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Psychological Principles of Successful Aging Technologies: A Mini-Review

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Key Words
Technology, aging · Successful aging · Lifespan psychology · Cognition · Resource allocation · Cuing structures

Abstract
Based on resource-oriented conceptions of successful lifespan development, we propose three principles for evaluating assistive technology: (a) net resource release; (b) person specificity, and (c) proximal versus distal frames of evaluation. We discuss how these general principles can aid the design and evaluation of assistive technology in adulthood and old age, and propose two technological strategies, one targeting sensorimotor and the other cognitive functioning. The sensorimotor strategy aims at releasing cognitive resources such as attention and working memory by reducing the cognitive demands of sensory or sensorimotor aspects of performance. The cognitive strategy attempts to provide adaptive and individualized cuing structures orienting the individual in time and space by providing prompts that connect properties of the environment to the individual's action goals. We argue that intelligent assistive technology continuously adjusts the balance between 'environmental support' and 'self-initiated processing' in person-specific and aging-sensitive ways, leading to enhanced allocation of cognitive resources. Furthermore, intelligent assistive technology may foster the generation of formerly latent cognitive resources by activating developmental reserves (plasticity). We conclude that 'lifespan technology', if co-constructed by behavioral scientists, engineers, and aging individuals, offers great promise for improving both the transition from middle adulthood to old age and the degree of autonomy in old age in present and future generations.

Introduction

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 are associated with cognitive, sensory, and motor impairments [1]. Hence, the precariousness of old age motivates innovation in each subsequent generation.

Human engineering technologies are a particularly promising example and active area of research for such innovation [2–10]. In recent years attention has been increasingly directed towards technology that learns from and helps to regulate human behavior [4, 9]. By making use of such intelligent and assistive technology, individuals of all ages, and aging individuals in particular, can delegate control over certain aspects of their everyday

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lives to technology while continuing to exert direct control in others.

Putting the vision of 'lifespan technology' into practice requires a conceptual framework that considers the evolving capabilities and constraints of aging individuals [3, 4, 11]. 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. In particular, intelligent (e.g., adaptive) assistive technology needs to be co-constructed by technological opportunities, psychological knowledge, and aging individuals themselves. To be effective, it has to learn and adapt to the needs, habits, and preferences of individuals, preferably well before major cognitive, sensory, and motor impairments have set in and taken over.

Given this premise, this article discusses the behavioral foundations of technology in old age, rather than technology per se. Based on resource allocation/generation views of successful lifespan development, we will propose three psychological principles, or guidelines, for the design and evaluation of assistive technology. We then will summarize key aging losses in cognitive, sensory, and motor domains, with special attention to their cumulative and interactive effects on everyday life. Finally, we will propose two strategies that address how technology may counteract the adverse effects of cognitive and sensorimotor losses on everyday competence.

Successful Aging as the Coordination of Selection, Optimization, and Compensation

