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IN-DEPTH REVIEW

Acquisition and application of new technology skills: the influence of age

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This paper reviews the literature relating to the effects of ageing on the acquisition and application of new technology skills. Experiential, physiological, and cognitive factors are identified that place older adults at a disadvantage, relative to younger adults, when using new technologies. Consistent with this position, experimental evidence indicates an advantage for younger adults in speed of task performance, coupled with a tendency toward greater accuracy. The possibility that these differences can be overcome by means of training intervention is considered. However, it seems that age differences in performance persist, regardless of a training regime. Although some older adults are capable of high levels of performance, these tend to be individuals of high cognitive ability, relative to their peers. When age group means are considered, the only way that older adults are able to equal the performance of younger adults on new technology tasks is through additional practice.

Key words: Adult ageing; human–computer interaction; human factors; individual differences.

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INTRODUCTION

New technology underpins more and more everyday tasks. Inherent in this development is the expectation that individuals either already possess, or will be able to acquire readily, the skills necessary to control and operate this technology. For example, completing banking transactions using automated teller machines (ATMs), programming video recorders, and accessing library catalogues all require information technology skills. Increasingly, people use personal computers for word processing, creating spreadsheets, utilizing databases, and accessing the Internet. Moreover, an increased reliance on information technology is apparent in the workplace where 'computer literacy' is becoming a major criterion of employability for many jobs.

However, there are good reasons to believe that, in comparison to younger adults, older adults (over 40 years of age for the purposes of this review: see reference[1]) may be disadvantaged by these changes. The rapid growth in the use of information technology over the past two decades has led to substantial cohort differences in exposure. Young people generally have been provided with greater opportunity and incentive to develop information technology skills than have their older counterparts. Computing has become an integral part of the school curriculum, and computer games, aimed predominantly at the young, have proliferated. In contrast, information technology training for older adults is often provided on a 'need to know' basis.

Age-related physiological and psychological changes may also serve to disadvantage the older user of information technology. There are well documented age-related declines in vision and hearing.[2,3] For instance, wearing bi-focal glasses may make it difficult to glance quickly from keyboard to screen and vice versa, and glare can also be a problem. Visual acuity (the ability to discriminate fine detail) and contrast sensitivity (the ability to discriminate among stimuli differing in contrast and in spatial frequency) show declines from middle age onwards.

A number of cognitive abilities, that are predictive of computer-based performance (see reference 4 for a review), also decline with age. In contrast to the performance of tasks requiring 'crystallized' intelligence (mainly verbal tasks, such as vocabulary), which remains constant or improves well into old age,[5,6] the performance of tasks requiring 'fluid' intelligence, such as inductive reasoning or spatial ability, declines markedly with age. Salthouse[7–9] presents evidence suggesting that the decline in fluid ability is related to changes in the efficiency of working memory, or the availability of

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attentional resources, which in turn, is strongly related to age-related decrement in processing speed.[10,12] There is much evidence that processing speed progressively decreases with age and that age-related behavioural slowing is a major contributor to age differences in human performance.[13-15] Further, the effects of age differences in processing speed become more apparent as task difficulty or complexity increases.[16,17]

AGEING AND THE PERFORMANCE OF COMPUTER-BASED TASKS

As might be expected from age-related declines in processing speed, studies of computer novices (although sometimes skilled typists) have found older adults to be slower, relative to younger adults, in their acquisition and performance of information technology skills. Older adults take longer to complete training for word processing tasks,[18-21] and perform comparatively more slowly following equivalent amounts of training on tasks involving word processing,[22,23] the use of a multi-function application (notepad and calendar),[24] and information retrieval.[25]

