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Lifelong Learning and Technology

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Two changes in the 20th Century unwittingly and fundamentally reshaped 21st Century societies in the developed world: Average life expectancy increased by nearly 30 years and fertility rates fell by half. Individuals are living longer than ever before in human history. In the United States, the average life expectancy is nearly 78 years and steadily rising. Among Japanese women, life expectancy is already 85 years (Oeppen & Vaupel, 2002). Arguably even more profound than individual aging, populations are aging at unprecedented speeds. In the developed world, the number of people over 65 will soon outnumber the number of children under 15 (Hayutin, 2007). Policy makers and pundits are responding mostly to relatively short-term consequences of population aging for social programs like Social Security and Medicare, but life will change in myriad ways and demand new norms for work, family, finances, and education. Virtually all of the societal “problems” associated with aging populations reflect a mismatch between societal practices and length of life where societal institutions and norms lag behind individual needs, a phenomenon that sociologists refer to as “structural lag.” (Riley, Kahn, & Foner, 1994). Educational systems built around the needs and strengths of people in their 20s and younger are inadequate for populations in which people live and often work for 5, 6, and 7 decades beyond those early years, especially in societies where the pace of scientific discoveries and technological advances is steadily increasingly. Eventually the social institutions and norms by which people live will change, but in the short term, informal science learning has a critical role to play in the health and wellbeing of entire societies.

Technological literacy, in particular, will be essential to insure life long engagement in rapidly changing societies. Given that the demographic landscape of the future predicts not only a much large proportion of older adults, but also potential labor shortages, it is important to consider how best to offer ongoing educational opportunities to people who may be working five and six decades beyond the completion of their formal educations. Effective solutions must consider at least three factors that likely affect learning in later adulthood. Two have been investigated thoroughly: 1) age-related declines in the processing of new information and 2) changes in motivation and the reprioritization of emotional wellbeing over new learning. The third influence on learning, only recently investigated in older adults, concerns the ways in which beliefs and stereotypes influence motivation and learning. We consider all three below. First, however, we delve more deeply into the current state of technology use among older adults.

Section 1

Technology and Aging

Benefits of Technology

Technological advances in the 20th century not only increased average life expectancy, automation also reduced the effort involved in many everyday chores, like washing clothes, cooking, and housecleaning (Rogers, Meyer, Walker, & Fisk, 1998). Today computers are part of almost every facet of life. Microwave ovens, programmable dishwashers, and even automobiles are technologically sophisticated. Online computer resources also have become an indispensable resource. Advertisers direct consumers to websites as often as telephones to order products. The Internet has become an important source of health-related and travel information, and an invaluable mode of communication with friends and family (Morrell, Mayhorn, & Bennett, 2000). Because computers increase the ease of communication, they serve important social functions (Chaffin & Harlow, 2005). In future societies, technology also will allow workers to bypass the physical demands of work which, in the past, drove otherwise productive workers into retirement (Czaja, 2001). Changing the landscape further is the narrowing gap between a new technology's inventions and their eventual widespread use. Charness (2006) points out that the time interval from discovery to marketplace for the facsimile (fax) machine was more than 100 years, whereas more recent advances come very quickly to the marketplace. This marvelously efficient dissemination has benefited many industries and consumers. Rarely, however, do new devices and techniques slip automatically into use. Even the simplest technology requires some degree of knowledge on the part of the user. In short, maintaining a current understanding of technology has become necessary for effective functioning in everyday life.

The potentials of technology to improve life are breathtaking. Yet technological societies present challenges for aging societies. Use of the Internet illustrates the problem. As of 2004, only 22% of people at least 65 years old were "online," compared to 58% of those 50-64 years old, 75% of those 30-49 years old, and 77% of those 18-29 years old (Pew Internet and American Life Project, 2004). In addition, older computer users are online much less frequently than their younger counterparts (Czaja et al., 2006) and have less experience with computers in general (Rogers, Cabrera, Walker, Gilbert, & Fisk, 1996). The fact that the majority of older adults are not employed likely contributes to this difference. Thus, although computers may serve to lower isolation risk in people of all ages, they disproportionately expand horizons and open windows to the world for young adults.

Clearly, today's middle aged cohorts are more facile with computers than previous cohorts. Some people contend that the generational gap in computer use will be closed as Baby Boom generations age. True enough, the percentage of older computer users will increase rapidly over the next decades, but with each decade comes newer technology that must also be learned in addition to that which was previously known. Addressing the psychology *behind* learning new skills in addition to the ways current technologies can be most easily fitted to an aging population's intrinsic goals and motivations will remain important.

Older Adults' Views of Technology

For the eventual purpose of informing technology training methods and manipulations for older adults, it is important to consider how older adults feel about technology. What are the apparent benefits and costs? Although some research reports a relatively negative view of computers among older adults, the majority of recent studies suggest that older adults find the benefits of computers compelling and are quite motivated to learn how to use them (Morrell et al., 2000).

By self report, a chief barrier to computer use among older adults is anxiety (Czaja et al., 2006; Ellis & Allaire, 1999; Laguna & Babcock, 1997), but other obstacles contribute. Older adults express less comfort with and confidence in computer skills than younger adults (Czaja et al., 2006) and less interest in general (Ellis & Allaire, 1999). In a recent focus group study of perceptions and use of various communication methods, Melenhorst, Rogers, and Bouwhuis (2006) found that older adults attributed fewer benefits to email compared to more traditional modes of communication, such as personal visits, telephones, and postal mail. However, even though older adults may not appreciate some aspects of computer use, it seems as though these negative outlooks are relative. Considered alone, it is clear that older adults are motivated to learn how to use computers.

By and large, older adults agree that computers are essential for functioning effectively in today's society and are interested in acquiring computer skills (Mayhorn, Stronge, McLaughlin, & Rogers, 2004). Underlying motivations to learn how to use computers appear to include enhanced contact with relatives (especially with grandchildren through email), learning for pleasure, remaining active, and searching for information (Mayhorn et al., 2004). In another focus group, older adults expressed a ***desire*** for using multiple types of technology from computers to VCRs, but an uneasiness rooted in the belief that they have a harder time than younger adults learning how to use new technologies (Rogers et al., 1998). Other studies also support older adults' desire to learn how to use computers in order to take advantage of email (Melenhorst, Rogers, & Caylor's study as cited in Mayhorn et al., 2004), and the benefits of search engines for accessing health-related information (Morrell et al., 2000; Stronge, Walker, & Rogers, 2001).