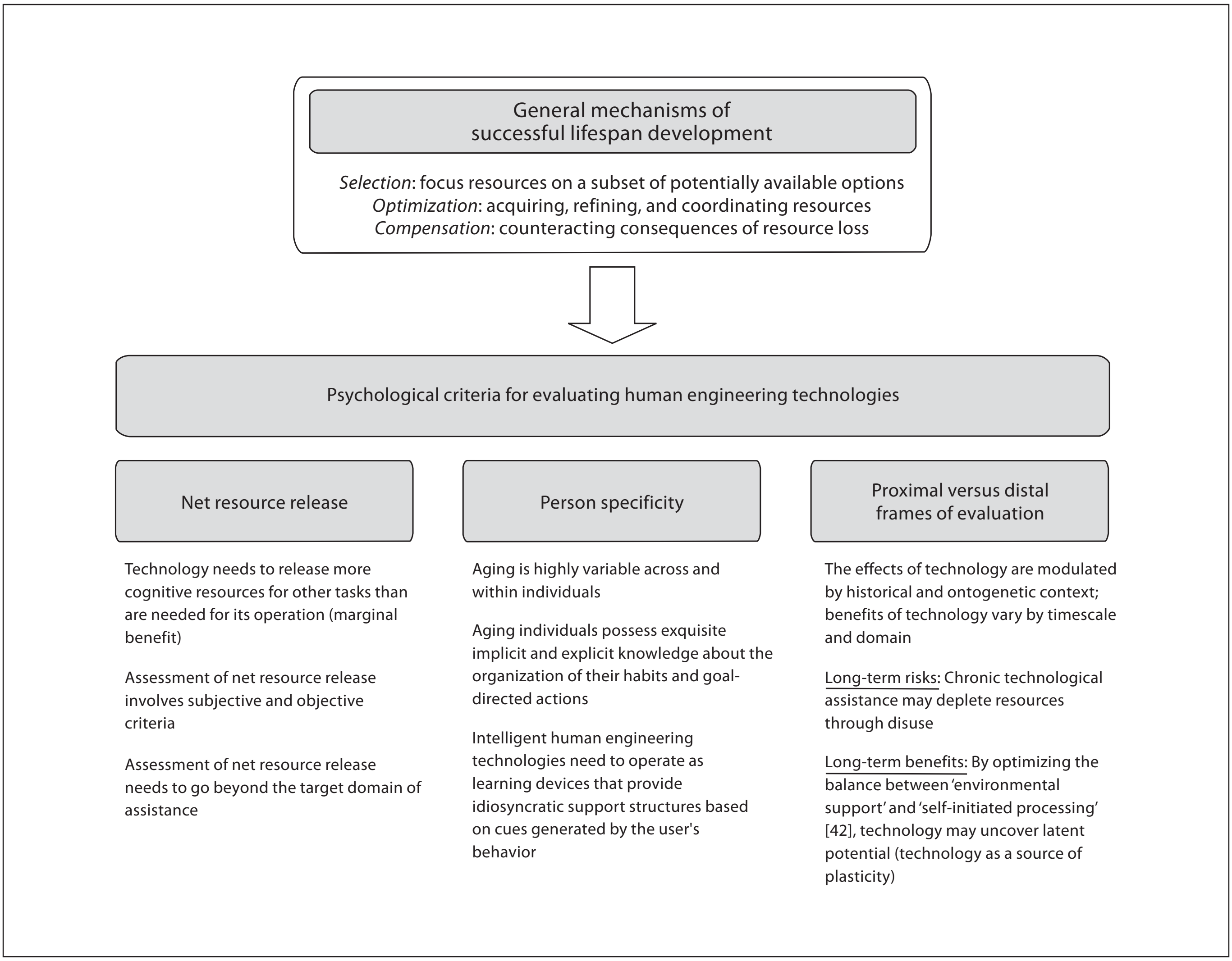
During all phases of life, human development unfolds within the range of opportunities and constraints that biological, psychological, and contextual characteristics provide. Such opportunities and constraints for development can be subsumed under the general notion of *resources*. Individuals differ in their access to resources. Moreover, within a given individual, quantity and quality of resources undergo fundamental changes throughout life.

In contrast to earlier phases of life, development in late adulthood and old age is characterized by a shift in directions of less resource gains and more resource losses [12–14]. Individuals might continue to gain, for example, in social status, material belongings, knowledge, and professional expertise. However, other resources such as physical fitness, health, sensory acuity, multi-tasking ability, and functional brain efficacy decrease throughout adulthood.

The decreasing gain-loss ratio of resources across the adult lifespan does not necessarily compromise adaptive functioning in all domains or in all individuals. Heterogeneity in functional status across individuals increases with age, and many individuals age successfully by various subjective and objective criteria, at biological, cognitive, and social levels [for an overview, see 15]. Hence, trying to gain a better understanding of *how* individuals manage to reach and maintain desirable levels of functioning in a life phase that is characterized by a host of objective and subjective resource losses is an intriguing task.

Psychological models of successful lifespan development attempt to identify person-environment constellations promoting adaptive functioning in old age [16–19]. Such models generally define successful development 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 an ill-defined task. It cannot be solved by a set of differential equations, neither by aging individuals themselves nor by behavioral scientists. However, successful development and aging can be approximated by heuristics and guidelines.

