DISSERTATION

SHEDDING LIGHT ON GREY AREAS: EXAMINING THE EFFECT OF TECHNOLOGY-BASED COLLABORATION ON THE LEARNING OUTCOMES OF OLDER AND YOUNGER ADULTS

Submitted by

Natalie E. Wolfson

Department of Psychology

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Colorado State University

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Doctoral Committee:

Advisor: Kurt Kraiger

Margaret Beier
Matthew Rhodes
Manfred Diehl

ABSTRACT

SHEDDING LIGHT ON GREY AREAS: EXAMINING THE EFFECT OF TECHNOLOGY-BASED COLLABORATION ON LEARNING OUTCOMES OF OLDER AND YOUNGER ADULTS

Given the emergent aging workforce and the rapid rise of technology-based training tools in organizational settings, I designed two studies to gain greater insight into whether or not older learners require computer-based instructional designs that are different from younger adults. Specifically, I conducted two studies to examine the effect of technology-based collaboration on older and younger adults' learning outcomes.

In Study 1, older and younger participants completed an online audiovisual training and reviewed training concepts either individually or in a chatroom context with other trainees. Results indicated that, across conditions, older adults performed worse on learning outcomes compared to younger adults and that older adults had a more negative perception of their chatroom experience compared to their younger counterparts.

In Study 2, I strengthened the collaborative learning manipulation, re-assessed the relationship between online collaboration and learning across age groups, and investigated turn-taking as a method of facilitating performance during the chatroom discussion. The two main findings for Study 2 were the following: 1) Age and instructional design condition (individual vs. collaboration) interacted to predict transfer performance. Quite surprisingly, younger adults performed similarly in the individual and collaborative conditions while older adults improved their performance in the collaborative condition compared to the individual condition. In effect, collaboration eliminated the performance gap that existed between older and younger adults in the individual condition. 2) Within the collaboration groups, those who engaged in a turn-taking protocol did slightly worse in terms of recall performance compared to those in the free-for-all collaboration condition. These findings speak to the need for age-specific instructional design and suggest that turn-taking might not be a strategy for boosting learning in a chatroom setting.

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INTRODUCTION

It is well-established that the workforce is aging. Because of diminishing savings, extended life spans, or simply a continued desire to maintain a social, stimulating, and structured lifestyle, more and more older individuals are staying in the workplace (Mitchell, Utkus, & Yang, 2005; Pew & Van Hemel, 2004). Cauchon (2010) recently noted that never in history have we seen such a large percentage of Americans age 55 and over continuing to stay employed. Older workers are less likely to voluntarily leave their organizations (Ng & Feldman, 2009), though the reasons for this are varied. The Bureau of Labor Statistics (2012) estimated that almost a third of Americans between the ages of 65 and 70 are employed, and even among those who are 75 years old or older, 7 percent are employed. Avery, McKay, and Wilson (2007) projected that by 2015, those aged 55 and over would comprise approximately 20% of the American workforce and Toossi (2009) estimated that by 2018, these individuals would constitute 25% of the workforce. Additionally, the Bureau of Labor Statistics (2005) predicted that the labor force participation rate for those aged 65 and over would increase to 19.7% by 2014.

We are also witnessing a rapid integration of technology-based training tools into organizational settings. For example, according to the American Society of Training and Development (ASTD) *State of the Industry Report*, 38.5% of all learning hours were delivered via technology-based methods in 2011 (up from 25.6% in 2004). Similarly, BEST organizations, those recognized by ASTD for their efforts to leverage learning in order to attain business results, delivered 49.9% of their formal learning hours via technology (up from 34.3% in 2004; Miller, 2012). ASTD authors predicted that, as the economy steadies, the use of these technology-based methods will continue to rise (Green & McGill, 2011). These technology-based training tools vary widely in terms of their level of sophistication, ranging from interactive video to web-based training to collaborative technologies to intelligent tutoring systems and simulations (Bell & Kozlowski, 2007; Pulichino, 2004). In the words of Brown and Ford (2002): "Computer-based training is the future – and the future has arrived." With these two emergent trends, a question arises of whether older adults require age-specific computer-based instruction or whether general design principles apply to people of all ages with relatively equal effectiveness. The purpose of this study is to gain greater insight into this question by examining the effect of different instructional design manipulations on the learning outcomes of older and younger adults.[1]

There are two perspectives on the need for age-specific technology-based instructional design. One is offered by Van Gerven, Paas, and Tabbers (2006), who proposed that general, age-independent principles would be effective for all adults and such principles would be *particularly* effective for *older adults* because older adults have more room for improvement and because these principles counteract age-related cognitive deficits. In other words, there is no need for age-specific instruction (one size fits all). One such principle is the use of worked examples as opposed to traditional practice problems (Paas, 1992; Ward & Sweller, 1990). With a worked example, learners are given a step-by-step model of how to solve a well-structured problem. Worked examples are presumably more effective than practice problems because they conserve working memory (WM) capacity by not requiring learners to compare their current state to the problem goal state. Other principles include the coherence effect (i.e., learning is enhanced when information not directly relevant to the learning goal is removed from instruction) and the segmentation principle (i.e., people learn best when they can self-pace).

[1] This paper focuses on needs of older adults in terms of training design. However, these findings should be considered within a much broader framework of training processes. For a review of how aging-related issues are implicated in training needs assessment, design, and implementation, see Beier. Teachout, and Cox (2012).

An alternative perspective suggests that there is a need for *unique* computerized instructional approaches for older adults; this view is rooted in theories such as resource allocation theory (Kanfer & Ackerman, 1989) and aptitude-treatment interactions (Cronbach & Snow, 1977). For example, Cronbach and Snow's conceptualization of aptitude-treatment interaction suggests that to optimize instructional outcomes, learning environments should differ depending on the ability level of learners. Accordingly, if there are differences in abilities between older and younger learners (e.g., WM), these differences should be reflected in different instructional methods. In support of this perspective, recent studies show that certain instructional principles have significantly different effects on learning outcomes of older and younger adults (e.g., Carter & Beier, 2010; Wolfson & Kraiger, 2012).

The purpose of this study is to gain greater insight into whether or not age-specific instruction is necessary by comparing the effect of computer-supported synchronous collaboration on the learning outcomes of older and younger adults. Synchronous collaboration is distinct from asynchronous collaboration in the sense that synchronous e-collaboration occurs when learners and instructors meet at the same time in a virtual learning environment. In contrast, asynchronous e-collaboration (e.g., email exchanges, threaded discussions, audiovisual presentations) entails that learners do not have a pre-determined learning time and can usually self-pace through instruction. Synchronous training tools such as broadcasted lectures, video conferences, and webinars have become the most rapidly-growing technology-based training delivery method. West, Donovan, Benedicks, and Carmody (2010) surveyed learning professionals across a wide variety of organizations and found that approximately 27% of corporate courses included synchronous training formats. Moreover, 33% of respondents reported an increase in the number of synchronous courses between 2008 and 2009 and 37% of respondents projected that this growth rate would persist between 2009 and 2010. The growing demand for synchronous training tools is primarily due to their declining cost and increased user friendliness (Koller, Harvey, & Magnotta, 2005; West et al., 2010).