Thus, not only are older adults becoming increasingly aware of the beneficial aspects of computing, older adults are emerging as the fastest growing group of adopters (Kelly, Morrell, Park, & Mayhorn, 1999; Purdie & Boulton-Lewis, 2003; Beisgen & Kraitchman, 2003; Mayhorn et al., 2004). Of course, this relatively high demand to learn may be due to saturation in computer use in other age groups, and there still remains a large difference between the number of older computer users and the number of younger computer users. Older adults are more likely than younger adults to learn to use computers from books and classes (Czaja et al., 2006). There has even been a reported increase in demand for e-learning courses about computer technology among older adults (Rossman's report in Mayhorn et al., 2004). Perhaps one reason for this still present gap could be the way computers are represented and taught, which fail to highlight benefits relevant to older people. Even though there are a growing number of older adults who understand these benefits and are willing to take part in various training methods, there has been minimal effort to market computers in ways that intrigue potential older users. One woman remarked that "bits and bytes were all Greek to her and she 'could use the electricity in a home without understanding how to put the wiring in'" (Mayhorn et al., 2004, p. 191).

Predictors of Computer Use

Because there is variability in computer use among older adults, it would be helpful to review what factors (psychological or otherwise) predict adoption and frequency of use. In the previously mentioned focus group described by Melenhorst et al. (2006), older adults emphasized most what they saw as 'absent' benefits and costs associated with each communication method – i.e., what a particular technology ***didn't*** offer that others did. In other words, rather than talk about barriers to adoption, these adults failed to see the benefits of adoption. The authors found that even though older adults viewed email as less appealing than other methods of communication, this was mostly because they failed to appreciate the benefits. Contrary to the common perception that older adults lack the necessary skills to use email, the lack of perceived benefits was the best predictor of adoption of novel technology (also see Sharit, Czaja, Perdomo, & Lee, 2004). For example, email use would be predicted best by actual benefit such as convenience or cost as well as by beneficial characteristics email lacks such as face to face interaction.

Similarly, in a large survey of adults ages 18 to 91, Czaja et al. (2006) found that perceived usefulness was a significant predictor for future use of email and word processing applications. In addition to the predictive value of perceived benefits, other factors also remain important for future use. In the same study, Czaja et al. found that fluid and crystallized intelligence, education level, self-efficacy, and anxiety were predictors of the breadth of increasing computer experience and use. Gender and ethnicity were also predictive. Older men used more types of technology than older women (no difference was found between middle aged men and women), and African-American and Hispanic adults used computers less than European-Americans. It remains unclear, however, whether these observed differences reflect ethnicity or socioeconomic status.

Psychological factors likely mediate computer use as well. In a survey, Ellis and Allaire (1999) explored whether level of computer anxiety and knowledge mediated the relationships between age and education on computer interest. As expected, computer anxiety was positively correlated with age, and computer knowledge and interest were negatively correlated with age. Interestingly, age was *not* fully mediated by anxiety, thus leading the researchers to hypothesize that perhaps the age effects could be more fully explained by computer-related efficacy differences (Ellis & Allaire, 1999). Indeed, higher self-efficacy has been found to predict lower computer anxiety which then predicted greater use of word processing programs (Brosnan, 1999).

Changes over the Life Span

Age-related Cognitive Decline and Presentation of Information

Unfortunately, older adults who decide to adopt new technologies and take advantage of the opportunities afforded to them from using computers face a technology that was designed for a target audience of young users. Although common perceptions of aging often paint an overly dramatic picture, age related decline in information processing is a reliable part of the aging process.

Most significantly, aging adults face a steady loss in what is called “fluid intelligence” or processing capacity (for a review see Craik & Salthouse, 2000). This decline can adversely affect performance on everyday tasks because of worsening attentional capacity (Salthouse, 1996), speed of processing (see Madden, 2001), and working memory (see Bäckman, Small, & Wahlin, 2001). Age-related declines in hearing, vision, and motor control appear to exacerbate deficits in fluid intelligence. One study examined the effects of hearing loss on performance on a recall task (McCoy et al., 2005). In this study, older adults with either good or moderate hearing were randomly prompted to repeat aloud the most recently heard word from a running list. Although hearing ability did not affect recall for the most recent word, differences in performance were seen for the recall of words two and three back in the list. These findings led the researchers to conclude that additional resource expenditures in hearing-impaired listeners to successfully perceive a word comes at the cost of processing resources that would otherwise be directed at encoding that word into memory (McCoy et al., 2005).

These age-related declines in fluid intelligence do not occur suddenly. In fact, performance on most tasks related to fluid intelligence begins declining in very young adulthood, and continues at a steady downward slope thereafter. For instance, when people are asked to perform multiple things at the same time, i.e. multi-tasking, age differences in performance can be seen in early midlife (Heckhausen, 2005). However, early declines may not be as readily apparent because routine tasks do not require a great deal of processing capacity. Moreover, there is some suggestion that future cognitive declines in middle-aged cohorts may be somewhat delayed and milder than those in the previous ones (Beier & Ackerman, 2005).

Even though, with training, older adults can significantly improve fluid abilities such as memory (Baltes & Kliegl, 1992), working memory declines appear to have a detrimental effect on the usability of computers for older adults (Czaja, 2001). Compared to younger adults, older adults make more errors while working on the computer (Charness, Schumann, & Boritz., 1992; Echt, Morrell, & Park, 1998) and have been found to perform at a lower level on a variety of common tasks even when typing speed and computer experience are controlled statistically (Czaja & Sharit, 1993). In addition, older adults demonstrate a reduced ability to inhibit extraneous information. Websites dense with text and graphics may be especially distracting for older visitors (Rogers & Fisk, 2001). This could be a crucial point to consider as Stronge et al. (2001) found that health related websites were not well tailored for older adults, even though they may serve as a key source of motivation for older adults to use the web (Morrell et al., 2000). There are other relatively straightforward changes that could further customize computers to accommodate age-related changes in sensation and cognition. Simple adjustments like reducing the glare on a computer screen may be beneficial (Mayhorn et al., 2004). Of course, many of the modifications aimed at improving utilization by older adults will appeal to users of all ages.

