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Older Adults and Technology-Based Instruction: Optimizing Learning Outcomes and Transfer

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Our purpose here is to provide an overview of the cognitive and socioemotional changes associated with aging and to propose ways that these changes can be accommodated in a technology-based training environment. We recommend that technology-based training for older adults should: (1) be highly structured, (2) provide feedback and adaptive guidance, (3) include metacognitive prompts, (4) incorporate principles derived from cognitive load theory and cognitive theory of multimedia learning, and (5) include a user interface that is simple and consistent throughout the course. With a focus on organizations as well as business schools, we then discuss contextual variables expected to enhance older learners' training motivation or improve their transfer of training. Finally, we will recommend areas worthy of exploration that might reveal age-specific differences in technology-based instruction (TBI) design.

That the U.S. and world labor force is aging is now well-recognized. The number of individuals 65 and older is increasing worldwide, with the fastest growing subgroup those over 80 (Czaja & Lee, 2007). A recent article in the popular press noted that the number of individuals 55 and older in the workforce is at an all-time high (*USA Today*, 2010). The article further noted that Americans 50 and older are staying employed longer than at any time since such demographics were tracked. For example, 55% of Americans 60–64 were employed during the first 11 months of 2010.

This trend of older Americans working will continue; by 2018, approximately one fourth of the American workforce will be comprised of individuals 55 and older (Toossi, 2009). Similarly, in the European Union, within the next 15 years, the percentage of workers over age 50 is projected to increase by almost 25% (*Economist*, 2006). Due to reasons such as greater longevity and dwindling savings, American workers are postponing retirement, leaving their ca-

reer jobs, and engaging in “bridge employment” (i.e., jobs that bridge careers and retirement), or reentering the workforce after retirement (Schultz & Adams, 2007). Consequently, there is an increasing need to train older workers, particularly when they are transitioning into new jobs.

Training delivery methods are changing as well, with an increased reliance on technology-based instruction (TBI; Kraiger & Ford, 2006). Green and McGill (2011) have documented the growing prevalence of TBI over the past decade; approximately one third of corporate training is now technology based. Thus, American workers are increasingly being required to make effective decisions about what they need to learn and then to engage in some form of TBI in order to perform their jobs effectively. Similarly, on-line instruction is becoming increasingly popular as a primary or supplementary form of instruction in universities and colleges (Allen & Seaman, 2011). What is more, Linardopoulos (2010) noted that more and more

working adults are drawn toward on-line courses as a form of continuing education.

The general link between cognitive processing in older adults and training design was recently examined by Beier and associates (Beier, 2008; Beier, Teachout, & Cox, 2012). Our work here differs from Beier's in that those papers addressed training in general, while we focus specifically on aging learners and TBI. Given the increasing prevalence of TBI in instruction, identifying challenges of training older learners and potential remedies is paramount.

Technology-based instruction is defined as any form of training that is delivered principally by way of technology. Technology-based instruction methods include interactive video systems, computer-based training, computer-assisted training, web-based training, e-learning, intelligent tutoring systems, computer-based simulations, and virtual reality training. All vary in the extent to which they are instructor-centric (i.e., an expert delivers the training material), learner-centric (a learner directs the training experience), or content-centric (learner engages with the content rather than with instructors or fellow learners; Koller, Harvey, & Magnotta, 2006). Although the diversity of TBI methods makes it impossible to make concrete statements about it as a whole, TBI can be challenging for trainees because they are often required to perform a variety of presumably simple, but interrelated, procedures in order to proceed through the training program, while also retaining core learning material. While we recognize there are substantive differences in training methods across the various forms of TBI, for the present analysis, we assume that each form presents similar cognitive and emotional challenges for learners. Specifically, common to most forms of TBI are asynchronous progression with self-pacing, decision making about content, and constant feedback. As we discuss below, these instructional properties present difficulties for learners related to content difficulty (intrinsic load), and also additional difficulties not relevant to the instructional purpose related to the ease or difficulty of navigating or interfacing with the technology (extraneous load; see Sweller, 1988; Sweller, van Merriënboer, & Paas, 1998). DeRouin, Fritzsche, and Salas (2004) argued that TBI places significantly greater demands on learners compared to traditional approaches. For older adults, however, TBI could be especially resource demanding because learners likely bring to the task a host of potential cognitive

decrements, such as reduced cognitive speed, reduced working memory capacity, and reduced ability to coordinate and integrate information. Resource allocation theory (Kanfer & Ackerman, 1989) is thus relevant here. It posits that motivation and ability (variables that tend to differ across older and younger adults) influence individuals' proximal self-regulatory process (metacognition, emotional control, and self-efficacy) and in turn, affect how information is processed. It is thus reasonable to expect that the efficacy of different training interventions will differ across age groups.

Although research often focuses on how age-related changes in cognition influence effective training design for older adults, it is important to remember also that motivation changes with age; these motivational changes must also be taken into account when designing TBI for older adults. We thus discuss below motivational changes in older adults, specifically Kanfer and Ackerman's (2004) review on intra-individual development, and socioemotional selectivity theory (Carstensen, 1995), which posits that as individuals near death, they are motivated to maximize enjoyment of their remaining years.

To be clear, prior research reveals multiple examples of an interaction between age and various training techniques (e.g., Carter & Beier 2010; Caplan & Schooler, 1990; Wolfson & Kraiger, 2012; Zandri & Charness, 1989). For example, Beier and Carter found that while younger adults tend to benefit from low-structure error-management training, older adults tend to benefit from high-structure error-management training. Wolfson and Kraiger (2012) found that advance organizers improved the transfer performance of older adults but not younger adults.

Generally, past research reveals an ordinal interaction in which certain instructional interventions show a differential impact on learning depending on participant age. For example, an instructional principle has no effect for younger learners, but a facilitating effect for older learners. Because most evidence suggests that when older and younger learners do respond differently to an instructional intervention, the difference is usually in magnitude and not direction, we argue that these principles can be considered reasonable recommendations in most situations where there is a chronologically diverse mix of learners. This means that researchers and practitioners alike must be aware of those instructional interventions that create disordinal interactions, to avoid inadvertently sabotaging younger

learners in the effort to facilitate older learners. These situations, however, appear to be the exception rather than the rule.