Baltes and Baltes [16] proposed three general mechanisms of successful development and aging: selection, optimization, and compensation (SOC) [19; for comparison with other models, see 20]. Given that pursuing all potentially possible developmental pathways exceeds available resources, the SOC theory posits that *selection* from the pool of available alternatives is one of the main mechanisms of developmental regulation [21]. The model distinguishes two forms of selection that serve different regulatory functions in lifespan development: *elective selection* occurs in response to new demands or tasks; *loss-based selection* occurs as a consequence of actual or anticipated loss of resources. Focused investment of resources gives development its direction and is a precondition for developmental specialization and the achievement of higher levels of functioning. *Optimization* reflects the gain aspect of development, defined as the acquisition, refinement, and concerted application of resources in selected domains for the achievement of higher functional levels. Lastly, *compensation* addresses the regulation of loss in development. It involves efforts to maintain a given level of functioning despite decline in, or loss of, previously available resources. It thus represents an alternative to loss-based selection, which implies a reorganization of life and functioning around the loss. It is assumed that the developmental mechanisms of selection, optimization, and compensation, if used in a co-



Selection: focus resources on a subset of potentially available options
Optimization: acquiring, refining, and coordinating resources
Compensation: counteracting consequences of resource loss

Technology needs to release more cognitive resources for other tasks than are needed for its operation (marginal benefit)

Assessment of net resource release involves subjective and objective criteria

Assessment of net resource release needs to go beyond the target domain of assistance

Aging is highly variable across and within individuals

Aging individuals possess exquisite implicit and explicit knowledge about the organization of their habits and goal-directed actions

Intelligent human engineering technologies need to operate as learning devices that provide idiosyncratic support structures based on cues generated by the user's behavior

The effects of technology are modulated by historical and ontogenetic context; benefits of technology vary by timescale and domain

Long-term risks: Chronic technological assistance may deplete resources through disuse

Long-term benefits: By optimizing the balance between 'environmental support' and 'self-initiated processing' [42], technology may uncover latent potential (technology as a source of plasticity)

Fig. 1. Psychological principles of successful aging technologies.

ordinated manner, help to maintain sufficiently high levels of performance in an increasingly small number of core domains.

We propose to define the principles for designing and evaluating technology for old age in relation to selection, optimization, and compensation as general mechanisms of successful development. In the following, three such criteria will be proposed: (a) net resource release, or marginal resource benefit; (b) person specificity, and (c) proximal versus distal frames of evaluation (fig. 1).

Net Resource Release (Marginal Resource Benefit)

The operation of technology usually requires an investment of physical and mental resources. It follows that the use of technology is adaptive only if these operation costs are lower than the payoff associated with other changes in processing when using the technology [20, 22, 23]. For instance, when the use of a notepad as a memory aid requires memorization of complex instructions, then 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.

Objective and subjective facets of net resource release, or the marginal resource benefit of technology use, need to be set apart and should both be taken seriously. Older individuals' 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 [for a recent example, see 24]. Thus, human engineering technologies fall short of their central objective if their use does not result in net resource release, both objectively and subjectively defined, at least in the long run. To render this outcome more likely, we need to know under what conditions behavior *with* technological assistance is in fact less resource-demanding than behavior *without*. Such an evaluation has to be based on a broad set of objective and subjective indicators that go beyond the target activity or functional domain. Most importantly, this evaluation requires as much knowledge about humans as agents with motives, preferences, and social expectations as about technology per se [25].

Person Specificity

The second criterion refers to person specificity and person adaptability. Older individuals differ greatly with respect to cognitive, sensory, and motor functioning [26–29]. Likewise, 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 [30]. Therefore, knowledge about the average aging individual provides little more than a viable starting point for the development and use of intelligent assistive technology. Beyond this starting point, the technology needs to fine-tune itself to the idiosyncrasies of the individual's behavior, to his or her specific competences, habits, and preferences [6]. Thus, technology not only needs to adapt to differences between individuals but it also needs to learn the behavioral ecology, or life space [31], of the individual user, preferably at a point in time when this ecology has not yet been severely compromised by disability and frailty. Later, when impairments in sensory, motor, and cognitive functions have become more prominent, the acquired knowledge of the individual's habits and life space can be used to assist the individual in maintaining his or her lifestyle as long as possible.

The principle of person specificity corresponds to the observation that selection, optimization, and compensation, while representing developmental mechanisms of broad applicability, take on different forms and constellations in different individuals and throughout ontogeny. For instance, the identity and number of domains that require compensation or loss-based selection in one form or another will vary both across individuals and within individuals over time. Given the palpable variability in behavioral competence and lifestyles within the elderly population, and the changes within individuals in the course of aging, adaptation to individual users is a precondition for enhancing net resource release.

Proximal and Distal Frames of Evaluation: Plasticity versus Disuse

Third, any assistive use of technology has to be evaluated on proximal and distal frames of reference, both on temporal and substantive dimensions. Prior 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 use of mobile communication devices when aged 80 in a different way than many members of today's generation of 80-year-olds do now.