Despite primary focus in the literature on problems related to computer use among older adults, it is important to point out the many advantages. Computer software makes it possible for elderly users to produce written documents equivalent in appearance and accuracy to users of any age. Arbitrary magnification of text and figures on screen compensates for many vision deficits. Printed text renders irrelevant the typical age-related declines in the legibility of handwriting. Online thesauruses help recall words that fail to come to memory. Typing errors are easily corrected. Furthermore, overlooked spelling and grammatical errors are detected and highlighted. Factual information is only a web-browser click away. Similar computer solutions are currently available for many drawing problems. Photographic manipulations that would have been inconceivable except for the most sophisticated professionals a generation ago are now simple and available at the fingertips for all ages. Going into old age without computers will soon be the equivalent of going without electricity and running water fifty years ago. With comprehensive $100 computers around the nearest corner, the barriers are almost entirely psychological.

Age-related Growth (and Stability)

Development over the life course is not simply a story of early pure gain followed by later pure loss, but rather an evolving balance of losses and gains that occur at every stage of life (Baltes, 1987). Although there are age-related declines especially associated with fluid processing tasks, many aspects of psychological functioning are relatively unaffected by the aging process. Some improve across adulthood. Because some degree of associated loss is eventually unavoidable, this means that successful aging must be defined not as the avoidance of decline but as the degree that one is able to maintain personal continuity through accommodation and balance (Brandtstädter, Rothermund, & Schmitz 1998). Though there is well documented decline in fluid intelligence, other types of intelligence remain well intact while still other domains may improve with age, thus potentially serving in the interest of striking a developmental balance.

"Crystallized intelligence," which refers to knowledge such as facts about the world and culture, as well as vocabulary and acquired expertise, remains relatively stable throughout later life (see Schaie 2005). As mentioned previously, world knowledge is a predictor of computer use (Czaja et al., 2006) likely reflecting the large predictive role that education plays. Moreover, Beier and Ackerman (2005) found that for adults of all ages, world knowledge was directly related to both technology and health-related learning tasks. This finding stresses the importance of taking into account more than just processing capacity (viz, the efficiency of new learning) in predictions of technological abilities. Expertise, i.e., knowledge in highly practiced domains like work, typically increase across adulthood and current knowledge about world events, academic facts, and health related information have been found to correlate positively with age (Beier & Ackerman, 2001). Not only is world knowledge maintained well into old age, decades of life experience lead older adults to enjoy higher levels of knowledge in other areas as well that may not always be measured on common intelligence tests.

Sternberg (2002) suggests that intelligence is not well captured by most tests; in addition to more classic "cognitive" tasks such as solving puzzles, one must also consider creative capacities as well as the practical application of skills in order to gain a more complete snapshot of intelligence. Moreover, Heckhausen (2005) stresses the importance of other factors that can affect functioning such as societal constraints and opportunities, and levels of experience and expertise. Most likely a result of a relative abundance of life experiences, older adults differ from younger adults in levels of wisdom, as well as life-planning skills and an understanding of the pragmatics of life (Clayton & Birren, 1980). Not only are older adults armed with an increased level of knowledge in many domains, other beneficial psychological changes in maturity and control take place that may affect the learning process.

Despite losses, there is evidence suggesting that older adults' sense of control over their own development, as well as their sense of personal self-efficacy, remains very stable even up to the latest stages of life (Brandtstädter et al., 1998). Also reflective of an increase in psychological maturity, age has been found to be associated with personal autonomy (Sheldon, Houser-Marko, & Kasser, 2006), a decrease in strivings for popularity and money, and even an increase in subjective well-being (Sheldon & Kasser, 2001). The greatest changes however may be those that reflect life experience and self regulation. Changes in these domains appear mostly beneficial to daily living, and we discuss them below.

Emotional Development Over the Life Span

Originally, theories surrounding the theme of loss as it applied to the aging process were based on observations about social and cognitive changes. In the social arena, it was clear that older adults engaged in fewer social interactions than their younger counterparts (for a review see Carstensen, 1998). This withdrawal was seen as an emotional disinvestment and was not only theorized as an essential part of the aging process, but of the *dying* process. It was hypothesized in disengagement theory that this withdrawal reflected emotional preparation for death (Cumming & Henry, 1961). Although it is true that older adults are not as socially active as they once were, more recent research suggests that this decrease does not result from emotional flattening but rather selective attention to the most important relationships. A social 'pruning' process occurs in which emotionally meaningful partners are retained and less meaningful partners are discarded (Carstensen, Gross, & Fung, 1997; Carstensen, Isaacowitz, & Charles, 1999).

Research has shown that day in and day out, the affective experiences, moods, and even the associated autonomic nervous system activity of older adults are more stable than younger peoples' (Lawton, Kleban, & Dean, 1993; Lawton, Kleban, Rajagopal, & Dean, 1992; Levenson, Carstensen, Friesen, & Ekman, 1991). This reduction in variability is associated with emotional maturity and regulation. While the emotional response levels in the autonomic nervous system may be reduced with age, older adults still experience emotions *subjectively* as intensely as their younger counterparts (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Tsai, Levenson, & Carstensen, 2000), and the pattern of autonomic responses in older adults is similar to that in younger adults. In other words, although older adults tend to have a smaller magnitude of autonomic response, they show the same patterns of physiological differentiation.

There is a growing body of evidence showing that older adults experience emotions at the same intensity as younger adults when they occur, but regulate or manage these emotions better. Based on real-time sampling in everyday life, older adults experience negative emotions less frequently than younger adults, and when they do experience them, they are of shorter duration (Carstensen et al., 2000). Moreover, positive emotions are experienced with comparable intensity and frequency among young and old. Thus, the overall ratio of positive to negative becomes increasingly favorable with age.