Our paper is organized as follows. We first review prior literature on cognitive changes associated with aging. Based on these changes, we provide recommendations for designing TBI. We then discuss socioemotional influences of older adults and corresponding contextual variables (within both organizational and business school settings) that should enhance older learners' training motivation or improve their learning. Finally, we recommend areas worthy of exploration that we suspect will reveal disordinal age-by-treatment interactions.

COGNITIVE CHANGES ASSOCIATED WITH AGING

Multiple cognitive declines commonly associated with aging are well-documented. The extent of these declines varies widely from person to person, but research indicates that age-associated deficits tend to be evident by the age of 65 (e.g., Kim, Hasher, & Zacks, 2007). That there are significant variations in cognitive and motivational processes within the older adult population is also worth noting (e.g., a 65-year-old individual compared to a 95-year-old individual). Those classified as "young-old" typically are between the ages of 55 and 75 and those classified as "old-old" are 75 years and beyond (Backman, Small, Wahlin, & Larsson, 2000; Echt, Morrell, & Park, 1998). These age group distinctions have implications for technology-based instructional performance. For example, Echt et al. (1998) found that when trained on basic computer skills young-old adults made fewer performance errors, needed less assistance, and took less time for training compared to old-old adults.

As a broader framework for understanding age-related cognitive changes, consider the fluid intelligence–crystallized intelligence distinction. Although there is some evidence to suggest a positive or stable relationship between age and crystallized intelligence (i.e., learned and practiced knowledge), research also suggests a negative relationship between age and fluid intelligence (i.e., the ability to think critically and solve novel problems; Horn & Cattell, 1967; Salthouse, 1996; Schaie, 1996). The following cognitive deficits can be considered different manifestations of the decline in fluid intelligence.

Slowing of Cognitive Processes

One of the most well-accepted and well-researched age-related cognitive declines is a general slowing of cognitive processes. Salthouse (2003) aggregated data across several studies in his laboratory and reported a correlation of $-.47$ between age and cognitive speed tasks. Studies also show that older adults have significantly slower reaction times (e.g., Cerella, 1990).

Importantly, processing speed has been hypothesized to be a potent mediator linking chronological age to declines in cognitive performance (Salthouse, 1996). One meta-analysis reported a mean correlation of $-.52$ between aging and speed of processing, and a correlation of $.35$ between speed of processing and a latent variable representing fluid intelligence (Verhaeghen & Salthouse, 1997). Notably, the relationship between age and fluid intelligence was mediated by speed. Research suggests that reduced cognitive speed explains not only reductions in fluid intelligence, but also other age-related cognitive declines, such as the diminution of working memory (WM) capacity. Specifically, Salthouse (1996) posited that slowing limits individuals' ability to perform mental functions in WM because products of early mental operations decay before they can be properly associated with the products of later mental operations.

Reduced Working Memory Capacity

Research also reveals a robust and reliable decline in working memory capacity across the adult lifespan, beginning in the 20s (Bopp & Verhaeghen, 2005; Park, Lautenschlager, Hedden, Davidson, Smith, & Smith, 2002; Park & Payer, 2006). *Working memory* refers to "a system for the temporary maintenance and manipulation of information, necessary for the performance of such complex cognitive activities as comprehension, learning, and reasoning" (Baddeley, 1992: 281). Working memory is one of the fundamental components of cognitive functioning and is associated with performance on a broad range of cognitive tasks involving memory, reasoning, judgment, and following directions (Park & Payer, 2006). Working memory is also associated with higher order cognitive processes, such as the control of complex cognition, monitoring and regulating performance, and goal-directed behavior (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

Because of the importance of working memory capacity to cognitive performance, this decline can have important implications for older adults' trainability and learning. For example, research demonstrates that reduced working memory capacity explains, at least partially, the negative relationship between age and skill acquisition (Kennedy, Partridge, & Raz, 2008) as well as the negative relationship between age and search task performance (Sharit, Hernández, Czaja, & Pirolli, 2008). Furthermore, Head, Raz, Gunning-Dixon, Williamson, and Acker (2002) found evidence that age and working memory capacity were negatively related to performance at early, but not later, stages of skill acquisition. These findings suggest that older adults will likely have a more difficult time learning completely novel material (material is more novel at early stages of learning) than material with which they are already somewhat familiar.

Two theories in educational psychology—cognitive load theory (CLT) and cognitive theory of multimedia learning (CTML)—are relevant here because they are based on the notion that humans have a cognitive architecture of limited capacity. They also provide a bridge between basic research and theory-based design of learning environments. Although not specifically developed as theories of aging, both CLT and CTML have empirical support and practical implications for use of TBI with older learners. According to CLT, humans have limited working memory capacity and care must be taken to ensure that the brain is not overloaded during learning (Sweller et al., 1998; Merriënboer & Sweller, 2005). In brief, CLT proposes that load on WM can be due to both intrinsic factors (e.g., content difficulty) and extraneous factors (e.g., the TBI interface). For present purposes, the key point is that learners' working memory may be overtaxed by factors both related and unrelated to the training content.

Cognitive theory of multimedia learning is closely related to CLT, but it is the basis of principles specifically applicable to technology-based-multimedia learning environments. Cognitive theory of multimedia learning considers the role of WM in filtering new information given multiple sensory processes (e.g., listening to a speaker while viewing slides). Accordingly, CTML places greater emphasis on the attentional aspects of learning (Mayer, 2001; Mayer, 2005). Again, this theory is relevant to the design of instructional systems, as it addresses the problems that may arise

when content and delivery demands overwhelm available working memory.

Reduced Cognitive Control Processes

Older adults also show declines in executive functions that control attention and direct information processing. Executive functions encompass a wide variety of cognitive processes including planning, WM, coordination and integration of information, task switching, inhibition, and metacognition (Fisk & Sharp, 2004). Neuroscientific studies show that declines in executive functioning are related to deterioration in the prefrontal cortex (West, 1996).

