interesting to track the awareness of age issues among interface designers. Welford [116] suggested that it would be valuable to include older users in usability testing on the grounds that their reduced cognitive reserves made them less robust in the face of new applications and hence more likely to demonstrate problems with the interface.

We need to consider the issue of appropriate tradeoffs in what we may call the “inter-generational fairness” of computer interfaces. Younger users should be able to make the best use of their faster responses and generally greater abilities. Thus it is not just a matter of whether our interface designs allow older users access to our software’s services but
also whether we can design for older users without crippling the power of our interfaces to serve younger users. This is similar to the acknowledged problem of designing for both novices and experts but the design techniques may be somewhat different.

As I type this I am listening to my wife calling for Bill Gates’ head as she prepares her lecture handouts. Why should an intelligent adult find using new software such a decidedly unpleasant experience? My wife is inclined to blame herself, Don Norman would point to the messy complexity of the interface, I suggest we add to this a lack of understanding of the problems of middle aged and older users. As we get older are we going to find that an increasing number of applications and interfaces join the video cassette controller as symbols of our alienation from our own culture?

Acknowledgements

I would like to thank Dr Neil Charness and the anonymous reviewers for helpful comments on earlier versions of this paper.

References