Within individuals, short-term and long-term benefits of technology may not always be congruent. For example, the use of GPS-based spatial navigation aids may have positive short-term effects upon way-finding behavior. However, this support may be harmful in the long run if it promotes chronic disuse of navigation skills and spatial orientation abilities. In fact, in light of associations between the size of brain structures involved in spatial behavior, such as the posterior hippocampus, and exposure to environments with high navigational demands, such as Inner City London for taxi drivers [32], one may speculate whether long-term reliance on GPS-based devices may compromise spatial navigation skills and abilities, and reduce the size and functional integrity of relevant brain structures. If this holds true, then the short-term gains associated with the use of navigation aids would be offset by a severe long-term loss.

Conversely, technology may not only enhance the allocation of currently available resources through net resource release, but actually foster the generation of new resources by activating developmental reserves, or latent cognitive potential. Just like other tools for the mind, such as mnemonic techniques for the encoding and retrieval of word lists [33, 34], technology has the potential to enhance performance through external support while keeping the task environment challenging at the same time. With this in mind, intelligent assistive technology is no more and no less than a new voice in the co-constructive dialogue between culture and biology that constitutes human ontogeny [11, 35, 36]. However, its outstanding capacity for adaptation and behavior regulation sets it apart from other cultural artifacts, offering the potential to keep the complexity of the individual's life space close to optimal levels of challenge, or just below the maximum manageable level of task difficulty [19]. Behavioral and neuronal aspects of plasticity are reduced but not fully lost in old age [37–39], and the functional circuitry of the human cortex is capable of short-term adaptation to changes in experience or internal milieu at all ages [40]. Therefore, providing individuals with an optimally challenging environment does indeed carry the promise to activate behavioral and neuronal reserves.

In sum, when it comes to gauging the long-term consequences of intelligent and assistive technology, both risks and opportunities need to be kept in mind (fig. 1). On the one hand, chronic reliance on technological aids may deplete resources through protracted disuse of skills and abilities, undermine motivation, and engender loss of autonomy. On the other hand, intelligent and assistive technology may activate latent potential by combining support with challenge, thereby enhancing motivation, social participation, and a sense of autonomy, with positive repercussions on cognitive development in old age [41].

As the specific needs and demands of a growing population of aging individuals compel engineers and industry to build technologically assisted environments, these environments will 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. To promote plasticity and avoid disuse, the effects of intelligent assistive technology on the mind and brain need to be carefully monitored and evaluated on multiple timescales and dimensions. Clearly, determining the right balance between 'environmental support' and 'self-initiated processing' [42] is a central task in this process.

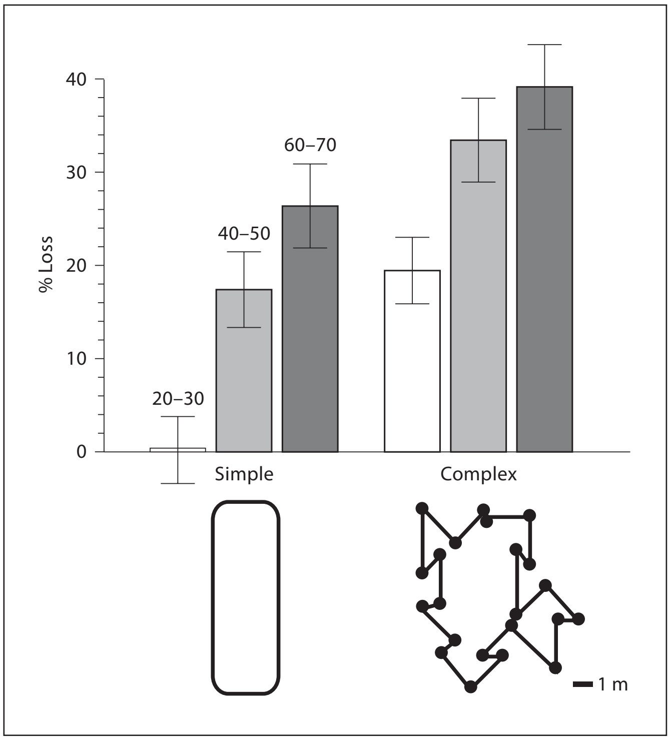


Fig. 2. Age differences in dual-task costs for memory performance as a function of concurrent walking. Cost scores refer to the percentage of loss in serial word recall in two walking encoding conditions (oval vs. aperiodic track) relative to the average of seated and standing encoding conditions. Middle-aged and old adults showed significantly higher dual-task costs than young adults. Error bars represent standard errors of the mean. Schematic drawings of the oval and aperiodic walking tracks are shown underneath. Adapted from Lindenberger et al. [44].