Theoretical Frameworks

Socioemotional Selectivity Theory

How can it be that older people experience significant loss in certain domains yet retain emotional well-being? Socioemotional selectivity theory (Carstensen et al., 1999) offers an explanation to this paradoxical storyline based on life-span changes in motivation. The theory is premised on the contention that humans monitor their place in the life cycle (i.e. one’s time left in life) and with age gradually perceive future horizons as more constrained. In contrast, younger people perceive the future as vast and open-ended. The more expansive one’s time perspective, the more goals will be directed toward acquiring information and expanding horizons. In other words, under conditions where the future looms large, people are motivated to gather information and expand their horizons. In contrast, when time is perceived as constrained, emotionally meaningful goals are pursued because they can be realized in the moment. Because of the constraints mortality imposes, older adults on average have a shorter time horizon compared to younger adults and are thus more likely to pursue emotionally meaningful goals.

Recent findings suggest that these motivational changes also affect cognitive processing. The term “positivity effect” has been coined to refer to reliable age differences in memory and attention in which younger people disproportionately attend to negative information and older people disproportionately focus on the positive (see Carstensen & Mikels, 2005; Mather & Carstensen, 2005). This effect has been found in many experiments including attentional differences in a dot-probe design for emotionally negative, positive, and neutral faces (Mather & Carstensen, 2003), autobiographical memory differences about the past (Kennedy, Mather, & Carstensen, 2004), amygdala response activity for emotional picture viewing (Mather et al., 2004), and recall and recognition differences in an affective picture memory task (Charles, Mather, & Carstensen, 2003). This pattern may represent a form of emotion regulation in older adults. That is, preference for positive information may serve wellbeing.

Affect Valuation

The *value* placed on different affective states also appears to change with age. The key tenet of affect valuation theory, formulated by Tsai (2003) and her colleagues is that cultures determine the desirability that people place on particular emotional states. The greater they value a state, the greater effort they place on experiencing it. Thus, affect valuation not only identifies preferred states, it predicts behavioral responses to particular affective states. For example, in cultures that place value on calm states people may pursue calming activities, whereas in cultures that place value on high arousal states people may engage in activities designed to generate excitement.

Age also influences valuation. Younger adults in East Asian cultures, for example, have been shown to disproportionately value positive emotions that are relatively low in arousal, such as calm and peaceful, whereas younger adults with American culture have been shown to value positive emotions that are relatively high in arousal, such as excitement and enthusiasm (Tsai, Knutson, & Fung, 2006; Eid & Diener, 2001). Tsai et al. (2006) argues that affect valuation predicts behavior better than actual affective experience. In other words, an individual in an American culture may not, on average, actually be in a positive, aroused state, but will tend to be motivated toward that state. Tsai (2003) predicts that older European American adults value emotions similarly to those with East Asian cultures. Moreover, Tsai (2003) finds that older adults value emotions that are calm and peaceful more than emotions that evoke excitement and elation, while younger adults disproportionately value emotions that signal excitement. Tsai also shows that younger adults focus on highly arousing stimuli more than older adults who focus relatively more on stimuli that are low in arousal.

Other Selectivity Considerations

As mentioned earlier, successful aging may depend on the ability one demonstrates in finding balance for losses with accommodative strategies. We have seen that older adults may disproportionately select emotionally meaningful goals relative to younger adults, but interestingly, older adults may be more selective in general than younger adults. Selective Optimization with Compensation theory (Baltes, 1987) suggests that in order to compensate for cognitive loss and the necessary lowered limits on some processing thresholds, older adults demonstrate an increased selection and specialization of available skills and resources. This is seen as a compensatory strategy because a larger amount of resources can be dedicated toward a smaller and more specialized set of motivations (Baltes, 1987; also see Freund & Baltes, 2000, Freund & Baltes, 2002).

Riediger and Freund (2006) expanded on this idea, proposing that older adults not only restrict the number of goals they are motivated to pursue but that they also *focus* these goals around central, important life domains. They suggest that by restricting and focusing, goal-related behavior improves due to increased inter-goal facilitation. In other words, because goals grow increasingly more related to one another, relevant behaviors are more adaptive than if one's goals were more diffuse. In one study, adults representing a wide age range were asked about their current goals at one time point and then were asked again about their progress and behavior toward these goals three months later. Riedeger and Freund (2006) found that the older adults demonstrated higher levels of inter-goal facilitation, and held more selective goals in that they were more similar in content and more centrally related to life-domains described as most important for life satisfaction.

The above theories and supporting data help to clarify potential motivational differences between older and younger adults, but of course motivation also varies *within* age groups. The majority of research on motivational influences on learning have concentrated on children and young adults. The aim of the next few sections will be to give an overview of the relevant theories and then later to discuss their relevance to current life-span theories of development and motivation.

Self-Theories of Intelligence

Dweck's (1986, 1999) highly influential self-theory of intelligence has been applied primarily to children and young adults. The theory contends that people generally hold one of two beliefs about intelligence. Although the degree varies by individual and context, people more or less hold either a *fixed*, or entity based view of intelligence, or an *incremental*, more malleable view of intelligence. Those who believe that their intelligence is fixed endorse the notion that indeed they are able to learn new things, but their intelligence level basically stays the same. On the other hand, those who are in the incremental camp believe that intelligence is something that can be changed and is a malleable quality that can be molded with effort. The self-theory one holds, however, has not been found to be related to one's actual intellectual ability, but the theory one holds does have tremendous behavioral consequences, particularly in the face of obstacles and failure.

