The Future of Aging: Individual and Societal Implications

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Technology and Aging: A Behavioral-Science Perspective

Ulman Lindenberger

Cultural evolution has transformed old age from an exceptional into a normative period of life. The human lifespan has become longer and more predictable. This increase in longevity has been achieved by reducing, circumventing, and postponing losses typically associated with aging. Nevertheless, advancing age continues to be associated with increasing frailty. Old age and especially advanced old age, or the Fourth Age of life, are marked by cognitive, sensory, and motor impairments. Hence, the precariousness and vulnerability of old age motivates innovation in each subsequent generation. Human engineering technologies are a promising example for such innovation. Of particular interest is technology that I would like to call intelligent and assistive, that is, technology that learns from and regulates human behavior.

Putting this positive vision of technology for old age into practice requires a framework in which the aging individual, with her or his specific needs, capabilities, and constraints, is at the center of attention. To be effective, intelligent assistive technology has to adapt to the needs, habits, and preferences of aging individuals, and it should to do so preferably well before life is dominated by frailty or chronic disease. Therefore, from a behavioral-science perspective, the design and evaluation of human engineering technology is as much a psychological task as it is a technological feat.

Towards A Conceptual and Evaluative Framework

Conceptual models in lifespan psychology define successful aging as the conjoint maximization of gains and the minimization of losses. Of course, the lifelong process of trying to maximize gains and minimize losses is a rather ill-defined task. It cannot be solved by a set of differential equations, neither by aging individuals themselves nor by behavioral scientists. Instead, successful development and aging is approximated by heuristics and guidelines.

Paul Baltes, together with the late Margret Baltes proposed three general mechanisms: selection, optimization, and compensation. Taken together, these three mechanisms aid successful development. Selection refers to focusing one's resources on a subset of potentially available options. Optimization requires the search for beneficial environments and the coordinated application of resources directed at learning and higher levels of functioning. Compensation involves efforts to maintain a given level of functioning despite decline in, or loss of, previously available resources. Psychological criteria for evaluating technology for old age should be defined in relation to these general mechanisms of successful lifespan development. In the following, I will propose three such criteria: net resource release, person specificity, and proximal versus distal frames of evaluation.

Net Resource Release (Marginal Gain)

The use of technology usually comes at a resource cost because its operation requires an investment of physical and mental resources. It follows that the use of technology is adaptive only if this cost is lower than the payoff associated with other changes in processing. For instance, when the use of a notepad as a memory aid requires memorization of complex operating instructions, the payoff of using the device may be negative, at least initially. This point is analogous to the definition of successful aging in terms of maximization of gains and minimization of losses.

Note that older adults' perception of net resource release is likely to determine the actual use of technology more than the cost/benefit ratio assessed in some objective manner. Human engineering technologies fall short of their central objective if their use does not result in net resource release, both objectively and subjectively defined, and at least in the long run. This evaluation has to be based on a broad set of objective and subjective indicators that go beyond the target activity or functional domain. Also, this evaluation requires as much knowledge about humans as it requires knowledge about technology; it requires close collaboration between engineers and behavioral scientists.

Person Specificity

The second criterion refers to person specificity and person adaptability. Older individuals differ greatly among each other with respect to cognitive, sensory, and motor functioning. For instance, average age trends do not apply to all members of the aging population. Some individuals in their 80s perform above the average level of people in their 50s in central aspects of everyday competence such as memory, visual acuity, or hearing. Therefore, knowledge about the average aging individual provides little more than a viable starting point for the development and use of intelligent assistive technology.

What we need is a kind of technology that fine-tunes itself to the idiosyncrasies of the individual's behavior, to his or her specific competencies, habits, and preferences. Thus, technology not only needs to adapt to differences between individuals but it needs to learn from and about the individual user. This individualized knowledge base can later be used to assist the individual in maintaining his or her relatively independent lifestyle when impairments in sensory, motor, and cognitive functions become more prominent. Given the enormous variability in behavioral competence within the elderly population, and the developmental nature of the aging process itself, adaptation to individual users is a precondition for optimizing certain forms of technological assistance in old age.

Proximal Versus Distal Frames of Evaluation

Third, any assistive use of technology has to be evaluated on a short-term and long-term basis. Prior lifespan exposure to the same or related technologies is likely to influence the amount of net resource release that can be achieved in old age. For example, today's generation of middle-aged adults will make different use of mobile phones when they will be 80 years of age than many members of today's generation of 80-year-olds.

Short-term and long-term effects of technology need not always be congruent. Take, for example, the use of GPS-based spatial navigation aids to assist spatial orientation while driving a car or shopping in a pedestrian area. After initial training, such aids may have positive short-term effects upon way-finding behavior. However, to the extent that navigation support results in "disuse" of navigation skills, excessive reliance on technological assistance may be harmful in the long run.

Just as the specific needs of a growing population of aging individuals impose demands on engineers and industry to construct supportive environments, such supportive environments may eventually reshape the architecture of the aging mind and brain to an extent that we do not and cannot yet fully know and understand at this point in time. Thus, the effects of intelligent assistive technology on mind and brain need to be carefully monitored and evaluated on multiple timescales and dimensions.