There is a considerable amount of theoretical and empirical support for the use of synchronous collaborative tools. Broadly, social constructivist theories, computer-based instructional models, and educational theories all suggest that collaboration should be fostered in computer-based training contexts to enhance learning. However, if age-specific instructional design views are correct, it could be that collaboration is only beneficial for younger learners. In the present research, participants were asked to discuss concepts covered in training in a chatroom setting; it is expected that this form of technology-mediated collaboration will facilitate or sustain levels of learning for younger adults but will hinder learning for older adults. Such findings would bolster the argument for age-specific instructional design. A disordinal interaction between age and instructional principle, though rarely found in the literature, would suggest that older learners and younger learners have opposite responses to the same instructional principle and thus, that training should be designed differently for individuals depending on their age group. This type of interaction may inform theory by helping us understand how age-related cognitive change influences information processing. An ordinal interaction would potentially inform decisions about how organizations allocate resources to different training formats.

I will begin by describing the influence of aging on cognitive and motivational processes and proceed to discuss research related to face-to-face and technology-supported collaboration. I then introduce Study 1, the intent of which was to determine whether chatroom-based environments differentially affect learning outcomes for older and younger adults. It is expected that a chatroom-based social learning environment will exacerbate age-related cognitive and socio-emotional deficits and widen the performance gap between older and younger adults compared to the individual learning condition. However, in Study 2, it is expected that a turn-taking protocol will compensate for the added challenges of chatroom-based learning and significantly reduce the age-related performance gap.

Influence of Aging on Cognitive and Motivational Processes

Research suggests that age-related cognitive declines are broad and exhibit a general linear decline beginning in early adulthood. Certainly, chronological age is merely a proxy for a series of cognitive, socio-emotional, psychomotor, and physical changes that occur throughout the lifespan (Barak & Schiffman, 1981; Cleveland & Shore, 1992; Mock & Eibach, 2011; Salthouse, Kausler, & Saults, 1990), but various studies converge on the notion that age-related cognitive changes are usually apparent when individuals have reached 50 years of age (Salthouse, 2004). While in my study I use learners over 60 (as is common in cognitive aging research; c.f., Fristoe, Salthouse, & Woodard, 1997; Kim, Hasher, & Zacks, 2007), for the present discussion, the reader should consider 50 as the approximate age at which age-related deficits are evident.

Here, I concentrate on those cognitive and socio-emotional changes that have implications for the design of computer-based training. As a broad framework for understanding the cognitive changes associated with aging, consider the distinction between crystallized intelligence (i.e., learned and practiced knowledge, like vocabulary and grammar) and fluid intelligence (i.e., the ability to adapt to new situations and solve novel problems) (Ackerman & Beier, 2006; Cattell, 1943). Research suggests that while crystallized intelligence is generally preserved or increases up until the age of 70 or so, fluid intelligence tends to deteriorate after young adulthood (Salthouse, 1999; Salthouse, 2004; Schaie, 1996). Cross-sectional studies reveal that, starting at age 20, fluid intelligence begins to steadily decline and continues to do so throughout adulthood (Jones & Conrad, 1933; Salthouse, 2004). Compared to cross-sectional studies, longitudinal designs suggest that cognitive decline begins later and is less steep (Hultsch, Hertzog, Dixon, & Small, 1998; Shaie, 1996). For example, using a principal database of 5,000 participants, researchers in the Seattle Longitudinal Study reported that, while there was some indication of cognitive decrement for some cohorts in their 50s, the average decrement before age 60 was less than two tenths of a standard deviation, but the average decrement by age 81 was one standard deviation for most intellectual abilities. Cross-sectional and longitudinal studies show differences with respect to the onset and magnitude of age-related cognitive declines; however both sets of studies demonstrate this general reduction in fluid abilities across time (Schaie, 1996; 2013). The following categories of age-related cognitive deficits represent different forms of this reduction in fluid intelligence.

Influence of Aging on Cognitive Processes.

Reduced Cognitive Speed

Perhaps the most widely demonstrated cognitive decline associated with aging is the decline in processing speed. As an example, older adults' reaction time is approximately 1.4-2.0 times slower than that of younger adults (e.g., Cerella, 1990). Salthouse (2004) asked participants to classify as quickly as they could various pairs of line patterns as identical or not and found that the correlation between age and speed was -.47. Further, studies indicate that the decline in cognitive speed is largely responsible for the decline in other cognitive abilities such as working memory (Salthouse, 1991, 1993, 1996).

Reduced Executive Functions

Another category of age-related changes is the diminution of executive functions. Executive functions refer to an individual's "higher level" cognitive processes that control attention and regulate thought and behavior by influencing more basic abilities like attention and motor skills. This category of intellectual functioning is necessary for goal-directed behavior, allowing individuals to monitor their progress in relation to goals and make adjustments based on new information or changing circumstances. This broad term encompasses a wide range of cognitive processes including working memory, coordination and integration of information, task-switching, inhibition, and metacognition (e.g., Alvarez & Emory, 2006; Fisk & Sharp, 2004). Neuroscience studies suggest that the decline in executive functioning is associated with deterioration in the prefrontal cortex (Miller & Cohen, 2001; West, 1996).

Reduced working memory capacity. Working memory refers to the temporary short-term storage space where incoming information is maintained and manipulated before it is transferred to a virtually limitless long-term memory. For example, if one is learning a new procedure, WM allows learners to hold the sequence of steps and their relationship with one another in consciousness so the information can be consolidated. Research shows that WM tends to deteriorate gradually across the lifespan, starting in the 20s (Bopp & Verhaeghen, 2005; Park, Lautenschlager, Hedden, Davidson, Smith, & Smith, 2002, Park & Payer, 2006). Aggregating data from 345 participants between the ages of 20 and 92, Park, et al., 2002 revealed that age explained between 24 and 32% of the variance in WM performance (depending on the specific assessment).

Importantly, working memory capacity is involved in higher-order executive functions such as monitoring and goal-oriented behavior, which has implications for learning performance

(Baddley & Hitch, 1974; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). In fact, research suggests that WM is an explanatory factor in the negative relationship between age and skill acquisition (Kennedy, Partridge, & Raz, 2008). Furthermore, Head, Raz, Gunning-Dixon, Williamson, and Acker (2002) found that WM was particularly critical for learning performance at early stages of skill acquisition.

What is more, there is ample theoretical evidence supporting a link between WM capacity and learning performance. For example, cognitive load theory (CLT) (Sweller, 1999; Sweller, Van Merrienboer, & Paas, 1998) and the cognitive theory of multimedia learning (CTML) (Mayer, 2001) are two empirically-supported theories of instructional design based on the notion that individuals have limited WM limited capacity, restricting the rate at which incoming information can be filtered. These theories will be fleshed out in more detail in the introduction to Study 2, but, for now, note that both theories posit that meaningful learning occurs when individuals can effectively select, organize, and integrate information with an existing knowledge structure. Accordingly, if individuals do not have the WM to effectively retain or manipulate incoming information, learning will suffer.

Reduced coordination and integration of information. Older adults have particular difficulty integrating and coordinating information. For example, in tasks that include multiple interrelated steps, older adults are less adept at managing and combining the information exchange between these steps. Thus, they tend to be at a greater disadvantage (compared to younger adults) when performing complex tasks (Oberauer & Kliegl, 2001). Similarly, research suggests that older adults have difficulty binding single units of information together and therefore, construct memories that are less cohesive compared to younger adults (Naveh-Banjamin, 2000). Real-world examples of this deficit include forgetting the name of a person they've met or where they put their office keys. Older adults are also deficient in remembering the source of information. They may remember a piece of information but fail to remember where they heard it or who told them (e.g., Rabinowitz, 1989).