Reduced Ability to Coordinate and Integrate Information

Aging is associated with a diminished ability to coordinate and integrate different sources of information (Mayr & Kliegl, 1993). This deficit is especially pronounced in tasks that require simultaneous retention and processing of information, such as reasoning and complex spatial processing (Mayr & Kliegl, 1993; Mayr, Kliegl, & Krampe, 1996). The inability to efficiently coordinate and integrate information is likely responsible for the "complexity effect." The complexity effect posits that greater task complexity is associated with a greater performance gap between younger and older adults (Oberauer & Kliegl, 2001).

Reduced Latent Inhibition

Another age-related decline is the decreased ability of older adults to maintain focus on task-relevant information (Connelly, Hasher, & Zacks, 1991; Hasher & Zacks, 1988). For instance, when Connelly et al. (1991) gave both older and younger adults passages to read and asked them to ignore all irrelevant text, both older and younger adults showed decreased reading speed and comprehension. However, older adults were more negatively affected by these distractions than were their younger counterparts (Connelly et al., 1991).

Decline in Metacognition

Another deficit commonly associated with aging concerns metacognition, the awareness and self-monitoring of cognitive processes to facilitate the encoding and retrieval of new information (Hertzog & Dunlosky, 2004). Metacognition is an important

factor in understanding learning and performance deficits in older adults; older adults show decline in their use of metacognitive skills, and this decline is associated with poorer performance on learning and skill acquisition tasks (Dunlosky & Hertzog, 2001).

Metacognition involves the mechanisms by which people reflect on their cognitive processes (monitoring), and use this information to regulate information processing and behavior (control; Koriati, 2007). Although the reason is unknown, there is convincing evidence that older adults are less likely to self-initiate metacognitive strategies compared to younger adults, even when they are capable of utilizing these strategies and when strategy use would result in increased performance (Touron & Hertzog, 2004).

In summary, cognitive aging is associated with reductions in cognitive processing speed, working memory capacity, coordination and integration of information, latent inhibition, and metacognitive activity. These executive functions are critical for the cognitive tasks that normally take place during technology-based instructional programs.

RECOMMENDATIONS FOR TECHNOLOGY-BASED INSTRUCTIONAL DESIGN

The following recommendations are oriented toward helping older learners master training content in TBI given the above challenges. Although these recommendations may be beneficial for all learners, we see these elements as particularly relevant to older learners because they accommodate important cognitive and emotional age-related changes. These types of ordinal interactions are crucial for planning cost-effective training programs. Recommendations for instructional design based on age-related cognitive decrements are summarized in Table 1.

Create a Highly Structured Learning Environment

Research demonstrates that low aptitude trainees require significantly more structure in their learning experience compared to high ability trainees (Snow, 1989; Snow & Lohman, 1984). Indeed, there is evidence that older adults (who tend to experience cognitive deficits) structure information less spontaneously compared to their younger counterparts and show learning benefits when the organization of information is facilitated (Sauz on, Claverie, & N'Kaoua, 2006; Witte, Freund, & Seby, 1990). To

create a highly structured learning environment, researchers recommend clearly defining learning objectives, breaking down training content into smaller, meaningful units, and directing learners' attention to core material (Crow, 2002; Mayhorn, Stronge, McLaughlin, & Rogers, 2004; Snow, 1989). These instructional objectives can be accomplished by highlighting crucial information and eliminating interesting but unnecessary components embedded in the program. Particularly in a learner-centric instructional environment in which the user directs the learning experience, it is critical that designers: (1) distinguish areas on a training website, where the user has and hasn't visited, (2) demonstrate how to optimally navigate through the training program (perhaps through a video tutorial), and (3) make learners aware of the types of decisions they will need to make throughout the training (Brown & Ford, 2002). Adaptive technologies (i.e., technologies designed to accommodate users' cognitive and psychomotor deficits and to optimize older adults' work experience) can also be used to integrate greater structure into training programs. Examples include reminder systems and personal organizers, programs that send reminders and that articulate, in a step-by-step manner, how to complete complex activities (Ability-Hub, 2003; National Research Council, 2004).

Another method of imposing structure in TBI is to utilize an advance organizer (AO). Advance organizers are introductory organizing frameworks (e.g., outlines, concept maps) for subsequent training content (Mayer, 1979; Preiss & Gayle, 2006), and they can be incorporated into virtually any type of TBI method (e.g., interactive videos, intelligent tutoring systems, computer-based simulations, etc.). Advance organizers provide an existing knowledge structure that helps learners effectively select, organize, and integrate training content into memory (Mayer, 1979). Meta-analyses indicate that, overall, they tend to promote meaningful learning (Luiten, Ames, & Ackerson, 1980; Stone, 1983). Furthermore, because AOs are purported to compensate for age-related decrements such as reduced working memory capacity and cognitive speed, AOs should be especially helpful for older adults. Advance organizers can capitalize on older adults' preserved crystallized intelligence by creating connections between new information and already-learned information. Several studies have found other interventions that provide struc-

TABLE 1
TBI Design Recommendations

Recommendation	Explanation
Create highly structured learning environment	<p>Clearly define learning objectives</p> <p>Break down training content into distinct, meaningful units</p> <p>Direct learners' attention to crucial information</p> <p>Eliminate interesting but unnecessary components of the program</p> <p>Demonstrate optimum navigation through training program</p> <p>Make learners aware of type of decisions to be made</p> <p>Use reminders and personal organizers</p> <p>Use advance organizers (i.e., organizing frameworks for training material presented prior to instruction)</p>
Utilize principles derived from CLT and CTML	<p>CLT and CTML are instructional design theories based on the notion that individuals have limited mental-processing capacity. Principles derived from these theories are designed to efficiently use learners' mental resources, e.g.:</p> <p>Worked example effect (individuals learn more effectively when they are presented with an example problem along with the solution steps and final answer to problem)</p> <p>Segmentation effect (learners should be able to self-pace through instruction)</p> <p>Coherence effect (individuals learn more deeply when information not directly relevant to the learning goal is removed from instruction)</p>
Customize training program in terms of feedback and adaptive guidance	<p>Correct errors as soon as possible</p> <p>Provide specific feedback not only about past performance but also future-oriented information</p> <p>Advise learners about what content to focus on and how to effectively sequence their study and practice as they move forward in their training</p>
Encourage use of metacognitive and cognitive strategies	<p>Inform learners of cognitive (organization, elaboration) and metacognitive (monitoring, self-regulation) strategies they could use to facilitate learning, e.g., paraphrasing information, creating and answering questions about the learning material, and transferring strategies from analogous problems</p> <p>Periodically prompt learners with questions such as "which main points have you already understood?" and "which examples can you think of that confirm or conflict with the learning content?"</p>
Design user interface to be simple and consistent throughout course	<p>Use easy-to-read font types, large type size, and accentuate the contrast between font and background</p> <p>Adjust control panel settings (e.g., slow down the double click speed requirement); use trackball rather than mouse</p> <p>Incorporate technologies to accommodate severe visual or psychomotor impairment, e.g., screen reading software that reads out information presented on screen; eye gaze systems, which allow learners to operate technologies using eye movements</p> <p>Give learners ability to customize appearance of screen</p> <p>Incorporate adaptive interfaces that change according to computer behavior of user</p> <p>Eliminate pull-down menus; present uniform tool bar across all content pages with images of each command</p> <p>Maintain uniform interface across content pages</p>