Technological Intervention in Old Age

With advancing age, sensory and sensorimotor functions such as seeing, hearing, and walking are increasingly in need of cognitive resource investments. However, relevant cognitive resources also decline. Two intervention strategies, one targeting sensory/ sensorimotor aspects of performance and the other targeting cognition, may help to attenuate the adverse effects of this quandary. Technology can play a central role in both.

The Sensory/Sensorimotor Strategy

The sensory/sensorimotor strategy attempts to free up cognitive resources such as attention and working memory by reducing the cognitive demands of sensory or sensorimotor aspects of performance. Past design recommendations often have favored this approach. Typical examples include the reduction of background noise as well as glare-free, high-contrast, and well-lit workplaces. Assistive technology of this kind is often consistent with task-appropriate environments in general. It obeys the general principles of "optimal design", and does not mandate any person- or task-specific adaptive capabilities. Other forms of technology targeting our sensory and bodily functions such as reading glasses or walking canes are person-specific but require little flexibility within persons.

However, assistive technology aimed at our senses is not always simple to use. For example, many older adults experience the operation of hearing aids with various non-automated amplification modes for different auditory environments as cumbersome, and simply prefer not to use them. Apparently, the net resource release of these aids is negative because the potential gain – less attention-demanding hearing – is outweighed by the resource demands associated with the operation of the aid itself. More recent hearing aids that automatically adapt their amplification strategy to the auditory scene are more likely to result in a net release of cognitive resources, and thus are more likely to be used.

At the same time, simple forms of sensory or sensorimotor supports that require little cognitive investment can be surprisingly effective. In a recent study at the Berlin Max Planck Institute for Human Development, we projected virtual maze-like museums in front of a treadmill. Young and older men were asked to perform a way-finding task in these virtual museums while walking on the treadmill. The task was to navigate from the entrance of the museum to its bistro twice in a row without taking wrong turns at intersections. In the sensorimotor support condition, participants were allowed to hold on to a handrail. In the no-support condition, participants were asked to walk freely on the treadmill.

We found that young adults' navigation performance was not affected by walking support. However, older adults showed much better navigation learning when holding on to the handrail. These results demonstrate once more the close connection between sensorimotor and cognitive aspects of behavior in old age. In older adults, support for walking not only improves postural control but also frees up attentional resources that can then be invested into cognitive aspects of the task such as spatial learning.

The Cognitive Strategy

Present-day technology sometimes invokes the impression that elderly users, and users in general, are expected to adapt their ways of thinking and acting to technological requirements. From a lifespan perspective, the opposite would generally make more sense. Engineers and psychologists should conceive of older individuals as "experts about themselves", as people who own a rich behavioral repertoire and body of knowledge in accordance to their personal preferences, habits, and specializations. That is, aging individuals possess privileged knowledge, both implicit and explicit, about the ways in which their actions are organized in time and space. At the same time, they experience problems in implementing this knowledge in the course of action, especially under difficult conditions – when they are tired, when distracting information is present, when multiple goals are pursued simultaneously, and whenever their sensory and sensorimotor systems are taxed. Therefore, a key purpose of intelligent assistive technology is to act as an external cuing structure that keeps older individuals on the track of their own goal-directed actions.

What determines the effectiveness with which external cues facilitate thought and action? Two aspects, compatibility and distinctiveness, are central. Cues are said to be compatible when they point to the task-relevant memory episode or action tendency. They are said to be distinctive when they activate the specific action required without co-activating a large number of competing actions.

Psychological research has shown that self-generated cues, that is, cues generated by the person him- or herself, are by far more effective in triggering appropriate actions than any other kind of cue. When individuals generate their own cues, either explicitly or as implicit residues of successful behavior and action, these cues are likely to match their knowledge, habits, and preferences, and are likely to be understood and processed adequately.

To implement user-generated cues, some technological systems currently in use or under investigation require explicit input and manual reprogramming from the user. This, in turn, greatly reduces the net cognitive resource release associated with the operation of such devices, at least during this initial phase of customizing. However, adapting technology to the individual user can also be accomplished in technologically more demanding but psychologically more promising ways. Put simply, the assistive device or the instrumented environment itself, rather than the user, can be charged with the task of learning the user's habits and preferences.

Initially, when knowledge about the individual user is absent, the technology will operate on the basis of a default model, such as the model of the "average user". This is followed by an extended period of person-specific "acculturation" in the course of which the regularities and contingencies that constitute the life of the individual user are eventually used as a basis for coming up with an effective cuing structure.

Conclusion

Old age may be the period of life in which human engineering technologies are needed the most, rather than the least. However, without a systematic consideration of behavioral requirements and psychological laws, technological genius may not make best contact with the idiosyncratic knowledge of aging individuals. Shortcomings of technology may more often reflect insufficient attention to psychological laws than technological problems per se. To be optimally effective in old age, intelligent assistive technology needs to be introduced into the everyday lives of young and middle-aged adults, well before sensory, sensorimotor, and cognitive impairments have taken over. Such technology should not be centered on, or restricted to, disability and pathology but promote successful lifespan development and aging at all levels of ability and disability. It should be a pleasure to use, and a status symbol to posses. As Arnold Gehlen once said, culture is our second nature. Technology for old age should not form an exception.

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