Reduced task-switching ability. Aging is also associated with difficulty alternating between tasks. The Wisconsin Card Sorting Test has served as a principal paradigm for examining task-switching performance. In this test, participants are required to sort cards into piles based on criteria such color, shape, or number. As they sort, they discover the sorting rule as they receive feedback from the tester. After participants correctly sort ten cards, the rule switches and participants have to discover the new sorting rule by inhibiting previous algorithms and reconfiguring a new task state in working memory. With age, participants tend to experience performance decrements in this task (Heaton, Chelune, Talley, Kay, & Curtiss, 1993; Robbins et al., 1998; Rhodes, 2004). For example, Rhodes' meta-analysis revealed robust age-related differences with regard to the number of categories achieved (i.e., the number of rules correctly identified indicated by a certain number of successful sorts) and perseverative errors (i.e., the number of sorts made accordingly to a previous rule that is no longer in operation).

Reduced latent inhibition. Studies consistently show that older adults have a deficiency in screening out irrelevant information, making them more easily distracted than younger adults. For example, Connelly, Hasher, and Zacks (1991) presented older and younger participants with reading material and asked them to ignore all italicized text interspersed throughout. Results indicated that, compared to younger adults, older adults were disproportionately slower in their reading when the text included these distractors. This was especially true when the italicized text was meaningfully related to the main text.

It is worth noting here that there may be a benefit to this reduction in latent inhibition. In an experiment by Biss, Ngo, Hasher, Campbell, and Rowe (2013), older and younger adults were asked to recall a list of test words. Afterwards, all participants completed a task in which certain test words appeared as distractors. Though subjects were told to ignore these words, older adults processed this distracting information and used it to enhance later memory performance. Essentially, older adults' propensity to attend to distracting information may help them overcome their memory limitations.

Reduced metacognition. Metacognition refers to people's awareness of and control over their cognitive processes. More specifically, metacognition refers to a process whereby individuals: 1) monitor their progress toward goals (monitoring), and, based on this information; 2) adjust their behavior and attention to achieve their objectives (control; Flavell, 1979; Koriat, 2007; Nelson, 1996). Importantly, metacognitive activity is linked to improved learning performance and may compensate for cognitive deficiencies (Veenman, Wilhelm & Beishuizen, 2004; Veenman & Spaans, 2005).

While older adults generally have intact monitoring skills, they do not always use their self-knowledge to exert control over their learning (Hertzog & Dunlosky, 2011; Hertzog, Hultsch, Craik, & Salthouse, 2000). For example, older adults are capable of using cognitive strategies such as interactive imagery and rote repetition, and benefit from explicit instruction to do so; however, research suggests that they are less likely to self-initiate them. This data trend is particularly true with free recall and associative memory tasks (Dunlosky & Hertzog, 2001; Kausler, 1994; Zivian & Darjes, 1983; Touron & Hertzog, 2004; Smith, 1980). There is some evidence to suggest that even when participants are informed of strategies, older adults utilize less effective ones than younger adults. Furthermore, they may not spontaneously apply learned strategies in novel contexts (Devolder & Pressley, 1992; Dunlosky, Kubat-Silman, & Hertzog, 2003).

In the following section, I summarize the influence of aging on motivational processes. Like the aforementioned cognitive changes, these motivational changes are potentially important for understanding how older adults will perform in computer-assisted collaborative learning settings.

Influence of Aging on Motivational Processes.

Kanfer and Ackerman (2004) outlined four patterns of age-related changes that have implications for work motivation. These include loss (i.e., decline in fluid intellectual abilities), growth (i.e., gain in crystallized intelligence), reorganization (i.e., fundamentally different motives for action that accompany aging), and exchange (i.e., changes in action tendencies). Earlier in this paper, I discussed aging and its association with changes in fluid and crystallized intelligence. Below I highlight reorganization and exchange, two motivational patterns that are most relevant to performance in technology-based collaborative instruction. I then touch on older adults' specific attitudes and performance related to technology.

Reorganization

Reorganization refers broadly to age-related changes in the organization and structure of personality and motivations. Research suggests that older adults experience shifts in fundamental motives for action and socioemotional selectivity theory represents a critical explanatory model (Kanfer & Ackerman, 2004). Socioemotional selectivity theory (Carstensen, 1995) posits that as individuals age, their goals are reoriented around affect and a limited time perspective. Specifically, their attention shifts from cognitive goals (e.g., acquiring knowledge, fostering new connections that will have future payoffs) to emotionally meaningful goals (e.g., maintaining close relationships with familiar others, regulating emotion). While young adults focus on knowledge-related goals and seek to develop new relationships that will pay off in the future, older adults tend to narrow their social circle, focusing on emotion-related goals and on individuals with whom they are close. For example, in the U.S., younger employees tend to place higher value on learning and promotion opportunities while older employees perceive social relations at work as more important (relative to younger employees) (Loscocco & Kalleberg, 1988). Socio-emotional selectivity theory suggests that younger adults would derive greater benefit from chatroom-based social learning compared to older adults. This is because acquiring knowledge from unfamiliar others aligns more strongly with the motives of younger adults.

Exchange

Exchange refers broadly to age-related changes in motivation, needs, and behavioral tendencies. Importantly, older adults have a greater need to protect their self-concept compared to younger adults (Kanfer & Ackerman, 2004). This is presumably because older adults become more conscious of their declining fluid abilities over time (Ackerman, Beier, & Bowen, 2002). Methods for protecting their self-concept include avoiding activities such as technology-based training that highlight their weaknesses (e.g., fluid intelligence) and seeking out opportunities to demonstrate their relative strengths (e.g. crystallized intelligence). Related to this is the predominant trend in the literature for older adults to use less primary control problem-solving strategies aimed at dealing directly with issues and more secondary control strategies aimed at modifying their emotional and psychological condition (e.g., Folkman, Lazarus, Pimley, & Novacek, 1987; Heckhausen & Schultz, 1995). Because of their need to prove themselves and their heightened fear of revealing deficiencies (Kanfer & Ackerman, 2004), older adults may be more likely to censor themselves and become more guarded in a social learning environment. It is thus reasonable to expect that older adults will be more reticent and consequently reap significantly less benefit from collaborative learning compared to younger adults.

Attitudes and Performance with Technology

The current generation of older adults was not exposed to computers until at a later age and therefore, they may encounter unique challenges when it comes to interacting with technology. Although older adults are aware of the beneficial aspects of using technology and have developed more positive affect and wider use of technology over time (e.g., Mayhorn, Stronge, McLaughlin, & Rogers, 2004; Pew Report, 2012;), there are also indications that older adults still feel less efficacious in their ability to operate computers compared to younger adults. Further, many older adults tend to report that technology is not that interesting, not relevant to them, and a waste of time (Czaja & Lee, 2003; Ellis & Allaire, 1999; Marquié, Jourdan-Boddaert, & Huet, 2002). For example, Czaja and Lee and Marquié et al. showed that older adults experience less computer-related efficacy, less comfort, and feel more negative about the effort required to utilize technology compared to younger adults. This is primarily because older adults tend to believe computers are not relevant to their lives. Additionally, older adults may have concerns that technology impinges on their privacy and security (Carpenter & Buday, 2007; Mitzner et al., 2010).

Presumably because of attitudinal, cognitive, perceptual, and motor-related barriers, older adults are more prone to performance deficiencies when using technology. For example, Charness, Kelley, Bosman, and Mottram (2001) found that older adults used approximately twice as much time as younger adults to learn a word processor, even when they had some prior experience with word processors. Chadwick-Dias, Tedesco, and Tullis (2004) reported an important distinction between Web experience (as measured by frequency of current use, number of years of Web use, number of web-based activities performed) and Web expertise (as measured by an association test in which participants matched a computer-related graphic image, such as an arrow key, with its function). The authors found that, even when Web *experience* was controlled using frequency of use, older adults demonstrated less Web *expertise* compared to their younger counterparts. In other words, assuming that older and younger adults interact with computers with equivalent frequency, older adults still experience significantly more performance issues.