Technology for Aging Individuals: Two Strategies

Available evidence indicates that sensory and sensorimotor functions such as seeing, hearing, and posture control decline and require increasing cognitive resource investments with advancing age [for review, see 43]. At the same, relevant cognitive resources also decline. In combination, these aging trends result in increasing demands on a decreasing resource, or the 'quandary of behavioral aging' [43, 44]. According to the present analysis, the key purpose of technology for old age is to attenuate the adverse effects of this quandary.

The findings reported by Lindenberger et al. [44] may help to illustrate the increasing reliance of sensorimotor functioning on attentional control. In this study, young, middle-aged, and older adults were instructed and trained in a memory technique that allowed them to recall an average of about 10–12 of 16 words in correct serial order. Individuals listened to all the words over headphones at a rate of 10 s/word and were then asked to recall the words in the order in which they had been presented to them. After training, the authors manipulated the condition under which individuals encoded the words. Specifically, sitting in a chair or standing still during encoding was contrasted with a condition in which they had to walk on one of two narrow tracks at normal walking speed while listening to the words. Figure 2 displays the loss in memory performance when individuals were walking on the simple track or more complex track compared to sitting or standing. Dual-task costs, or the costs of concurrent walking on memory performance, increased substantially with age, and were particularly pronounced for the complex track. In the domain of walking, age-based increments in dual-task costs were observed as well. A like-

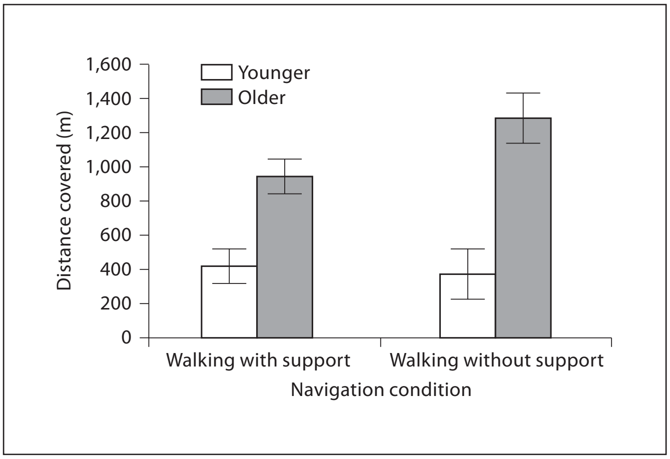


Fig. 3. Adult age differences in way-finding (spatial navigation) performance are shaped by sensorimotor demands. Bars display the mean distance covered to criterion as a function of age group (young and older adults) and walking demand (with or without handrail). Provision of a handrail does not alter the way-finding performance of the young adults, but considerably improves the way-finding performance of older adults. Error bars represent standard errors of the mean. Adapted from Lövdén et al. [46].

ly explanation for this finding is that walking requires an increasing amount of cognitive resources with advancing age, which need to be displaced from the memory task to the monitoring of sensorimotor performance. Interestingly, this tendency was already present in middle-aged adults. Also, the trends reported in this study certainly underestimate population trends because the group of older adults was unusually fit and healthy.

Informed by these findings, which suggest an increasing interdependence among sensory, sensorimotor, and cognitive functions with advancing age, we would like to propose two intervention strategies that may help to attenuate its adverse effects on everyday competence in old age. One of the two strategies targets the sensory/sensorimotor aspect of the quandary, and the other its cognitive side. Especially in the latter, intelligent and assistive technology can play a prominent role.

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. This strategy is generally less difficult to implement than the cognitive strategy. Therefore, past design recommendations often favor this approach [45]. 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, obeys the general principles of 'optimal design', and does not mandate any person-specific or task-specific adaptive capabilities. Other forms of technology targeting sensory and bodily functions such as reading glasses or walking canes are person-specific but, once adopted, require relatively little flexibility within persons (though occasional adjustments need to be made).

However, assistive technology aimed at the senses can also be rather complex. For example, many older adults experience the operation of hearing aids with various non-automated amplification modes for different auditory environments as cumbersome, and tend not to use such aids even though they own them. 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 automatically adapt their amplification strategy to the auditory scene, are more likely to result in a net release of cognitive resources, and are thus more likely to be used.