Those who hold a fixed view of intelligence are prone to exhibit maladaptive or helpless behavioral patterns. These individuals are motivated by the desire to perform well, receive positive feedback, and therefore increase their perceived competence. Because of this increased emphasis on performance, challenging tasks are seen as obstacles for their competence. Therefore, difficult tasks are associated with low persistence and negative emotional experiences. To these individuals, easy tasks are preferable because feedback is most likely to be positive and supportive of their sense of competence. Upon hearing negative feedback for a given task, those who believe their intelligence is fixed attribute their failures or any other observed error to a low ability level. This attributional style also leads to some interesting and perhaps unexpected consequences. Because these individuals are chiefly concerned with how their competence is perceived both by others and by themselves, any increase in effort is seen not as necessary hard work but instead as an indication of their low ability. In addition, even though these fixed intelligence believers tend to choose easy tasks and avoid difficult ones, they may actually choose extremely difficult tasks because there is no expectation to succeed (also see Dweck, 2002). Unfortunately, these overly difficult tasks are not adaptive to the learning process.

Those who hold an incremental view of intelligence are instead motivated to achieve learning goals. These individuals are interested in the process of learning itself, thereby actually increasing their competence in a given task or activity. Challenges for these individuals are not seen as obstacles, but rather as opportunities to learn new things and are associated not with anxiety or frustration but with positive emotions. Upon hearing negative feedback, the incremental theorist tends to attribute failure to a lack of effort, not a lack of ability. This behavioral pattern is adaptive and leads to more challenge seeking and higher persistence on tasks compared to those with a fixed theory of intelligence. Moreover, children with effort-based goals have demonstrated more success in transferring their knowledge to novel tasks and domains (Farrell & Dweck's work as cited in Dweck, 1986).

External Influences

But how do external factors influence one's motivation to achieve different goals that lead to either adaptive or maladaptive patterns of behavior? Or, to what degree are these self-theories malleable? Many studies have shown that in fact these self-theories are surprisingly easy to manipulate. One factor that can have an impact is the type of feedback or praise given.

In a study of 5th graders' performance on puzzle tasks, Mueller & Dweck (1998) showed that the praise a child received could be either beneficial or detrimental depending on whether it concentrated on the child's effort or on the child's ability. Children who were initially praised for their apparently strong effort later solved more puzzles, chose more difficult puzzles to work on, and enjoyed their experience more compared to children who had initially been praised for their strong ability for solving puzzles. Also, children praised for effort attributed failures in the puzzle task to a lack of effort whereas children praised for ability attributed failures to low ability. Not only can people's beliefs of intelligence and performance be molded by the type of praise received, they can also be molded by the way a task is construed or worded (also see Henderlong & Lepper, 2002).

When students are told that a certain task measures whether you "have it or you don't," students will be oriented toward a fixed theory. If students are told that a task requires an ability that can be learned, students will be oriented toward a malleable theory (Dweck, 2002). Interestingly, Martocchio (1994) found that those who received a malleable style of instructions in a computer learning environment demonstrated less anxiety, a higher sense of efficacy, and ended up learning more than those who had read entity-driven instructions.

In an attempt to break the learned helplessness cycle, much research has concentrated on manipulating how performance is related to unstable, controllable factors. Many of these studies have centered on higher status students conveying a message to struggling younger students (for a review see Wilson, Damiani, & Shelton, 2002). In these studies the more experienced students emphasized the unstable and controllable factors that could help explain why the younger students happened to perform poorly early on. This strategy has been largely successful at improving the performance of the younger students over long periods of time. In another study, Good, Aronson, & Inzlicht (2003) actually taught the incremental message (that intelligence is malleable through effort) to junior high students who then used the message as a part of a personal web page project. Over the following year, the message was reinforced though email correspondence. The results of this long-term intervention were beneficial; relative to controls, students who received the incremental message and reinforcements demonstrated improved performance in both math and reading. It is interesting that a once-present gap between male (higher) and female (lower) math performance had virtually disappeared.

Memory Stereotypes and Implications for Research

Earlier, we saw how new technology can be an important asset to an increasingly aging population. On the one hand, it seems as though older adults are motivated to learn how to use technologies such as computers, but on the other hand, it appears that some obstacles remain. Certainly, age-tailored improvements can be made for computers like simpler web page formats and less technological jargon. But, motivation to learn how to use new technology may be more psychological in nature. As mentioned earlier, though decline in fluid intelligence is reliable, the extent of loss is often overstated. Importantly, declines often can be countered simply by providing a self-paced learning environment or by otherwise de-emphasizing cognitive demands (Beier & Ackerman, 2005; Echt, Morrell, & Park, 1998). Similarly, other unnecessary obstacles may be present based on the way a task is framed. Although some types of memory performance do indeed decrease with age, stereotypes surrounding these declines may exacerbate these effects.

Young and old alike widely believe that memory declines with age (Ryan, 1992). Although true to some extent, such beliefs can cause people to over-diagnose failures or shortcomings in memory performance as indicative of low *ability* (Parr & Siegert, 1993).

These beliefs can then reduce motivation and lead to even poorer performance (Rahhal, Hasher, & Colcombe, 2001). There are clear parallels between beliefs about memory and entity models of intelligence. When aging adults believe that memory inevitably declines, and attribute memory failures to ability, they typically reduce efforts that would otherwise aid performance. In one study, for example, younger and older adults completed a variety of memory tasks such as recalling and recognizing common nouns, associating names with faces, and remembering hypothetical appointments (Devolder & Pressley, 1992). Participants then generated lists of the factors that influenced their performance. Younger adults attributed their performance to relatively controllable factors while older adults disproportionately attributed performance to uncontrollable factors. Those who listed uncontrollable factors performed more poorly than those who did not.

Because older adults often view cognitive failures as the inevitable result of aging, they are also viewed as uncontrollable (Miller & Lachman, 1999). Unfortunately, older adults have been found to set memory performance goals too high, thereby reducing the amount of objectively positive feedback they receive (West, Bagwell, & Dark-Freudman, 2005; West, Welch, & Thorn, 2001). Appropriate goal setting can counter this problem (see Pervin, 1989).When performance goals are set at levels that are more readily attainable, older adults appear to be more motivated to achieve them and report enhanced feelings of efficacy (West et al., 2001). Therefore, appropriate goal-setting seems to be a sensible addition for training programs or interventions in any domain for older adults. But what could be even more important to consider is the malleability of these maladaptive strategies older adults exhibit. In other words, are the attributional styles of older adults flexible like young people's self-theories of intelligence?