In sum, research on cognitive changes associated with age suggest that older adults experience not only a reduction in cognitive speed, but also a diminution of higher-order executive functions such as working memory, task-switching, and latent inhibition, which may have negative implications for how they learn in a computer-based training context. Research on age-related emotional changes indicates that older adults tend to focus on emotional goals (e.g., interactions with familiar others), engage in behaviors that protect their self-concept, and experience more apprehension about utilizing technology. Likewise, these changes do not bode well for performance in a collaborative computer-based training environment.

Next, I will discuss research related to collaborative learning in face-to-face and technology-mediated environments (irrespective of learner age). While research tends to affirm the importance of social learning, there is reason to believe that there will be age differences in how individuals respond to this instructional design feature.

Collaboration and Learning in Face-to-Face and Technology-Mediated Environments

Learning in Face-to-Face Collaborative Environments

According to Barkley, Cross, and Major (2005), collaborative learning refers to “an approach to learning in which a group of learners seeks to learn something together and in which the group depends on the joint efforts of each member to do so" (pp. 4-5). This collaborative process is distinct from cooperation and competition in the sense that with cooperation, learners typically divide up the labor to accomplish a task and with competition, learners compete against each other to enhance their knowledge and skills (Shute, Lajoie, & Gluck, 2000). Dillenboug (1999) outlined the common features of collaborative interactions. First, collaboration involves relatively symmetrical structure, meaning collaborators participate in the same kinds of activities, they have relatively similar knowledge and status levels, as well as common group goals. Second, collaboration involves interactivity and negotiation. Interactivity refers to the degree to which learners influence one another's thinking and negotiation refers to the degree to which different members can shape the shared understanding. In other words, when there is a high degree of negotiation, no single individual monopolizes discussion or imposes their opinions upon the group. Interactivity and negotiation strongly contribute to the quality of the interaction.

According to Johnson and Johnson (2004), effective collaboration is characterized by: 1) Positive interdependence, 2) promotive interaction, 3) individual accountability, 4) appropriate use of social skills and 5) group processing. Positive interdependence exists when group members perceive that there is value in collaborating and that collaboration bolsters achievement at the group as well as the individual level. Promotive interaction means that group members behave respectfully, challenge one another's ideas, and support one another's learning efforts. Individual accountability is achieved when learners feel compelled to contribute and responsible for their own learning. Social skills are also critical for effective collaboration and include learners' ability to clearly communicate, resolve conflicts, and earn the trust of other members. Finally, group processing refers to group members reflecting upon their team's behavior and interaction patterns and devising methods for improving their performance.

There is ample theoretical support linking collaboration to positive learning outcomes. Social constructivists, for example, argue that learning is a social phenomenon that arises through learners' negotiation of meaning. That is, knowledge emerges when learners collaborate among themselves and with instructors to present their conceptual understandings, resolve conflicts, integrate different points of view, and reach a consensus as to meaning of concepts, relationships, and so forth (Paliscar, 1998, Piaget, 1985; Vygotsky, 1978). One critical mediator is cognitive conflict. Drawing from Piaget's (1932) model of developmental stages, socio-constructivists maintain that when learners become aware of an incongruity between their knowledge structure and the knowledge structure of others, they are forced to explain and justify their positions, ultimately triggering cognitive change (Dillenbourg, 1999; Vygotsky, 1978). There is considerable research to support this perspective. For example, Webb (1991) found an inverted U-shaped relationship between disagreement levels among learners and performance such that moderate levels of disagreement tended to optimize math performance. Other work suggests that elaboration is a crucial mediator in the relationship between collaboration and learning performance. Elaboration is the process whereby learners use "prior knowledge to continuously expand and refine new material based on such processes as organizing, restructuring, interconnecting, integrating new elements of information, identifying relations between them, and relating the new material to the learner's prior knowledge" (Kalyuga, 2009, p. 402). For example, learners might use analogies, provide examples, or relate training information to everyday experiences (van Boxtel, van der Linden, & Kanselaar, 2000). Research suggests that providing elaborated explanations or "self-explanations" scaffolds knowledge, generates more complex mental structures, and ultimately improves individual learning outcomes (Aleven & Koedinger, 2002; Teasley, 1995; Webb, 1989, 1991).

Situated cognition theory (Brown, Collins, & Duguid, 1989) also has relevance to collaborative learning. This theory poses that learning is not something that occurs only inside the mind but is inextricably linked to the social context. The implication of this is that learning is enhanced when groups learn using realistic problems in real-world contexts. Moreover, the whole is more than the sum of its parts, meaning that collaboration allows the co-construction of knowledge and produces different effects at the individual and group level.

Research shows that collaborative interactions facilitate learning by allowing learners to build upon others' responses, receive feedback, and prune errors in their own thinking (Marjanovic, 1999; Ross, Spencer, Blatz, & Restorick, 2008; Shneiderman et al., 1998). Additionally, collaboration as studied has been linked to many key learning behaviors, skills, and attitudes. For example, collaborative learning has been associated with active learning, motivation, persistence with problem-solving tasks, use of alternative learning strategies, metacognition, critical thinking, and transference of learned strategies to other contexts (Alavi, 1994; Duren & Cherrington, 1992; Hidi & Harackiewicz, 2000; Panitz, 2001; Schraw & Moshman, 1995; Thayer-Bacon, 2000; Kulik & Kulik, 1979). Other ancillary social and psychological benefits include the development of social support networks, enhanced cooperation and diversity skills, and higher self-esteem (Panitz, 2001). It should be mentioned that there are potential disadvantages to collaborative learning such as reduced personal responsibility, social contagion of erroneous thinking, collaborative inhibition (Blumenfeld et al.,1991; Roediger, Meade, & Bergman, 2001; Weldon & Bellinger, 1997) and moderators to its effectiveness (e.g., communication skills, ability composition of group, motivation, personality, and task characteristics). Indeed, there is a great deal of variability surrounding the effects of collaboration. However, meta-analyses indicate that, on the whole, small collaborative groups tend to promote greater achievement, learning, and transfer compared to individual learning among young adults (e.g., Johnson & Johnson, 1989; Johnson, Johnson, & Smith, 1991; Lou, Abrami, & d'Apollonia, 2001; Lou et al., 1996).

Learning in Technology-Mediated Collaborative Environments.

While there is conceptual and empirical support for collaborative learning in general, various theories and models within educational psychology, cognitive psychology, and training research support the specific proposition that *technology-mediated* collaboration (TMC) can enhance learning. Kraiger (2008) posited that technology-based instruction (TBI) may be an ideal delivery method for facilitating the social aspects of learning because this medium makes social distinctions less apparent and encourages equal participation among learners (even those who are typically more withdrawn). With TMC, less confident or socially constrained students are given the anonymity to contribute freely without judgment as well as the time to gather their thoughts (Bump, 1990; Kraiger, 2008). Research suggests that TMC has some advantages over face-to-face collaboration. Specifically, TMC tends to encourage more questioning behavior, higher-quality responses, and more thoughtful discussion (Camin, Glicken, Hall, Quarantillo, & Merenstein, 2001; Hillman, 1999; Kruger & Cohen, 1996,Tutty & Klein, 2007).