Basic forms of sensory or sensorimotor supports that require little cognitive investment can be surprisingly effective. In a recent study, we projected virtual maze-like museums in front of a treadmill [46]. Young and older men were asked to perform a way-finding task in each of several of 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.

As shown in figure 3, young adults' navigation performance was not affected by walking support. However, older adults showed better navigation learning when holding on to the handrail. These results indicate that supporting stability of gait in old age can have a beneficial effect on spatial navigation performance and demonstrate 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 navigation-related processing.

The Cognitive Strategy

Whereas the sensory/sensorimotor strategy, similar to exercise, helps cognition by alleviating the attentional load imposed by the senses and the body, the cognitive strategy aims at reducing cognitive resource demands through genuinely cognitive rather than sensory or sensorimotor means. Here, we highlight research on expertise and expert systems [47], particularly research on skilled memory performance [33, 34, 48]. Apparently, this line of research has had little influence on the development of technology for the elderly so far [49].

Present-day technology sometimes gives the impression that elderly users, and users in general, are expected to adapt their ways of thinking and acting to technological requirements. From a psychological and developmental perspective, and as has been noted by others [4, 8, 50, 51], the opposite seems desirable. That is, engineers and psychologists should think of older individuals as 'experts on themselves,' as people who have a rich behavioral repertoire and body of knowledge with respect to their personal preferences, habits, and specializations. In other words, 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 goals are present, when multiple goals are pursued simultaneously, and whenever their sensory and sensorimotor systems are taxed and in need of additional attention. Hence, we propose that 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.

Basic psychological research has provided ample evidence that external cuing effectively supports goal-directed action [33]. The invention of mnemonic devices, which dates back to Ancient Greece and Rome, underscores the power of cuing structures as organizers of thought and action, which in turn reflects the ubiquitous interplay of various binding mechanisms in learning and memory. In this sense, any well-organized body of knowledge, especially if linked to a sequence of external prompts, constitutes an effective cuing structure [34]. For this reason, individuals show superior memory performance in their domains of expertise, be it bridge [52] or various areas of professional specialization [47].

What determines the effectiveness with which external prompts or cues facilitate thought and action? Two aspects, compatibility and distinctiveness, are central [48, 53]. Cues are said to be compatible when they point to attributes that are functionally related to the task-relevant memory episode or action tendency. For instance, a stop signal effectively cues the action of stopping one's car because it has been firmly associated with this action during prior learning episodes. The compatibility of other cues may vary widely from person to person because the corresponding individual learning histories are less uniform.

In addition to being compatible, cues should also be distinctive; that is, they should activate the specific action required without co-activating a large number of competing actions. Again, cue distinctiveness may not be invariant across persons and contexts [54]. Depending on context and knowledge, cues that are distinct for one person may be ambiguous for another. The recent proliferation of ring tones in mobile phones attests the speed with which distinctiveness of cues can be gained, and lost.

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. Therefore, such cues should show superior compatibility and distinctiveness compared to cues generated by other people. Mäntylä [48] tested this hypothesis by asking college students to define their own retrieval cues by generating properties or features for each to-be-remembered word presented at study. The outcome of these experiments was quite spectacular. Self-generated properties that were presented as cues during recall resulted in exceptionally high levels of memory performance. For example, after 7 days, participants recalled on average 327 of the 504 words when given three self-generated properties as cues; immediately after study, they recalled 459 of the 504 words. Also, self-generated retrieval cues were far more effective than those generated by someone else. Fortunately, similar though somewhat attenuated effects have been observed among older adults [55].

In sum, 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. Of course, this is not surprising. 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 processed adequately. Therefore, such cues should show superior compatibility and distinctiveness compared to cues generated by other people.

Therefore, we propose that intelligent assistive technology needs to provide adaptive cuing structures orienting individuals in time and space by providing prompts that connect properties in the environment to the action goals of the individual. Cues are helpful when they prompt the appropriate action at the right point in time. To this end, they need to be compatible and distinct. Self-generated cues excel on both dimensions. Hence, technology designers are kindly asked to adapt the properties of assistive devices to aging individuals' needs, competencies, habits, and preferences. To approximate this goal, some of the systems currently in use or under investigation require explicit input and manual reprogramming from the user of the assistive device. This, in turn, greatly reduces the net cognitive resource release associated with the operation of such devices, at least during the initial phases 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. We envision the functioning of intelligent assistive technology as a multi-layered, lifelong process of individualization. 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'. Explicit off-line information about the user's cognitive, sensory, and sensorimotor abilities as well as his or her preferences and habits may be entered to modify these default parameters. This is followed by an extended period of person-specific 'acculturation' of the device that permits the intelligent assistive technology to learn the regularities and contingencies that permeate the life of the individual user.