Although it appears that in some cases older adults' attributions for memory failures are less malleable than younger adults' (Guo, Erber, & Szuchman, 1999), other studies have found that age differences in attributions are not present when situational contexts for failure are provided (Cherry & Brigman, 2005), and that actual age-related performance differences on memory tasks disappear when the memory nature of the task is de-emphasized (Hess, Auman, Colcombe, & Rahhal, 2003; Rahhal et al., 2001). Such research highlights the importance of taking into account potentially maladaptive attributions about learning. Earlier, we saw that anxiety may play a role in older adults' adoption of new technology. If anxiety levels are associated with concerns about a fixed or uncontrollable ability related to computer use, then a prudent suggestion for any such program of training or instruction would be to de-emphasize that ability. Interestingly, upon being directed toward adopting the incremental theory of intelligence, older adults may actually be the most susceptible to behavioral change in areas that present the most psychological barriers. For instance, in the intervention study by Good et al. (2003), students who received the incremental message improved their performance, but it was the *girls* who showed the most improvement in math. Potentially, the intervention not only provided a healthier attributional style in general, but it also may have served to break down the stereotype that girls aren't good at math.

Another program of research could investigate the benefits of not just de-emphasizing skills that older adults believe to be uncontrollable, but instead to highlight areas in which older adults show improvements. Earlier, we reviewed many areas where older adults continue to improve. For instance, older adults' levels of crystallized intelligence equal or exceed those of younger adults. Additionally, crystallized intelligence is predictive of computer learning. Therefore, training programs that explain these facts to older adults may serve to reduce anxiety and most importantly increase their perceived efficacy. Moreover, perceived control may be beneficial on other levels. For instance, Mayhorn et al. (2004) found that older adults saw user input as an important part of the training process. Because personal autonomy may increase with age (Sheldon, Houser-Marko, & Kasser, 2006), sensed control over the training process could be a welcomed change for older adults, especially in light of theoretical models that suggest one's control over the external world declines after mid-life (Heckhausen & Schulz, 1998).

Earlier, we saw that older adults exhibit motivational shifts with age. So could training programs or interventions exploit these changes? According to socioemotional selectivity theory and potential differences in affect valuation, older adults disproportionately attend to and are motivated by goals that are emotionally and socially meaningful in nature, and oriented toward stimuli that are positive and are calming. Certainly, children's preference for playful, stimulating, and exciting information has been utilized to increase intrinsic motivation in learning programs in the past. Cordova & Lepper (1996) found that using a personalized, game-like environment of instruction led to an increase in children's performance, challenge seeking, and confidence. Based on the same logic that Cordova and Lepper used in developing "starship captains" and a space theme to draw on children's interests, one can envision training programs that would draw similarly on an understanding of older adults' goals. For instance, one could construct a training program designed to teach the basics of email by demonstrating the relative ease they might experience in reaching loved ones. Such programs would therefore be tailored to older adults' tendency to value socially and emotionally meaningful goals. In this way, interventions could be designed that capitalize on older adults' increasingly focused and centralized goals while still adhering to their most important life domains and emotional biases.

Section 2

Use of Scientific and Technical Knowledge

As our world becomes more and more technologically complex, both opportunity and challenge increase. It is a characteristic of good engineering to design products that are easy to use. Section 1 deals largely with computing and computer-related products, today's most complicated, and most broadly useful invention. However, the principles are the same for almost all devices. Frequently, the easiest way to learn to use a new device is to ask for guidance from someone who is already familiar with the device. In the workplace, this probably is the most common way of learning. Even computers fall in this category. In the early days of computers, only the most specialized engineers could deal directly with computers in machine language. That era was followed by programming languages and a new career path of software engineering. With desktop computers and software application packages such as word processors, literally everyone can interact with computers. Users in the workplace increase their skills largely by asking their neighbor which key combinations work for the application they are currently using.

The retired rarely have someone readily available to answer their specific technical questions and, for that reason, rely in disproportionate numbers on formal courses to develop the degree of computer literacy they need to function. Psychology has much to offer the teachers and students in these courses, as Section 1 explains. How we evaluate and use the scientific and technical knowledge that we acquire is quite another matter, and this problem becomes greater and greater as science progresses and the results become more readily available to the average citizen through the Internet, the World Wide Web, online libraries, and sophisticated browsers. Without doubt, the qualitatively improved accessibility of knowledge from these sources will empower individuals with tools for greater control over their lives. As the Reformation created a revolution in organized religion by giving the Protestant world direct access to the Bible through translations into common languages of the day, the Internet and its components are revolutionizing the way we live our everyday lives by giving every user access to the entire world of knowledge. Knowing how to evaluate and use this knowledge constructively is the ultimate challenge.

Research in the social sciences has little to say about this subject. However, it does suggest that successfully using available knowledge can have profound positive effects on longevity, quality of individual lives and the costs of health care (House et al., 1992; House, Lantz, & Herd, 2005). House et al. (2005) found much lower morbidity among elderly who had postgraduate or professional levels of education than similar groups with lower levels of education.[1] Their study followed subjects that were age 62 in 1986 for an additional 15 years, scoring as “healthy” only those who said that they could perform normal tasks of daily living without assistance. Even at age 62, subjects with high levels of education were healthier than others in the study group. Remarkably, however, the highly educated group showed almost no increase in morbidity in the following 15 years. Subjects with lower levels of education reported a steady decline in health over that same period. This study can be used primarily for hypothesis generation. It needs to be independently confirmed. Confounding variables such as access to health care and income levels must be thoroughly investigated. Finally, it will be important to tease out those aspects of the experience and knowledge of the highly educated that are responsible for improved health. However, the study offers promise that, if individuals are able to obtain, evaluate and use knowledge effectively, their quality of life and the span of their highly productive years can be significantly extended. Many known contributions from science, technology and medicine almost doubled the average length of life for the US population in the 20th Century, but there is little in the mortality and morbidity distributions with age to suggest that much was done to increase the inherent life span encoded in our genes. However, the remarkable data in Figure 1 give us hope that empowering people with knowledge and the skills to evaluate it will keep many more people well and productive almost until the time of death. This, of course, is the ideal for the individual and for society.