Transactional distance theory suggests that distance education should be designed such that transactional distance (i.e., a psychological and communication gap that presents potential for misunderstanding) is minimized. Holding training structure and learner autonomy constant, an increase in dialogue between learners and instructors should reduce transactional distance and, in turn, facilitate learning (Moore & Kearsley, 1996). Similarly, Brown and Ford’s (2002) input-process-output model of technology-based instruction also inherently supports the efficacy of collaborative instruction. Brown and Ford proposed that, in order to optimize learning via TBI, technology must be designed to encourage the following active learning states in learners: motivation, mastery orientation, and mindfulness. Most relevant here is the mindfulness component. According to Brown and Ford, mindfulness refers to deliberate and systematic efforts by learners to evaluate incoming information and incorporate it into their existing knowledge structures. Mindful learners plan and monitor their progress relative to learning goals. Collaboration may be particularly helpful in terms of promoting mindfulness because learners are given the opportunity to compare their conceptualization of the training material with others. More specifically, learners can assess how well their understanding of a concept aligns with that of others, and accordingly, make better future decisions regarding how to allocate their attention. We can also expect self-efficacy to be enhanced in a social learning environment. By gaining certainty that their understanding of the learning material matches that of others, learners will likely feel more confident in their ability to perform well. Research has consistently revealed a significant positive relationship between self-efficacy and performance (Bandura, 1986; Gist & Mitchell, 1992; Gist, Stevens, & Bavetta, 1991;Stajkovic & Luthens, 1998).

Researchers have also garnered *empirical* support for TMC as a learning tool (e.g., Akpinar & Turan, 2012; Justen, Waldrop, & Adams, 1990; Katz & Lesgold, 1993). TMC has been shown to facilitate problem-solving (e.g., Uribe, Klein, & Sullivan, 2003) and cognitive task performance (Hall, 1997). For example, using a sample of 127 MBA students, Alavi (1994) compared the efficacy of a group decision support system (GDSS) designed to enhance the collaborative learning process to a traditional classroom learning environment. Results indicated that those in the GDSS condition not only achieved higher scores on the final course exam, but also reported higher levels of perceived learning, skill development, and interest in the learning material. Additionally, Uribe et al. (2003) demonstrated that technology-based collaboration produced more positive learning outcomes compared to individual technology-based programs. In their study, participants completed a technology-based instructional program that covered a particular problem-solving approach. Afterward, participants worked on an ill-defined problem either on their own in a web-based environment or in dyads using computer-mediated synchronous communication. Results indicated that those in the computer-mediated collaborative condition spent significantly more time on the problem and exhibited higher performance compared to those who worked alone. These kinds of positive effects span across the literature. 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 participants in individual computer-based instruction.

While the aforementioned studies present encouraging results about the efficacy of TMC, there is much more to learn about the effects of computer-mediated collaboration on learning outcomes in synchronous, chat-based environments. Murphy and Collins (1997) as well as Hara (2002) suggested that research on synchronous TMC has been primarily limited to the recreational use of online chat systems. A scan of the more current literature revealed that, while TMC has been examined in an instructional context -in both asynchronous environments (e.g., Alrushiedat, 2012; Brewer et al., 2006) and synchronous environments (e.g., Uribe et al., 2003; Weinel et al., 2011), compared against face-to-face collaboration (e.g., Alavi, 1994; Loewen & Reissner, 2009; Tutty et al., 2007; Weinel et al., 2011) and compared against individual TBI (Susman, 1998; Uribe et al., 2003), few studies, are concerned specifically with comparing chatroom-based TBI (with multiple learners, not just dyads) and individual TBI in terms of their effect on later individual learning. Moreover, it would be beneficial to examine the efficacy of online chatrooms in more controlled, experimental environments.

Furthermore, the majority of collaboration research (in both face-to-face and virtual environments) focused on children grade K-12 and college samples (e.g., Akpinar & Turan, 2012; Alavi, 1994; Althaus, 1997; Hall, 1997, Johnson, Johnson, & Stanne, 1985; MacDonald, 2003; Sapp & Simon, 2005; Sherman & Klein, 1995; Susman, 1998; Tutty & Klein, 2008; Uribe et al., 2003). To date, I know of no study that has compared the effectiveness of TMC across age groups. Older adults are likely to endorse the cognitive compensation function of face-to-face collaboration (e.g., Berg, Schindler, Smith, Skinner, & Beveridge, 2011). Further, research suggests that collaboration in face-to-face environments can benefit older adults' later individual memory performance (e.g., Blumen & Stern, 2011). However, there are reasons to believe that TMC (and a chatroom-based instructional context in particular) would be detrimental to learning among older adults. For one, research suggests that lower ability learners (e.g., high in cognitive deficiencies) need high levels of structure in training (Snow, 1989). This implies that older adults, who generally have slower cognitive speed would struggle in more flexible, group interaction environments compared to individual web-based training.

Generally, older adults are expected to experience learning decrements in chatroom-based training environments because chatrooms exacerbate cognitive and socio-emotional processes compromised by age-related deficits. For example, social interaction may not accommodate older adult's reduced metacognition for the following reason: While several studies show that interventions can improve metacognitive control processes and performance for older adults (e.g., Dunlosky & Hertzog, 2001), Dunlosky, Kubat-Silman, and Hertzog (2003) suggested that these interventions may only be helpful for older adults under conditions of self-pacing. Self-pacing is important to self-regulated learning because it allows learners control over when and how they learn. Older adults will not generally be able to self -pace as effectively in a social learning environment as they would in self-paced individual training because group processes determine the pace of presentation of material. Additionally, by allowing for a simultaneous exchange of information, chatrooms may create idiosyncratic sequences of comments that older adults, in particular, have difficulty appropriately filtering, coordinating, and assimilating into their existing knowledge structure. For these reasons and more, social interaction is expected to hinder learning for older adults in a chat environment. See Table 1 for a comprehensive listing of how known age-related changes might affect learners in a chatroom context. In this table, I compare the efficacy of chatroom-based learning to an individual review session among older adults. By an individual review session, I mean a session in which learners answer identical training-related review questions to those in the collaboration group, but do so individually.

The Current Study

The purpose of these two experiments is to examine the impact of age and collaborative learning (in the form of a chatroom) on training outcomes. In Study 1, I sought to determine whether there was a general age-related performance gap and whether chatroom-based learning differentially affected the learning outcomes of older and younger adults. As explained earlier, the finding that older and younger adults respond significantly differently to a chatroom instructional context would contribute to the discussion about age-specific TBI design. Subsequently, in Study 2, I build upon these findings to examine the impact of turn-taking on learning outcomes of older and younger adults within a chatroom context.

Study 1 Hypotheses.

Given that older adults experience a host of age-related cognitive declines, it is expected that they will struggle more with learning material compared to younger adults. This prediction is consistent with previous findings suggesting that older adults learn less rapidly and show less mastery of training-related content (e.g., Elias, Elias, Robbins, & Gage, 1987; Kubeck, Delp, Haslett, & McDaniel, 1996; Wolfson & Kraiger, 2012). As an example, Kubeck et al.'s meta-analysis revealed that, across a wide variety of occupations and training tasks, older adults required more time to learn the training content and exhibited poorer performance on training-related tasks compared to younger adults. Accordingly, given fixed length training, I propose the following:

Hypothesis 1: There will be a main effect of age on learning outcomes such that older adults will perform worse than younger adults.