(continued)

TABLE 1
(continued)

Recommendation	Explanation
Implement policies and processes on <i>organizational, social, and psychological</i> levels that bolster older adults' motivation and self-efficacy for learning and performance	Implement age bias policies Encourage supervisors to talk positively about instruction Clarify the role of TBI in terms of its impact on organizational objectives Communicate confidence in abilities and skills of older workers Lighten employee workload prior to training Emphasize older adults' strengths, such as experience and relevant knowledge Integrate emotionally salient motivators into training process by emphasizing to older learners that through training, they will be better able to help others and guide younger employees
Ensure help resources are readily available	Integrate help menus into instruction Appoint supervisors or coworkers to provide assistance Encourage trainees to customize and personalize their on-line training experience by consulting outside sources such as family or business leaders

Note. TBI = technology-based instruction; CLT = cognitive load theory; CTML = cognitive theory of multimedia learning.

ture to text information helpful for older learners (e.g., Noh, Shake Parsi, Joncich, Morrow, & Stine-Morrow, 2007; Soederberg Miller, 2009).

Mayer (1979) proposed that AOs should be presented under the following conditions in order to be maximally effective: (1) training content should be unfamiliar to the learner, (2) tests should measure broader learning outcomes, such as transfer and long-term retention, (3) prior to learning, contextual knowledge conveyed by the advance organizer should be well-integrated into trainees' long-term memory, (4) the AO must be designed in such a way that it is actively used during the learning process. In TBI, it is important that the AO is designed to adhere to these conditions in order to optimize its effectiveness for older adults. Thompson (1997) found that when AOs became a prominent part of instructional design and users were informed of their importance to the learning process, the performance gap between older and younger adults diminished. Furthermore, Wolfson and Kraiger (2012) found that AOs, when used in accordance with the aforementioned conditions in a TBI environment, significantly improved older adults' ability to generate creative solutions to applied problems.

Utilize Principles Derived from CLT and CTML

Another set of strategies for providing structure are drawn directly from principles proposed by CLT and CTML scholars. To date, only a few of these principles have been tested on older adults; however, ev-

idence suggests that they facilitate learning with this age group. For example, the *worked example effect* is the notion that individuals learn more effectively when they are presented with an example problem along with the solution steps and the final answer to the problem. According to CLT, this method is superior to conventional practice problems in which learners solve problems on their own. Van Gerven, Paas, Van Merriënboer, and Schmidt (2002) found that worked examples were significantly more beneficial for older learners compared to younger learners, presumably because they accommodate age-related cognitive deficits such as reduced WM. Worked examples impose less load on learners by reducing the need to constantly monitor their progress toward the goal of the problem. We see the worked example principle as particularly applicable in instructor-centric TBI modes (where an expert delivers the training material) or content-centric modes (where learners engages solely with content rather than instructors or fellow learners) rather than learner-centric modes (where learners are given greater freedom to explore, make mistakes, and individualize their learning experience). Other instructional principles that have been found to improve learning outcomes for older adults include the following effects.

Modality Effect

Learning outcomes improve when information is presented in audiovisual form as opposed to in

only one mode. It is assumed that working memory has two separate, independent channels for processing auditory and visual information and, by utilizing both channels, there is a reduced chance of overloading either (Moreno & Mayer, 1999). Van Gerven et al. (2003) and Van Gerven, Paas, Van Merriënboer, and Schmidt (2006) found a main effect of the modality principle on learning outcomes across both older and younger adult samples.

Segmentation Effect

Given that older adults are slower to learn, they should be allowed to self-pace as they proceed through DVDs, interactive videos, web-based learning programs, simulations, and so on. Asynchronous (as opposed to synchronous) collaborative formats are advantageous in this sense, because they give users more time to generate opinions. Research suggests that when older learners can control the amount of time spent on each segment of TBI, their performance improves and age differences in learning performance diminish (Beier & Ackerman, 2005; Callahan, Kiker, & Cross, 2003).

Coherence Effect

Learning outcomes improve when information not directly relevant to the learning goal (e.g., unrelated pictures and videos) is removed from instruction (Mayer, 2005). This principle can be applied across all TBI methods. Kalyuga (2009), for example, argued that simulations should be designed such that they strip away extraneous details that are not critical to the learning objective (a leadership or team simulation concerned with *people* in an organization would be best designed without attention to broader system features such as marketing channels and cost accounting). Wolfson and Kraiger (2012) found that older adults benefited from instructional coherence in learning material presented on the computer.

Customize the Training Program in the Form of Feedback and Adaptive Guidance

Research indicates that compared to younger adults, older adults tend to make more mistakes in completing given tasks with digital devices (Czaja & Sharit, 1993; Laberge & Scialfa, 2005; Sayers, 2004), ask for help more frequently than younger adults during TBI (e.g., Craik, 1986; Zandri & Char-

ness, 1989), don't self-regulate as spontaneously (Touron & Hertzog, 2009), and place lower value on increased choice compared to younger adults (Reed, Mikels, & Simon, 2008). Therefore, it stands to reason that older adults would require greater guidance and feedback with learner-centric TBI. In fact, studies show that older learners' computer performance improves significantly when errors are corrected as soon as possible and when task-specific feedback is provided (Hollis-Sawyer & Sterns, 1999; Morrell & Echt, 1996).