The Fundamentally Negative Nature of Knowledge

In societies where enormous volumes of information flow directly to the public, and where conflicting "facts" abound, it is essential that the general public gain a basic understanding about the inevitably tentative nature of knowledge. The challenge begins at the most basic level. Our culture tells us that certain "facts" are correct. We consider knowledge to be a collection of these "facts." Yet this is clearly a perverted view of knowledge. Scientists understand that we do not know the ultimate truth about even the simplest physical principles. Instead, what we call knowledge is a collection of models of the ultimate truth. We make guesses and test them against the Ultimate Authority, i.e., the observable world about us. These tests only tell us if we are wrong.

This fundamental characteristic of knowledge is just as true for us today as it was for our most primitive ancestors. Two profound changes have taken place since that time, however. First, the invention of writing gradually augmented word of mouth in transmitting models of truth from one person to the next and from one generation to the next. Second, the scientific method systematized the process of testing models of the truth. But, they are still *models* of the truth, not qualitatively the truth itself—and the never-ending search for the truth goes on. For centuries, theoretical predictions based on Newton's Laws of motion were more precise than experimental observations. Today, however, the global positioning system you may have in your pocket requires a more sophisticated model of gravitation and time than Newton's for its operation. Although this more advanced and more complete model is extremely powerful, no physicist claims that Einstein's general theory of relativity is the ultimate truth. In the more complex fields of biology and medicine, it has become common practice to characterize models of the truth by the quantitative probability of their being wrong. In social science, anthropology and paleontology, the model building process is slow and experimental tests are time consuming, expensive and incomplete. Many moral and ethical principles are testable in principle only in reference to some arbitrary goal and cannot be tested in an absolute sense. Still, these principles may determine the survival of a culture.

In a crude and superficial way, we consciously and unconsciously test the models that we use to guide our daily lives. However, in a real sense, every person lives almost entirely by faith—faith in the models that others have tested, and which collectively constitute all of available knowledge. A single scientist, whose entire training and subsequent career may be given to advanced, specialized model testing, may devote years of intense effort to the testing a single hypothesis. Human culture provides an efficient way to learn from the efforts of others and pass knowledge along to our children. In our rush to absorb the knowledge needed for survival in modern society, it is easy to overlook the fundamentally negative nature of that knowledge—to realize that no model is complete whether it is a theory of gravitation or a theory of biological evolution. After being force-fed with "facts" by our educational systems, we must retain the perspectives and tools to evaluate the "facts," whether they come from our medical advisors or from a page on the Internet. It is tempting to speculate that the particular qualities of the highly educated that are responsible for their low morbidity in later years of life is that they have been forced to work at the edge of thoroughly tested models of truth and have learned through training and daily experience how to evaluate those models and use them effectively.

The qualitatively improved accessibility of knowledge that we have going into the 21st Century inevitably will change our culture and enhance our control over our daily lives and our destinies. It will occur even without concerted guidance from our social structures, in which case, it may primarily benefit the highly educated. Or with research, we may learn how to spread the benefits of our collective knowledge to a much larger fraction of society. At the core of any solution, we must face the fact that modern scientific knowledge is far too complex for even the brightest or best educated individual to evaluate all facets of knowledge. There are inklings today of approaches to these problems that would not have been possible even a decade ago.

General Knowledge

A decade ago, advanced thinkers had made several encyclopedias available online—perhaps with a subscription fee. Today, the most used encyclopedia is one that has grown spontaneously from the contributions of many specialists throughout the world and it is entirely free to anyone with an Internet connection. Almost any individual scientist groans when asked about the entries about his own area of expertise in Wikipedia. So, clearly we can hope for improvements and refinements in this convenient reference to concise elementary information of specific topics. It may be argued that a malleable encyclopedia with constant review by thousands of experts could be more reliable than the classic sources of general knowledge. The fact that many specialists anonymously and with considerable effort share their expertise with the world is a spectacular concept. It is barely more than the germ of an idea at the present time but it is spreading rapidly throughout the Web. Volunteers do the most of the work. Webmasters provide the venue and sometimes make fortunes. Professional organizations also use the Internet for the dissemination of knowledge in various ways. In these examples, information which appears on the website has been subjected to some degree of critical review and can be taken by the casual reader to represent a consensus of experts to a greater degree than an isolated webpage from a single author.

Commercial Products

Compared with the evaluation of diets or testing of economic theory, consumer product testing is relatively simple and inexpensive. Still, it is beyond the capacity of the individual consumer to test all of the competing products before making a purchase. For many years, the non-profit organization, Consumers Union (Yonkers, NY), has taken on the task of testing products for efficacy and durability. A “best buy” rating in Consumers’ Reports for a given product is no guarantee of satisfaction, and it does not eliminate the need for buyers to make their own critical evaluations of the information available but it does give them a significant advantage in their purchase that would not be available from the manufacturers’ advertisements.

Services

Rating services for personal and professional services that perform as well as Consumers’ Union for commercial products do not exist at the present time. Although the need may be as great, the job is far more difficult than rating devices. A Sears Model 4510 refrigerator is the same throughout the country. Once tested, the results might be used in the purchase of thousands of refrigerators. Services are local and personal. The challenge is greater but not altogether impossible. There have long been accreditation agencies for institutions and certain professionals, of course. News magazines rate universities and medical institutions. Angie’s List is a relatively new online club in which members report their experiences with providers of lawn care, appliance and home repair, builders and contractors and a very long list of other personal services. Overall, there is ample room for innovation in guidance on the choice of service providers.