It seems reasonable to suppose that, if given sufficient additional practice, the performance of older adults would be comparable to that of younger adults. For example, Charness and Campbell[26] demonstrated that, in the case of a simple mental calculation task, older participants were able to equal the performance speed of younger participants with an additional 3 minutes of practice per year of age difference. Similarly, in the information retrieval experiment of Westerman *et al.*[25], the performance of older adults in later trial blocks was roughly equivalent to that of younger adults in the first trial block. However, perhaps a more important question is whether, if older and younger adults are given the same amount of practice over an extended period of time, there comes a point where performance reaches equivalence. It may be, for example, that as task components become automatized, and no longer require attentional resources, age differences disappear.[27] Although such effects may apply to the most simple perceptual-motor tasks,[28] they are not apparent for more complex cognitive tasks. For example, Jordan and Rabbitt[29] found that although older participants improved more rapidly with practice than did younger participants on a speeded choice-response task, they were continually at a performance disadvantage, even at the end of the training period. With respect to new technology tasks, the study by Westerman *et al.*[25] of information retrieval, demonstrated that, although the acquisition slope of older adults was initially steeper, they remained at a continual performance disadvantage (although it should be noted that the training period in this experiment was comparatively brief). Moreover, in a recent study of the experienced users of word processors (>100 hours), Westerman *et al.*[30] found a speed advantage for younger users, and Czaja and Sharit[31] found that older adults were slower on data entry, file modification, and inventory management tasks, even when the effects of previous computer experience were controlled. In summary, it would seem that for older adults to perform new technology tasks as rapidly as younger adults they require additional practice. If younger and older adults receive equivalent amounts of practice then older adults will perform more slowly than younger adults, regardless of the overall length of training. It seems probable that this is due to pervasive age-related changes in processing speed. In support of this latter conjecture, Westerman *et al.*[25] found that when the effects of simple processing speed were statistically controlled, age differences in information retrieval task performance disappeared.

The pattern of results with respect to age differences in the accuracy with which new technology tasks are performed is less clear. Some investigators have reported that, following a similar initial period of training, there is no difference in the comparative error rates of younger and older adults. For example, following a lengthy (12-hour) training period on a word processing task, Hartley *et al.*[23] found no differences in accuracy between younger and older participants. Similarly, in a study of experienced users of word processors (>100 hours), Westerman *et al.*[30] found there were no effects of age upon performance accuracy. Garfein *et al.*[32] examined the effects of age on the performance of computer novices on a spreadsheet task and found no significant differences. However, it is important to note that the age range of this latter experiment was somewhat restricted (only 49-67 years). Availability of assistance may be an important determinant of age-related differences in performance accuracy. Older participants request relatively more assistance during training,[18,20,23,24] and in a second study, when availability of assistance was restricted, Hartley *et al.*[23] found a performance disadvantage in the accuracy of older adults.

Other studies have found age to be predictive of only certain types of error. Elias *et al.*[20] and Czaja *et al.*[22] found this to be the case for word processing tasks. Similarly, Greene *et al.*[33] found the effects of age on the use of a database query language were determined by the logical operator (language component) required for the query. No meaningful interpretation of these age differences in error types appears possible.

Finally, a number of studies have found a more pervasive effect of age on performance accuracy, with older adults performing more poorly than younger adults, when using word processors,[19,21] multi-application packages (notepad and calendar,[24] spreadsheet and word processor[34]), and spreadsheets.[35] Czaja and Sharit[31] found age differences in performance accuracy, which favoured younger adults, on data entry, file modification, and inventory management tasks that were independent of computer experience. Charness *et al.*[18] found that, following training, older participants had lower scores on a test of word processor functions than did younger ones.

In summary, although there is a consistent effect of age on response times, the pattern for accuracy is less clear. This, in part, could be due to age-related differences in a speed accuracy trade-off, given that older adults tend to place relatively greater importance on accuracy.[36] However, as with response times, older adults generally perform more poorly than younger adults.

TRAINING STRATEGIES AND THE OLDER ADULT

The pattern of age differences in performance, as described above, is unfortunate, because there are reasons to believe that, in many respects, older adults may derive comparatively greater benefit from using information technology.[37] It can help to overcome problems relating to independence and mobility (e.g. providing facilities for home shopping, social networks, or home working); be used to augment cognitive skills (e.g. to support declining memory ability); and serve to reduce the physical demands associated with task performance.