Beyond feedback, however, older trainees may benefit significantly from adaptive guidance. *Adaptive guidance* refers to instruction in which learners are provided with not only feedback about their past performance, but also with future-oriented information (Bell & Kozlowski, 2002). For example, learners would be advised about what content they should focus on and how to effectively sequence their study and practice as they move forward in their training. Research suggests that *guided* TBI tends to produce better learning outcomes compared to TBI that is solely controlled by the learner or solely controlled by the computer program (e.g., Bell, Kanar, Liu, Forman, & Singh, 2006; Bell & Kozlowski, 2002; Santiago & Okey, 1992). Presumably, guided instruction leverages the advantages associated with both user-controlled instruction and program-controlled instruction. Trainees tend not to be reliable judges of what and how to learn (Kraiger & Jerden, 2007; Tennyson & Rothen, 1979), so guided instruction offers them direction while also allowing them a measure of control, which trainees like. Bell and Kozlowski (2002) found that when trainees were given advice or guidance in addition to control, they acquired significantly more knowledge and performed better compared to trainees who received feedback on the same aspects of performance, but did not receive any guidance information. While not specific to older learners, these results suggest that, while feedback is important, guidance contributes above and beyond feedback to improving trainees' learning.

The reduced demands allowed low ability learners in particular to implement advice more effectively. To our knowledge, there has been no research examining the effect of adaptive guidance specifically on older adults' performance in TBI. However, research to date suggests that older learners would benefit from adaptive guidance in a TBI context, particularly in later stages of the learning process.

Encourage the Use of Metacognitive and Cognitive Strategies

As mentioned earlier, one cognitive control process compromised by aging is metacognitive activity. In monitoring and regulating their cognitive processes, learners may employ cognitive strategies such as paraphrasing information, creating and answering questions concerning learning materials, and transferring strategies from analogous problems. These mental operations are intended to help learners elaborate and manipulate information so that it may be more effectively integrated into memory. Thus, one method of increasing metacognition among older adults is to encourage the use of metacognitive strategies.

Research suggests that prompting metacognitive strategies can boost memory performance among older adults. For example, Dunlosky and Hertzog (2001) demonstrated that when older learners were informed of cognitive strategies they could use to facilitate learning, they were more likely to use them and benefit significantly from them. Another method of fostering metacognition is to prompt learners with questions such as, "Which examples can you think of that illustrate, confirm, or conflict with the learning content?" and, "Which main points have you already understood well?" (Berthold, Nuckles & Renkl, 2007; Sitzmann, Bell, Kraiger, & Kanar, 2009; Sitzmann & Ely, 2010). Although they were not studying older adults, Berthold et al. (2007) found that subjects who were exposed to these metacognitive prompts outperformed subjects in the control condition. Similarly, Sitzmann et al. (2009) found that periodic prompts in an on-line training program improved learning (relative to a control group) for two samples of adult on-line college instructors. In order to foster greater learning among older adults in a TBI environment, it would be advantageous to have these questions posed at strategic points during instruction (e.g., after each module, as particularly difficult concepts are introduced, or at critical decision points of computer simulations).

Design the User Interface to Be Simple and Consistent Throughout the Course

Another important implication of CLT is that cognitive resources devoted to the user interface can interact with available learner resources to diminish net learning. In other words, if the learning area is "messy," or screen prompts to advance

pages or submit work vary across training content, learners may become overloaded and retain less of the relevant content. Thus, it is important that the design of the user interface takes into consideration age-related cognitive, psychomotor, and sensory declines.

In terms of text appearance, it is recommended that developers use easy-to-read font types (e.g., Helvetica), large type size, and accentuate the contrast between font and background (Bean & Laven, 2003; Charness & Boot, 2009). To accommodate older adults' reduced psychomotor speed, it may also be necessary to adjust control panel settings (e.g., slow down the double click speed requirement) and to use a trackball rather than a mouse, as the former requires users to use less force in performing tasks. On a related note, practitioners are using "adaptive technologies," a broader category of technologies that are geared toward accommodating individuals' deficits or disabilities and improving older adults' work experiences. For example, adaptive technologies intended to accommodate visual impairment include screen enlargement software and screen reading software that reads out information presented on screen, such as text and graphic icons. Technologies designed to compensate for psychomotor impairment include speech recognition systems, which allow learners to navigate through sites and input information by speaking aloud rather than using a mouse or keyboard, and eye gaze systems, which allow learners to operate technologies using simply their eye movements. Some adaptive technologies have monitoring capability—based on these data, the interface can further morph to suit the cognitive, motivational, and psychomotor profile of the individual user (AbilityHub, 2003; National Research Council, 2004). These kinds of intelligent interfaces are likely to be more beneficial to older adults because their age-induced deficits are supported and they can smoothly proceed through the program without having their attention drawn from core learning material. Furthermore, older adults should be able to manually adjust and customize the appearance of the screen and the audio settings to suit their perceptual needs. Adjustments include resizing windows, changing the colors on the screen, and altering the size of graphics (American Library Association, 2004; Moseley & Dessinger, 2007).

Other cognitive constraints should be taken into account in interface design. Jones and Bayen (1998) noted that, because older adults tend to have dif-

difficulty remembering the source of acquired knowledge, they may not be able to remember where particular commands are located in menu systems. One solution to this issue is to eliminate pull-down menus and instead, to present a uniform toolbar across all content pages with images of each command. For example, rather than requiring users to search for the "Save" command under various menu options, users could simply click on an icon along the top of the page labeled "Save." Additionally, to preserve working memory capacity, instructional designers should consider maintaining a uniform interface across content pages (Brown & Ford, 2002), using active as opposed to passive voice, and not requiring trainees to make inferences based on the text.