Health Care

Reducing morbidity in old age will require much more than a rating system for health care providers, as desirable as that might be. Both internal and external factors are gradually shifting the responsibility for health care decisions from the medical profession to the patient. Life style choices, of course, are entirely the responsibility of the individual. Wise choice of diet, exercise, avoidance of toxic and infectious environments and hazardous activity together are probably the most important factors leading to a long and healthy life. When illness strikes, it is very probably discovered by the patient, who must perform a preliminary diagnosis before even seeking professional help. Thanks to advances in medical knowledge and technology, most serious illnesses are treated through a series of referrals from the primary care physician to medical specialists. As the patient interacts with a range of specialists, technicians, nurses and aides, it may be that the patient is the only participant in the process who is in a position to see the whole picture. In such a situation, the more the patient understands about the physiology, pathology and pharmacology of the problem, the better they can guide their own care.

Fortuitously, the technology of the Internet is beginning to provide health information in a form that empowers the individual patient to participate intelligently in treatment decisions. It is very common today for patients to search the Web for information about every aspect of their health problems. When they interact with their physicians, they come armed with specific questions, they direct the attention of the physician to symptoms that might be otherwise overlooked and they require less instruction. In this development, there is a shift in the role of the physician from unilateral decision maker to health consultant. The patient can never be expected to achieve the global perspective of a medical doctor or research scientist. However, many patients do become remarkably knowledgeable about their specific health problems. When this happens, it improves the efficiency of the health care providers and improves outcomes for the patients.

For the patient to go much beyond the Wikipedia level of health care information requires a comparatively simple set of tools that are second nature to scientists but do not come naturally to every individual. Needed is the ability to use the concept of statistical significance at a very elementary level, to weigh the value of a small, preliminary study or a large double-blind clinical trial, to think quantitatively about the probabilities of success for alternative treat options, to understand the basis for predictions about long term side effects of treatment. Above all, it is important that patients understand that any knowledge that they acquire is, in fact, a model—probably a very preliminary model—of the ultimate truth. For that reason, any decision that they make about their life styles or their treatments in illness is a gamble with tradeoffs and probabilities of success. Little about the present availability of knowledge guarantees that the users will have these tools. It should not be difficult, however, to include that kind of preparation in the kinds of teaching that are discussed in Section 1.

Even today, computer-aided technology is making it possible for individuals to accept an informed responsibility for their lifestyles and health care. Physicians retain their traditional roles as experts in diagnosis and treatment decision as well as gatekeepers to the bizarre world of insurance coverage. The role of physicians will change very slowly. But, there is every hope that patients may soon become much more sophisticated about their illnesses and treatment options. Perhaps the greatest obstacle to success in that movement is the great mass of information that is available and the difficulty that the average user has in sorting the valuable information from the chaff.

The Wiki phenomenon suggests a potential solution to this problem. Some combination of organizations like the American Medical Association, the Institute of

Medicine or the National Institutes of Health can create on the Web a living, changing compendium of medical knowledge. It can be presented in layers with simple explanations readily understood by patients at the entrance with links to more specialized and technical levels, supported by documentation and referrals to specific studies that would provide useful information to the most sophisticated of the medical profession.

We do not know what factors gave the highly educated participants in the House study longer and healthier lives. The most likely factors are critical, problem-solving abilities, honed by daily challenges, and applied for their own benefits to the subject of health care. If that hypothesis is correct, a great deal of the advantages currently held only by the highly educated can be transferred to a much larger fraction of the population.

Conclusion: Science and technology are responsible for the near doubling of life expectancy in the 20th Century. There are more older people alive today than ever before in history. There will be more in the future. In order to fully realize the benefits of this unprecedented accomplishment, we must build a culture that supports long life. Indubitably, technology will be part of this 21st Century culture. An understanding of science and the ability to adopt new technologies has become a basic requirement for young and old alike.

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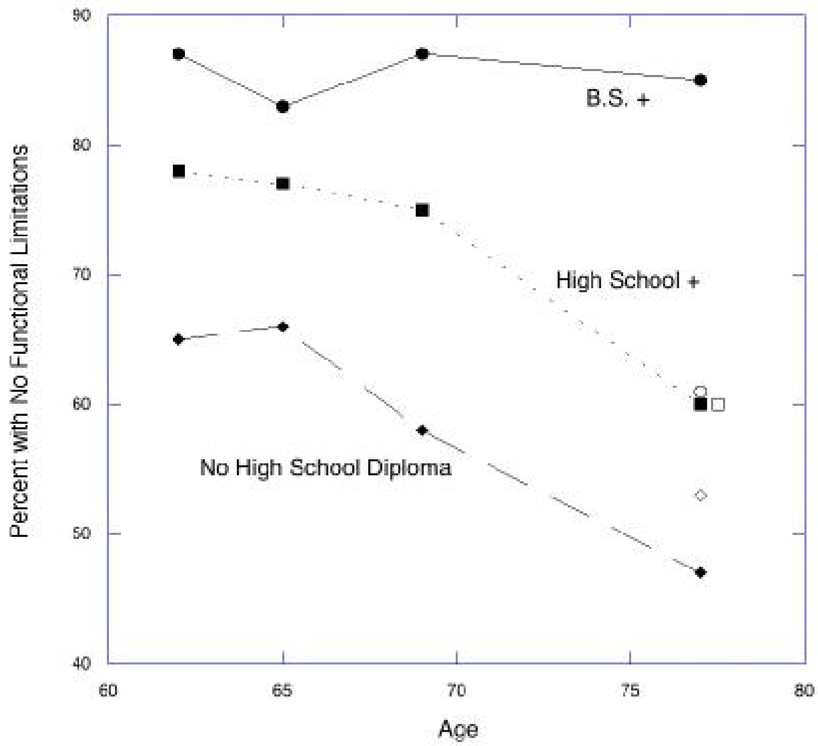
Footnotes

[1] Stephen Smith (2004) found similar disparities with socioeconomic status (SEC) in health for subjects in the 1991-1996 National Health Interviews Study. Of the many factors associated with SEC status, he found the strongest correlation with level of education.

Figure Captions

Figure 1. Health status for subjects who were 62 in 1986 followed over the next 15 years (filled symbols), *i.e.* from 1986 to 2001. The corresponding open symbols are the health status reported for 77-year-olds in 1986 (Adapted from House et al., 2005).


90
80
70
60
50
40
60
65
70
75
80
Age
Percent with No Functional Limitations
B.S. +
High School +
No High School Diploma