While studies support the overall efficacy of TMC (e.g., Uribe et al., 2003; Susman, 1998), there is reason to believe the effectiveness of TMC differs by age. As noted above, aging is associated with cognitive deficits including diminished cognitive speed, working memory capacity, and metacognition. It is expected that these deficits will be exacerbated in a technology-mediated collaborative learning environments such as a chatroom. For example, older adults have particular difficulty coordinating and integrating information into a cohesive memory compared to younger adults. In a chatroom context, where comments may be disjointed or tangential to one another, older adults may be less capable of extracting from conversation a well-integrated understanding of the material. Furthermore, because learners need to hold information in memory as well as read new messages and compose responses, this requirement may impose excessive load on older learners who tend to have less working memory resources. Table 1 delineates how age-related changes may have negative implications for learning in a chatroom setting. By contrast, based on the results of previous research (e.g., Susman, 1998;

Uribe et al., 2003), I expect younger adults to increase or sustain levels of performance in the collaboration condition compared to the individualized TBI condition). Accordingly:

Hypothesis 2: The performance gap between older and younger adults will widen in the chatroom condition compared to the individual review condition.

To examine the impact of age and collaborative learning (in the form of a chatroom) on training outcomes, I first conducted a pilot study using thirty undergraduate students at Colorado State University. The purposes of this study were: 1) to ensure the technology worked properly and that participants clearly understood instructions; and 2) to ensure timing for different segments of the experiment was appropriate. Following this pilot study, I conducted Study 1. In the following section, I detail the participants, materials, procedure, and results of the main experiment within Study 1.

METHODS: STUDY 1

Participants

Participants were 62 younger adults between the ages of 18 and 30 years (M_{age} = 20.4, SD = 3.1) and 57 older adults 60 years of age or above (M_{age} = 68.2, SD = 8.4). Younger adults were recruited from the Introductory Psychology research pool at Colorado State University and offered course credit in exchange for their participation. Older adults were recruited through friends and acquaintances who recommended potential older participants or through a database of seniors who had previously participated in psychological research at Colorado State University. Additionally, six older adults were recruited from Meetup.com. Meetup.com is a website that helps individuals organize local groups based on shared interests. As the largest network of local groups, Meetup.com includes 92,000 groups and 9.5 million members. A search for “seniors” returned 784 groups and I contacted a total of 82 groups by sending a personal message to group organizers and asking them to forward a recruitment message to their members. With the exception of eight older adults who were given $10 in exchange for their participation, the other older adults were not offered an incentive for their participation other than the opportunity to sharpen their computer skills and learn information relevant to daily life.

Six younger adults and nine older adults were eliminated from the analyses because they experienced significant technological problems, were associated with extreme test scores, or because they failed to answer both the recall and the transfer questions. Demographic information for the final sample (n = 104) with 56 younger adults (M_{age} = 20.3, SD = 2.9) and 48 older adults (M_{age} = 68.1, SD = 8.1) is included in Table 2.

Design

This experiment used a 2 (young adult, older adult) by 2 (no collaboration, collaboration) between-subjects study design. The following variables were measured and used to either screen participants or serve as potential control variables: Training-related self-efficacy, computer experience, computer anxiety, mental and physical health, personality, and working memory capacity.

Training Content and Independent Variables

Training Content.

Participants listened to a set-paced audio-visual PowerPoint presentation about the basics of communication. This presentation was adapted from Nelson (2012) and included information about the benefits of effective communication, the costs of poor communication, the various types of communication, as well as barriers to and strategies for effective communication.

Review Questions.

Following the PowerPoint presentation, participants in both the control and the collaboration condition were asked to answer four review questions. The purpose of these questions was to help learners rehearse, organize, and retain training material before taking a test on what they learned. These questions were designed such that there was no one correct answer. Because the training content was relatively simple (i.e., learners did not have to keep in mind complex relationships between different units of information), I was concerned that discussion questions with one correct answer might stifle discussion and suppress sharing from group members. Therefore, the questions were designed to be subjective to arouse interest, prompt learners to recall more units of information, and ultimately foster greater group learning.

Across conditions, the questions were identical and presented in the following order: 1) “What is the most destructive barrier to communication and why?” 2) “What is the most effective strategy for communication and why?” 3) “Please describe a communication scenario between two or more people that illustrates at least four barriers to effective communication” and 4) “Imagine the following scenario: Max was just handed back his in-class essay. He flips through the comments to the back page to discover that he received a poor grade. Angry and frustrated, Max decides to approach his professor, Dr. Cooper, to dispute the grade. He heard from his classmates that Dr. Cooper is very stubborn when it comes to changing grades so Max opts to take an aggressive approach to the conversation. After class, he makes his way to the front of the student line and, once he gets the attention of his professor, he begins to rattle off reasons why he should deserves a higher grade (e.g., “I wrote a lot!”, “I studied for 2 hours the night before!”). Meanwhile, behind Max, students wait impatiently to discuss different class-related matters. Considering Max's emotional state, Dr. Cooper tells Max that they can discuss his grade at a later date. Give Max some constructive feedback. What could he have done to communicate more effectively in this scenario?”

Those in the control group answered the review questions on their own. They were presented with each of the four questions individually and were given six minutes to type their response before they were automatically forwarded to the next question. Those in the collaboration group answered the review questions with 2-4 other participants via an online chatroom. Collaboration group participants were presented with each of the four questions individually and were given six minutes to discuss the questions. For each question, a confederate, who served as the “secretary” during the discussion, moderated the discussion and synthesized everyone's input to generate an answer on behalf of the group (see the *Procedure* section).

Measures

The following measures were used either to screen participants or considered as potential covariates. Appendices A – F list all of the screening tools and potential covariates, except for the working memory test, which is a dynamic web-based number tool.

Short Blessed Test. The Short Blessed Test, modified and validated by Katzman, et al. (1983), consists of six items, and assesses participants' orientation, concentration, and memory. This test served as a screening device for all older adults to ensure that none of them had any cognitive impairments. A score between 0 and 4 indicated normal cognition, a score between 5 and 9 indicated questionable impairment, and a score of 10 or more indicated impairment consistent with dementia. All older participants ultimately included in this study scored between zero and four. One older adult was disqualified because she scored a 10.

Training Self-Efficacy. Gunthrie and Schwoerer's (1994) five-item scale was used to assess training self-efficacy. Items were modified very slightly to reflect how participants felt they would perform in this particular upcoming training. Using a scale of 1 (strongly disagree) to 7 (strongly agree), participants responded to items such as "I will do well in the upcoming training" and "I will be able to learn information and skills in the upcoming training." Cronbach's alpha for this study was 0.91.

Computer Understanding and Experience. The Computer Understanding and Experience (CUE) scale was used to assess computer experience (Potosky & Bobko, 1998). The CUE is comprised of a technical factor and a general competence factor. Because the technical factor was not as relevant to this study's computer task (e.g., "I know how to write computer programs, “I know how to install software on a personal computer”), only the six-item general competence factor was used. Example items from this factor include, “I am computer literate,” and “I am good at using computers.” α = .83.

Computer Anxiety. A modified version of the Computer Anxiety Rating Scale validated by Heinssen, Glass, and Knight (1987) was used to assess computer anxiety. This is a 19-item questionnaire in which participants were asked to indicate the extent to which they agree with statements such as, “I have avoided computers because they are unfamiliar and somewhat intimidating to me,” and “I feel apprehensive about using computers.” Three items were removed from the scale, however, because they were quite dated (e.g., “I am sure that with time and practice I will be as comfortable working with computers as I am in working with a typewriter”). α = 0.88 for the remaining 16 items.

Physical and Mental Health. A shortened version of the SF-36 health survey was used to assess the mental and physical health of participants. This version is based on 12 items from the SF-36 scale. Example items include, “Does your current health status limit you from climbing several flights of stairs?” and “How much of the time during the past 4 weeks have you felt calm and peaceful?” (Ware, Kosinski, Turner- Bowker, & Gandek, 2002). α = 0.84.