In summary, we recommend that TBI for older learners should: (1) be highly structured, (2) provide feedback and adaptive guidance, (3) include metacognitive prompts, (4) utilize principles derived from CLT and CTML, and (5) design the user interface to be simple and consistent throughout the course. Arguably, these recommendations are significantly more important for older adults as the training content becomes more novel or difficult. Charness, Kelley, Bosman, and Mottram (2001) found that age-related performance differences were most prominent in computer tasks when users were novices. When intrinsic load is elevated and older adults can no longer rely on crystallized (learned and practiced) knowledge to compensate for reductions in fluid intelligence, it is critical that TBI adheres to known design principles in order to optimally support learning.

MOTIVATIONAL INFLUENCES ON OLDER ADULTS' TRAINING AND TRANSFER PERFORMANCE

Socioemotional Changes

We next we discuss socioemotional changes associated with aging and corresponding contextual features that can be implemented to optimize technology-based instruction (TBI) motivation and transfer performance. A proposed framework by Kanfer and Ackerman (2004) explains the impact of aging on work motivation and is relevant here. Kanfer and Ackerman (2004) delineated four distinct patterns of intraindividual development: loss (i.e., decline in fluid intellectual abilities), growth (i.e., gain in crystallized intelligence), reorganization (i.e., fundamentally different motives for ac-

tion that accompany aging), and exchange (i.e., changes in action tendencies). We discussed aging and its association with changes in fluid and crystallized intelligence above. Below, we highlight some of the age-related changes classified under the "reorganization" and "exchange" categories that have implications for training motivation and transfer.

Reorganization

Socioemotional selectivity theory (Carstensen, 1995) is a well-recognized framework for understanding the shifts in motivation associated with aging. According to the theory, people judge age as time left *until death*, not time *since birth*. According to the theory, younger adults have an expanded time perspective, which leads them to focus on cognitive goals that might be useful immediately or sometime in the future (e.g., acquiring knowledge, career planning and development); whereas, older adults have a limited time perspective, leading them to focus on the short time they have left and pursue emotional goals (e.g., emotional regulation, social interactions with familiar others; Carstensen, Mikels, & Mather, 2006).

Exchange

Exchange refers to changes in action tendencies with aging. Kanfer and Ackerman (2004) reviewed exchange patterns associated with aging by drawing from research in personality, self-concept, affect and emotion, and stage-based development models. Research suggests that older adults tend to demonstrate increased conscientiousness and agreeableness, but decreases in openness to experience and career motivation (McCrae et al., 1999, 2000; Warr, Miles, & Platts, 2001). Furthermore, aging is associated with an increased need to protect one's self-concept; therefore, instructors might expect older employees to avoid challenging TBI situations or to resist fully exploring features and modules of a computer-based training program for fear of making mistakes. Alternately, older employees may seek out opportunities to demonstrate or hone their learned or practiced skills. On the positive side, older adults experience improved emotional management and functioning. Studies specifically show that older adults experience less negative emotion, better emotional regulation, better interpersonal relationships, and less anger and psychopathology compared to their younger coun-

terparts (see Carstensen et al., 2006, for a review). Overall, these findings indicate that we can expect older learners to have unique motivational needs with regard to the design and delivery of TBI.

Older Adults' Attitudes Toward Technology

Research reveals that, as a group, older adults have complex attitudes toward technology. On the one hand, there is evidence of wider use and positive affect toward computers among older adults over time. The Pew Report (2012), for example, found that 53% of American adults ages 65 and older use the Internet or e-mail, and, of those, 70% integrate the Internet into their daily lives. However, there are also older adults who still feel that technology is uninteresting, fear inducing, or a waste of time. Czaja and Lee (2003) and Marquie et al. (2002) showed that older adults experience greater computer anxiety and feel more negative about the effort required to utilize technology. This is often driven by their perception that computers are not relevant to their lives. Moreover, older adults have heightened concerns regarding security and privacy protection (Carpenter & Buday, 2007).

Contextual Influences

Beyond the design of the TBI itself, it is important to keep in mind that contextual factors critically influence older adults' training motivation and transfer performance. As Maurer (2001) pointed out by way of his career learning framework, self-efficacy for development is a significant intermediary variable that should be targeted to increase older learners' training and development motivation. We focus in this paper on contextual variables expected to enhance motivation and transfer for formal technology-based training programs; however, we note that promoting life-long learning (i.e., self-initiated and self-directed education beyond school or formal training programs) requires attention to even broader system features (Kraiger & Wolfson, 2011). For example, to encourage educational experiences that are self-directed and informal in nature, organizations and business schools could focus on (1) fostering a culture where experimentation, flexibility, and learning are valued; (2) embedding customized learning experiences into individuals' daily work; (3) designing a system for tracking and rewarding life-long learning behavior; (4) establishing a knowledge data-

base where information about individuals' areas of expertise can be captured; and (5) selecting individuals into the organizations with a proclivity for continuous learning.

Consideration of Organizational Context

As mentioned earlier, socioemotional selectivity theory posits that adults tend to become less concerned with developing their skills or acquiring knowledge as they age and more concerned with fulfilling emotional goals (Carstensen, 1993). Furthermore, older adults tend to see technology as anxiety provoking and less relevant to their lives (Czaja & Lee, 2003). Accordingly, older adults may need extra encouragement to participate in TBI, to persist through it, and to utilize their new knowledge on the job. It is also worth noting that older adults are likely to occupy positions of seniority in organizations. McCall (2010) argued that leadership development is most facilitative when it involves on-the-job, experience-based learning (e.g., hardships, job assignments) rather than formal training (e.g., workshops, personal growth programs). We might expect then, that older leaders would require technology to provide support for activities in which they are already engaged (e.g., just-in-time web-based learning, e-coaching, learner-centric TBI formats), while older adults lower in the organizational hierarchy may derive greater benefit from more formal TBI programs (e.g., intelligent tutoring systems, interactive video systems).

Maurer (2001) suggested that in order to influence older adults' learning and development decisions, organizational leaders should attend to organizational variables (e.g., subtle and blatant agism), social variables (e.g., attitudes of coworkers and supervisors toward training), psychological variables (e.g., self-efficacy), and physiological variables (e.g., changes in health and cognitive ability). While Maurer proposed these contextual predictors with attention to learning and development decisions in general, arguably, they become even more influential in a TBI context with older workers because older learners experience more apprehension about TBI. While not comparing TBI to traditional training environments directly, Ronen (2010) did indeed find that some of the critical contextual antecedents of TBI transfer were self-efficacy, core self-evaluation, TBI usability, supervisor support, and workload. Additionally, physical location predicted the number of distract-

ing activities in which the trainee engaged, but multitasking did not ultimately influence transfer.