A key issue, then, is whether it is possible to devise training regimes that will attenuate, or eliminate the disadvantages experienced by older users with respect to the use of information technology. Previous reviews of this area have provided some ambitious and commendable attempts to marry theories of age-related changes in basic capacities to the training of older adults in information technologies.[37–39] For example, Jones and Bayen[38] provide an overview of age-related effects on processing speed, processing resource availability, inhibitory processes, and sensory capacities, together with specific recommendations for the design of training regimes that would be suited to the older user. However, direct empirical support for a training regime that is more beneficial to older adults than it is to younger adults is hard to find. For example, Gist *et al.*[35] found no significant interaction between age and the use of a 'behavioural modelling' strategy (interactive computer-presented tutorial versus video tape demonstration), with respect to the acquisition of spreadsheet skills. Similarly, Czaja *et al.*[22] found no interaction between age and the use of instructor-based, on-line, or manual-based instruction for word processing, and Charness *et al.*[18] found no interaction between age and the provision, or not, of an advance organizer for a word processor, or between age and self-paced versus fixed-paced tutorial conditions. In these instances it would appear that effective training is effective for all (regardless of age). In contrast, Zandri and Charness[24] reported an interaction for performance accuracy, between age and the provision of a 'jargon sheet' (explaining computer terminology and commands), given to participants prior to an experimental session that required the use of a multifunction application. However, the nature of this interaction was such that younger adults performed more poorly when provided with the sheet, whereas there was very little difference in the performance of older adults. There was also a three-way interaction between age, provision of a jargon sheet, and whether learning took place individually or with a partner, but this was based on very low cell numbers and, again, was not consistent with any justifiable theoretical position.

A difficulty with studies of this type concerns the demonstration of equivalence of learning outcome. For example, Mead and Fisk[40] examined the effects of procedural versus conceptual training on the performance of younger and older adults while using a simulated automatic teller machine (ATM). The data were interpreted as consistent with older adults deriving comparatively greater benefit from procedural training. However, it is not clear that the skills acquired were the same in both conditions. It would seem probable that participants in the 'conceptual' training condition acquired more transferable skills, and also that the training received in this condition was cognitively more complex. An important methodological issue, therefore, concerns the range of testing conditions that follow comparisons of different training regimes.

Another approach to the development of training regimes that are particularly advantageous to older adults is to consider whether comparable performance to that of younger adults could be achieved by performing tasks in a different way, or with a different emphasis on constituent components. Task performance strategies that minimize the effects of age-related cognitive declines may be possible. For example, by 'looking ahead' further than their younger counterparts, with respect to the number of 'to-be-typed' characters, older adults who are skilled typists are able to compensate for other performance deficiencies.[41,42] Westerman *et al.*[30] investigated compensatory processes in the more complex task of word processing. Through a process of task decomposition, a number of 'molecular component' tasks were devised, and the performance of younger and older adults was tested on each. This experiment provided only weak evidence for compensatory processes. There was some indication that better older performers relied more heavily on typing skill than did younger performers of comparable standard. It may be that there is sufficient consistency of stimulus–response mapping[43] for this task component that age differences are eliminated due to automatization (see above). However, in general, it appeared that older and younger adults performed the 'molar' task in the same way. Importantly, the relatively more able older adults, with respect to 'molar' task performance, tended to be those who had higher basic cognitive abilities (e.g. spatial ability), possibly through less pronounced age-related decline.

CONCLUSIONS

In summary, it would appear that, across a range of new technology tasks, older adults perform more slowly. In many instances they also perform less accurately, although this may be restricted to certain types of error, may not be apparent if training is extensive, and may be influenced by age-related differences in speed–accuracy trade off. There is little evidence to suggest that this pattern of performance disadvantage for older adults can be modified substantially by the adoption of specific training regimes. Generally, if a training regime is better for older adults it will also be better for younger adults. It would seem that older adults are only able to match the performance of younger adults if they are given more extensive training.

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