Big Five Personality Facets. John, Naumann, and Soto’s (2008) Big Five Inventory was used to assess participants’ openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Participants were presented with statements such as “I am someone who is talkative” and “I am someone who tends to find fault with others” and asked to indicate the extent to which they agree or disagree with each statement on a scale from 1 (disagree strongly) to 5 (agree strongly). In this study, Cronbach’s alphas were as follows:

openness to experience (10 items; α = 0.83), conscientiousness (9 items; α = 0.81), extraversion (8 items; α = .67), agreeableness (9 items; α = .79), neuroticism (8 items; α = 0.88).

Working Memory. Working memory was evaluated using a Web-based tool developed by Cavanagh (2011). Participants were presented with two rows of boxes. When the boxes first appeared, the top row of boxes contained two to five single-digit numbers and the bottom row was empty. After two seconds, the top row of numbers disappeared and a simple mathematical operation (addition or subtraction) appeared in one of the bottom row boxes. The participants' goal was to remember the sequence of numbers in the top row and only change the number in the box that had an addition or subtraction operation immediately below it. Participants were presented with these mathematical operations several times, so they were required to continually update the top row sequence in their memory. After several mathematical operations, participants were asked to type the final sequence of numbers. This exercise consisted of sixteen separate series of operations and total scores could range from zero to sixteen. Participants received one point if they provided the correct final sequence and zero if any of the numbers in their sequence were incorrect.

Evaluation of Chatroom Experience. Following the computer-based training and chatroom discussion, participants in the collaboration condition completed an exploratory 25-item survey I designed to assess why the chatroom experience was effective or ineffective. Using a scale from 1(strongly disagree) to 5 (strongly agree), participants responded to items such as, "During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom," and "I withheld ideas in the chatroom because I was worried others would think I was stupid." Participants also responded to open-ended questions (e.g., "In what way did the chatroom experience hinder your learning?" and "In what way did the chatroom experience help your learning?")

Evaluation of Individual Review Session. After the computer-based training and the individual review session, those in the control/no collaboration condition completed a survey designed to gain insight into why the review session was effective or ineffective. Ten questions were pulled from the "Evaluation of Chatroom Experience" survey based on whether or not they could be applied to the individual review session. Example items included, "I was motivated to answer the review questions well" and "I had adequate time to answer the review questions."

Learning outcome measures.

Recall. Participants were given a recall test. Recall tests are different from recognition tests in that participants are required to generate responses themselves rather than recognize the correct response from a list of options. The recall test consisted of the following three questions:

1) "The training program provided three reasons why effective communication is important. List as many of these as you can."

2) "The training covered 20 barriers to effective communication. List as many of these as you can."

3) The training covered 24 strategies for effective communication. List as many of these as you can."

Essays were scored based on the extent to which they aligned with the points presented in the training. Question 1 was worth 3 points - one point was awarded for each of the following responses: 1) stronger and healthier relationships, 2) career advancements, 3) organizational effectiveness. Question 2 was worth 20 points - one point was awarded for each of twenty possible responses, including "fear of asking questions," "having different goals for communication," and "preconceptions." Question 3 was worth 24 points – one point was awarded for each of 24 possible responses, including "say things in multiple ways," "encourage others to ask questions," and "provide feedback to the speaker."

Transfer. Two transfer questions were designed to assess the extent to which participants could apply what they learned to real-world scenarios. For present purposes, transfer is defined as the extent to which learners apply what they learned on the job (or in this case, in a hypothetical employment context) following training (Kraiger, 2002). Specifically, participants watched two videos depicting an employee interacting with his boss in a negative manner (video 1) and in a positive manner (video 2). Participants were asked to list all of the barriers to communication illustrated in video 1 and all of the strategies for communication illustrated in video 2. For transfer question 1, participants were awarded points for each of fifteen possible idea units, including "lack of practice or experience," and "distractions." For transfer question 2, participants were awarded points for each of 22 possible ideas, including "empathize," and "provide context or background."

The above test questions were chosen based on Lawshe's (1975) content validation procedure. After viewing the training video, five subject matter experts evaluated the test questions in terms of how essential they were to assessing learners' understanding of the training. Then, I applied Lawshe's quantitative index (Content Validity Ratio [CVR]) to calculate the content validity of each item. In accordance with Lawshe's requirements for five panelists, items that scored above .99 were retained.

Two undergraduate research assistants served as raters for this study. They were trained in one 1.5-hour session using a scoring protocol developed for this study. The intraclass correlation between rater 1 and rater 2 was acceptable for the first 50% of responses (for each question, the ICC was between 0.99 and 1.00), so the raters split the remaining responses and scored them separately.

Procedure

Before beginning this study, older and younger participants were randomly assigned to one of two conditions (collaboration condition or no collaboration/control condition). Participants completed the entire two-part study online, outside of the lab without an experimenter present. For part one, participants were given approximately four days to complete an hour-long online survey. This survey captured demographic information and assessed participants' training self-efficacy, computer understanding and experience, computer anxiety, physical and mental health, personality, and working memory.

Several days later, for part two, participants listened to a 22-minute set-paced audiovisual presentation about the basics of communication. Following the audiovisual presentation, those in the control condition answered four review questions on their own. Each question was presented individually and participants were given six minutes to respond before they were automatically forwarded to the next question. Those in the collaboration condition received the same questions for six minutes each, but they discussed these questions with two to four other participants via an online chatroom. Each group session was composed of learners from the same age group. A confederate, assigned to the "secretary" role, observed the chatroom conversation, helped direct the discussion, and synthesized everyone's input to generate an answer for each question on behalf of the group. To encourage contributions by learners, the secretary used Paul's (1993) Taxonomy of Socratic Questions. These questions include 1) questions of clarification (e.g., "What do you mean when you say you think Max should run his idea up a flagpole and see who salutes?" , 2) questions that probe assumptions, 3) questions that probe reasons and evidence (e.g., “what makes you say that?”, 4) questions about viewpoints, and 5) questions that probe implications and consequences (e.g., “what are the potential consequences of beginning a conversation with preconceptions about the other person?”). Across conditions, review questions were presented in the order listed in the “Training Content and Independent Variables” section.

Following the training, all participants completed learning outcome measures. Participants were required to spend a minimum of 10 minutes and a maximum of 20 minutes completing the test questions. After 20 minutes, answers were automatically submitted and participants were forwarded to the final survey portion of the study. Depending on which instructional condition participants had been assigned, they responded to questions designed to assess the costs and benefits of their individual review session experience or their chatroom experience. The entire study (across sessions) took participants approximately 2.5 hours to complete.

RESULTS: STUDY 1

Correlations among all study variables are presented in Table 3. The correlation table shows that the recall and transfer measures were moderately correlated (r = .47), suggesting that these outcomes were related but distinct constructs. That the correlation was less than 1.0, corrected for measurement error, supports Kraiger, Ford, and Salas' (1993) proposition that learning is multidimensional (i.e., different learning outcomes are differentially affected by training conditions). Potential covariates exhibited generally weak correlations with the dependent variables except for the online chat experience, extraversion, and working memory capacity, which were all significantly related to transfer (r = .21, -.22, and .34, respectively). However, none of the potential covariates yielded significant relationships with the recall measure (r = .06, -.05, and .12, respectively). Therefore, none of the potential covariates were included in subsequent analyses.

Because the learning outcomes measures were distinct but intercorrelated dimensions, a multivariate analysis of covariance (MANOVA) was conducted with age and collaboration condition as the independent variables and recall and transfer performance as the dependent variables.