Based on this framework and extant literature, organizational leaders can increase motivation and transfer of TBI by implementing age bias policies, encouraging supervisors talk positively about the instruction, clarifying the role of TBI in terms of its impact on organizational objectives, communicating confidence in the abilities and skills of older workers, rewarding participation in TBI, lightening employee workload prior to TBI participation, and ensuring TBI adheres to research-based design principles (Knowles, 1990; Rouiller & Goldstein, 1993; Tracey, Tannenbaum, & Kavanagh, 1995).

Consideration of Business School Context

The TBI design principles proposed earlier are just as relevant in a business school context as they are in an organizational context. Indeed, older adults have a considerable presence in face-to-face as well as on-line business courses. Cao and Sakchutchawan (2011) accumulated 7 years' worth of demographic data from an MBA program in a comprehensive 4-year university and found that students' ages ranged from 22 to 90 and that older adults were significantly more likely to register for on-line courses. Therefore, this section is intended to provide specific guidance to business school professors facilitating technology-based courses or "blended" courses with both face-to-face and on-line components.

Older students who share the classroom and sometimes compete against younger students may be especially at risk for suffering from the negative effects of stereotype threat (Steele & Aronson, 1995). Instructors can help ameliorate this problem by emphasizing older students' strengths, such as experience and relevant knowledge. Instructors can actually use this opportunity to combat the negative stereotypes of older adults by encouraging interaction between younger and older students, for example, through group projects. Not only will this personal interaction likely help younger students overcome their negative stereotypes of older adults (cf. Allport, 1954), but group-based projects may be more motivating for older students, many of whom care more about relationships than achievement (Carstensen, 1993).

Older adults seek more help during TBI than do younger adults (e.g., Craik, 1986; Zandri & Charney, 1989). This is important in modern class-

rooms, many of which make technology an integral part of the course (Parker & Burnie, 2009). Lectures are often delivered using electronic media such as slide presentations, and course material is often posted on-line. Additionally, collaborative websites and social media such as Twitter and Facebook are used to encourage peer-to-peer and learner-to-instructor interactions. Instructors need to ensure that older adults are comfortable with this technology and make resources available to help them.

Finally, specific training principles can be incorporated into courses to facilitate learning for older adults. Instructors can ensure that multimedia presentations are loud enough and large enough for older learners. They can address slowing of cognitive processes by moving through the lecture at an appropriate pace. Instructors might even consider "flipping the classroom," a technique of the Khan Academy, in which students learn the material on-line at home at their own pace and then practice in the classroom using case studies or problem sets with individualized guidance and feedback from the instructor (Thompson, 2011). Finally, instructors can utilize iClickers to provide immediate feedback to older learners about their mastery of course material.

In a complete virtual-learning environment, these environmental features become less relevant. In fact, we argue that if designed appropriately, on-line formats will provide unique educational opportunities for older learners because they can take their time in learning and utilize different tools (e.g., e-mail, forums, web conferencing, simulations) to enhance their understanding of concepts. To facilitate comfort and ease with the technology-based format, instructors might provide video tutorials that depict how to navigate through the site, require students to generate customized profiles including their personal and career-related goals, and relay their personal contact information to students in case urgent issues arise. Because the instructor's presence is less apparent in an on-line setting, instructors should also encourage students to consult their classmates or outside sources such as family members or business leaders. These face-to-face interactions are a way to supplement on-line learning and allow learners to further customize and personalize their business school experience. This "blended" learning approach tends to produce more positive affective and cognitive outcomes among learners com-

pared to either face-to-face or pure e-learning (e.g., Howard & Wellins, 2008; Brandon Hall Research, 2007).

RECOMMENDATIONS FOR FUTURE RESEARCH

Although our practical recommendations are designed to aid older learners, we recognize that there is still much unknown about the relative effects on them of different instructional principles. Toward that end, we present below several areas worthy of further exploration that we expect to produce crossover (disordinal) age-by-treatment interactions, thus contributing to theory.

Incentives and TBI

There is a paucity of research examining strategies for enhancing older workers' motivation to participate in training (Charness & Czaja, 2006) and this is perhaps one important area where we might find age-specific differences.

With regard to psychological variables, Maurer and colleagues have focused mainly on self-efficacy and expectancy (Maurer, 2001; Maurer, Weiss, & Barbeite, 2003). We agree these are important psychological variables to investigate when looking at why older adults decide to participate in training (or not). This research has looked principally at self-efficacy at learning, but given our understanding of socioemotive differences between younger and older learners, it may be useful to look at other types of specific self-efficacy, such as self-efficacy for emotional control or self-efficacy for maintaining meaningful relationships. For example, McAdams, Aubin, and Logan (1993) found that generativity motives emerge only in midlife and are a primary source of feelings of accomplishment. *Generativity motives* refer to older individuals' desire to help others and provide support and guidance to younger generations. It is worth examining older workers' perceptions of training as an avenue to satisfy their career needs, but also an avenue to satisfy their socioemotional needs. Ultimately, we might find training programs designed for older adults should emphasize possible emotional outcomes of training, such as being better able to help coworkers or fellow MBA students, while training programs designed for younger adults should emphasize knowledge-related outcomes of training and opportunities for career development.

Within the training itself, reward structures may need to be designed differently based on learners' age groups. Research suggests that older adults tend to experience negative affect less frequently (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000) and positive affect as often (Carstensen et al., 2000) or more frequently (Mroczek & Kolarz, 1998) than do young adults. This may explain why older adults are more forgiving of negative computer experiences than are younger adults (Coyne & Nielsen, 2002). Ji, Choi, Lee, Han, Kim, and Lee (2010) posited that while a proper reward system is a critical feature for digital games, it is particularly important in games for older adults. Future researchers might investigate the differential impact of positive rewards (e.g., receiving points or virtual trophies for achieving a certain level of mastery) versus negative feedback across age groups. Of course, if an age by reward structure interaction does emerge, this is not to suggest that practitioners should design unique reward structures for older and younger adults within the same program or organization. Younger adults might perceive the situation as unfair if older adults were incentivized differently from them. Rather, practitioners might choose a particular reward structure based on the predominant age groups of trainees.