Intelligent Assistive Technology for Old Age: An Imaginary Case Study

Ms. Miller, a 90-year-old widow, lives in her own apartment in a small town. Her core family consists of two daughters and their families. Ms. Miller is mentally fit and physically healthy, and has no intention of giving up her apartment. Last summer, she won an open-age card game tournament and she keeps the trophy with great pride in her living room.

On her 90th birthday, Ms. Miller receives a handheld electronic device from one of her daughters. The device looks like a mobile phone and can be used as such. Ms. Miller has been using mobile phones for several years, and starts using the handheld device for this purpose, taking it with her on all errands. In addition to serving as a mobile phone, the new device also has other capabilities: It is equipped with GPS, a large and well-lit SMS display, a movement sensor, an infrared receiver/transmitter, and machine-learning capabilities. At home, it is electronically connected to the stationary telephone, and registers all of its calls.

Initially, Ms. Miller does not make active use of any of these additional functions. However, most of these additional functions are operating from the first day. Thanks to its machine-learning capabilities, the device detects regularities in Ms. Miller's life. For example, it registers: (a) that Ms. Miller calls the younger of her daughters about every other day in the afternoon; (b) that she calls the other daughter each day early in the morning; (c) that she walks to the cemetery once a week to visit the grave of her late husband; (d) that she goes to the hairdresser each Saturday morning, and (e) that she moves the device each day sometime before 9 o'clock in the morning.

With advancing age, Ms. Miller's cognitive abilities eventually begin to decline. At age 94, she tends to forget planned actions and gets more easily distracted than before. In this situation, the handheld slowly starts acting as a personalized cuing device that assists Ms. Miller with her everyday activities. At first, Ms. Miller feels annoyed by messages from the handheld that remind of her things she may want to do by making remarks such as 'Good time to call your daughter Anna!' or 'What about the hairdresser?' However, she eventually gets used to these kinds of prompts. She also notices that her relatives are impressed by her persisting independence and competence. The device continues to take notice of enduring changes in daily routines, and adapts to them. For example, the visit to the cemetery is now taking place every other week, rather than every week.

Ms. Miller also has begun to make use of the shopping aid component of the device. Before leaving her apartment for shopping, she sits down at the kitchen table, and takes all the time she needs to register the shopping items on the device with a voice key. She then goes to a shopping mall equipped with infrared sensors matching those of the handheld device. The sensors make contact with Ms. Miller device, register her shopping list, and come up with a shopping route, navigating Ms. Miller through the mall from shop to shop by giving directions on the display. When Ms. Miller has reached a shop, the device prompts her with the shopping items that are available at this location. If an item is sold out, it redirects Ms. Miller to another store in the mall that may also sell that item, and reconfigures the shopping route accordingly. In this manner, the device keeps track of the shopping list and navigates Ms. Miller through the mall until all her shopping needs are satisfied.

One morning, Ms. Miller feels sick and is not able to leave her bed. The movement sensor notes that the device has not yet been moved, and the device starts ringing. Ms. Miller cannot respond because the device is too far away from bed. At 9:20 a.m., the device automatically calls the hospital and an ambulance arrives in time to provide medical treatment.

All technological components described in this imaginary case study, including the shopping assistant, are available [56–58]. However, to the best of our knowledge, a device of this kind has not yet been developed.

Conclusion

In this article, we discussed technology for old age from the perspective of lifespan psychology [11, 14]. Old age may be the period of life in which human engineering technologies are needed the most, rather than the least. However, without systematic consideration of behavior and human agency, technological genius misses the idiosyncratic knowledge and habits of aging individuals [9]. Some of the shortcomings of present-day technology aimed at enhancing everyday competence among the elderly may reflect insufficient attention to psychological laws rather than technological problems. According to the present analysis, 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 disability and pathology but be geared at promoting successful lifespan development at all ages. It should be a pleasure to use, and a status symbol to possess. If Gehlen [59] is right that culture is humans' second nature, then technology, a historically recent aspect of culture, should not form an exception.

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