On-Line Collaboration

Research suggests that collaboration promotes positive learning outcomes in face-to-face as well as TBI contexts. For example, technology-mediated collaboration (TMC) has been shown to facilitate problem solving (e.g., Uribe, Klein, & Sullivan, 2003) and cognitive task performance (Hall, 1997). A meta-analysis of 36 studies by Susman (1998) revealed that participants in TMC conditions experienced greater increases in elaboration, higher order thinking, metacognitive processes, and divergent thinking than did participants in individual TBI. Most of these studies, however, have been conducted with K-12 students or college-age participants (e.g., Hall, 1997; Susman, 1998; Uribe et al., 2003). Furthermore, there is reason to believe that regardless of format (synchronous on-line chat, asynchronous forums such as discussion boards or e-mail, video chat), on-line collaboration may be less appealing and effective for older adults.

Technology-mediated collaboration might exacerbate age-related declines, for example, working memory (WM) capacity and reduced cognitive speed. Compared to learners in an individual TBI

session, collaborating with others requires learners to hold more information in memory. This could be overwhelming, particularly for older adults with reduced WM capacity or reduced cognitive speed. In a social training environment, individuals have limited control over the discussion pace and may not be able to effectively construct knowledge structures around the training material. Synchronous chat rooms are likely to be particularly detrimental to learning for older adults because conversations in a chat room may be more disjointed compared to free-flowing face-to-face conversations. Older adults have particular difficulty integrating and coordinating information, and therefore, might struggle in a chat room. We encourage future research to explore the influence of various technology-mediated forms of collaboration on learning outcomes of older and younger adults.

Procedural Versus Conceptual Training

There is some research to suggest that older adults require step-by-step procedural training compared to younger adults, who may require more conceptual model-based training (e.g., Carter & Beier, 2010). Caplan and Schooler (1990) found that older adults performed significantly worse than younger adults after they were presented with an analogical model of a software program. Furthermore, Mitchell, Brown, and Murphy (1990) found that procedural training was more beneficial to training performance compared to concept training and that this effect was more pronounced for older adults. For more examples, see Mead and Fisk (1998); Meade and colleagues (1997), and Morrell, Park, Mayhorn, and Echt (1995).

There are multiple theoretical explanations for why procedural training may be more beneficial to older adults than conceptual model-based training. Cognitive load theory (CLT) would posit that conceptual training poses too much germane load on older adults. Caplan and Schooler (1990) reasoned that, compared to younger adults, older adults have inferior processing capacity to elaborate, organize, and extract rules from conceptual models. We need more research in this area to confirm if this is a consistent finding, under what circumstances this age by training intervention interaction (concept vs. action) occurs, and for which learning outcome measures.

Technology-Based Information Resources

Organizations are increasingly using knowledge management techniques in which information about what and how to perform tasks is mined, stored, and then disseminated on demand to workers, delivering just-in-time training. Knowledge management is distinct from TBI in that instruction is usually a dynamic process where information is intentionally conveyed to learners; whereas, information stored in knowledge management systems is largely static—that is, the information is usually controlled by a set of experts and offered as a relatively fixed system through which learners can access content (Brown, Charlier, & Pierotti, 2012). Due to the differences in these information systems, research is needed to find out if, and to what extent, effective design principles for TBI transfer to knowledge management systems.

Exploring New Methodologies for TBI Development

Moving forward, researchers and instructional designers might focus on using more innovative approaches to determining how older learners interact with and respond to various TBI manipulations. For example, researchers might conduct cognitive task analyses (via interviews, verbal report, or diagramming methods; Chipman, Schraagen, & Shalim, 2000) to model cognitive processes involved in TBI. This can ultimately give us insight into how older and younger adults approach training tasks and how they might learn best. Another potential avenue is to use eye-tracking methodologies or neurocognitive measurements from EEGs or MRIs to determine how the brain responds to different instructional manipulations. If different parts of the brain are activated across age groups, this may indicate that older and younger adults have different mechanisms for learning, and that age-specific instruction is necessary.

Roos, Dickinson, Goodman, Mival, Syme, and Tiwari (2003) of the Usable Technology for Older People: Inclusive and Appropriate (UTOPIA) project introduced the concept of mutual inspiration in TBI design. According to this approach, TBI development is a collaborative, formative evaluation process between the older learner and the instructional designer. Both parties aim to gain common ground and understanding through asking each other questions and observing how the other interacts with technology and makes decisions regard-

ing learning. This approach to TBI development is unique in that both parties have relatively equal say in the design process. The hope is that mutual involvement in technology development from start to finish will spark innovation and products that are optimally suited to older users. This is a relatively new methodology and future research is needed to affirm its value.

Another potentially fruitful avenue is to investigate the more proximal predictors of age effects in technology-based instruction. We know that older adults tend to have cognitive and motivational processes that are distinct from younger adults, but what kinds of changes are accounting for most of the learning difference in TBI settings? It may be useful to segment older adults into smaller groups (old-old vs. young-old; psychological age, personality, computer experience) to determine the relative importance of age-related variables in computer-assisted learning. By gaining insight into this question, practitioners and researchers can better understand and accommodate the technology needs of older adults.

CONCLUSION

We have outlined several important instructional design and contextual considerations for delivering technology-based instruction to older adults in an organizational and business school setting. Older adults experience a series of psychological, cognitive, and psychomotor changes, which must be attended to in training design. As discussed here, older adults should be given technology-based instruction that (1) is highly structured, (2) provides feedback and adaptive guidance, (3) includes metacognitive prompts, (4) incorporates principles derived from cognitive load theory and cognitive theory of multimedia learning, and (5) includes a user interface that is simple and consistent throughout the course. Furthermore, effort should be expended toward creating contextual conditions that improve self-efficacy and training motivation among older employees and MBA students. As we mentioned, further research should be conducted to determine if there is a need for age-specific instructional formats and if so, to determine what instructional principles are helpful for which age group, under what conditions, and why.

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