Tables 4 and 5 show the cell means and standard deviations across the recall and transfer outcome variables. First, results of the MANOVA revealed that there was a multivariate effect of age on learning outcomes such that older adults on average performed worse than younger adults (λ = 0.75, $F(2, 99)$ = 16.56, n_p^2 = .25, p = .00). Univariate between-subjects tests indicated that age did not significantly predict recall performance (p =.47; n_p^2 = .01; $M_{\text{younger adults}}$ = 14.7, $M_{\text{older adults}}$ = 16.0), but did predict transfer performance (p = .00; n_p^2 = .16; $M_{\text{younger adults}}$ = 11.4, $M_{\text{older adults}}$ = 6.5).

The multivariate effect of collaboration on learning was not significant ($\lambda = 1.0$, F (2, 99) = .09, $n_p^2 = .00$, $p = .91$). Additionally, the interaction between age and collaboration condition was not significant ($\lambda = 0.99$, F (2, 99) = .62, $n_p^2 = .01$, $p = .54$). While the pattern of the data corresponded with my hypothesis (i.e., younger adults seemed to benefit slightly from collaboration and older adults experienced small learning decrements from collaboration), the results were not significant, due at least in part to large within cell variances.

Survey Results

An independent samples t-test indicated that, as expected, older adults reported more negative perceptions of their chatroom experience compared to younger adults. More specifically, older adults were less likely to endorse the following statements: (1) *"The information other participants presented triggered the recall of new information that would not have been available to me if I was answering questions on my own,"* t(50) =2.35, p=0.02, $M_{younger} = 4.0$, $M_{older} = 3.4$; (2) *"Feedback from others in the chatroom helped to curtail errors in my own thinking,"* t(50) = 1.79, p =0.08 (marginally significant), $M_{younger} = 3.5$, $M_{older} = 3.0$; (3) *"During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom,"* t(50) = 2.80, p= 0.01, $M_{younger} = 4.0$, $M_{older} = 3.3$; and (4) *"My experience in the chatroom helped me to better evaluate where I stood relative to my learning goals,"* t(50) = 1.74, p= 0.09 (marginally significant), $M_{younger} = 3.5$, $M_{older} = 3.1$.

For the remaining survey questions, older and younger adults did not respond significantly differently. The results were as follows: (1) *"During the online chat, the input of other group members disrupted my own ability to recall information,"* t(50) = -.16, p= 0.87, $M_{younger} = 2.3$, $M_{older} = 2.4$; (2) *"I felt empowered during the chatroom discussion"* t(50) = -.34, p= 0.73, $M_{younger} = 3.3$, $M_{older} = 3.4$, (3) *"I felt accountable for participating in the online* *discussion,"* t(50) = -1.53, p= 0.13, $M_{younger}$ = 3.8, M_{older} = 4.1; (4) *"Discussing the material in an online chatroom helped me learn,"* t(50) = .21, p= 0.83, $M_{younger}$ = 3.6, M_{older} = 3.6; (5) *"I withheld ideas in the chatroom because I was worried that others would think I was stupid,"* t(50) = .43, p= 0.67, $M_{younger}$ = 2.0, M_{older} = 1.9; (6) *"I felt free to challenge others' ideas in the chatroom,"* t(50) = .51, p= 0.61, $M_{younger}$ = 3.5, M_{older} = 3.4; (7) *"I was motivated to learn from others in the chatroom,"* t(50) = -0.1, p =.95, $M_{younger}$ = 3.6, M_{older} = 3.6; (8) *"Others provided their input too quickly, so it was hard for me to keep up with the conversation in the chatroom,"* t(50) = -0.80, p = .43, $M_{younger}$ = 2.2, M_{older} = 2.4; (9) *"It was difficult to synthesize all of the information presented in the chatroom,"* t(50) = .05, p =.96, $M_{younger}$ = 2.5, M_{older} = 2.4; (10) *"I would have performed better on the test if I had reviewed the material by answering discussion questions on my own (rather than with others),"* t(50) = .57, p=.57, $M_{younger}$ = 2.9, M_{older} = 2.7; (11) *"I would have benefited more from the chatroom if we had gotten more time to discuss the material,"* t(50) = -.87, p = 0.39, $M_{younger}$ = 2.5, M_{older} = 2.8; (12) *"I felt overwhelmed by the amount of information exchanged in the chatroom,"* t(50) = .59, p =.56, $M_{younger}$ =2.1, M_{older} =2.0; (13)*"The conversation in the chatroom was often irrelevant to the discussion questions,"* t(50) = -1.50, p=.14, $M_{younger}$ =1.8, M_{older} = 2.1.; (14) *"We had adequate time to discuss the questions,"* t(50) = 1.0, p = .32, $M_{younger}$ = 4.0, M_{older} =3.7. See Table 6 for a summary of these results.

DISCUSSION: STUDY 1

The purpose of this study was to examine the effect of technology-based collaboration (via an online chatroom) on the learning outcomes of older and younger adults. It was expected that there would be an age effect such that older adults would perform worse overall on learning outcome measures compared to younger adults. Furthermore, it was hypothesized that there would be an interaction between collaboration condition and age, such that younger adults would benefit or sustain levels of training performance in the collaboration condition but older adults would experience decrements to their performance in the collaboration condition.

Results indicated that older adults performed worse on the transfer measure compared to younger adults. Given older adults' various cognitive deficiencies, previous meta-analytic research showing that older adults learn less efficiently than younger adults (e.g., Kubeck et al., 1996), and research showing that older adults tend to have more Web-based performance issues (Chadwick-Dias et al. 2004), these results accorded with expectations.

Second, while there was a slight indication that collaboration benefitted younger adults' performance and harmed older adults' performance, the age by instructional design interaction was not significant.

Finally, older adults generally reported more negative perceptions of collaborative learning. For example, older adults in the collaboration condition were less likely to agree that the chatroom helped them monitor their learning and refine their understanding of the material. Specifically, they were less likely to agree that the chatroom discussion helped them evaluate where they stood relative to their learning goals, triggered the recall of new information, curtailed errors in their thinking, or re-activated information that they had forgotten.

Why did I not find a significant age by treatment interaction, as expected? Results indicated high within-cell variability (across the four conditions, standard deviations ranged from 6.9 to 10.1 for the recall measure and from 4.8 to 7.1 for the transfer measure), suggesting that the manipulation was not strong enough to outweigh individual differences in learning within conditions. It would thus be helpful to reduce within-cell variance. One strategy for doing this is to strengthen the collaboration manipulation. To enhance the manipulation in preparation for study 2, I: 1) shortened the training and eliminated additional material on which participants were not directly tested, 2) added avatars and an icebreaker activity, 3) gave participants more detailed instructions about how to effectively communicate with one another before they entered the chatroom, 4) changed the discussion questions such that input from all participants was necessary to answer the question, and 5) placed larger groups (four to seven participants) within each chatroom session.

The purpose of the avatars was to increase social presence, a concept that refers to the extent to which individuals are aware of each other in a technology-mediated communication setting (Short, Williams, & Christie, 1976). An avatar is a graphical icon presented on the screen that represents and is controlled by the user. Research shows that, particularly with judgment tasks with no one fixed answer, high social presence is important and increases user satisfaction (Chou & Min, 2009; Johnson, Hornik, & Salas, 2008). The instructions about how to effectively communicate were incorporated into the training to enhance the quality of the interaction. Shute, Lajoie, and Gluck (2000) suggested that, in order to leverage the benefits of collaboration, learners need to understand how to communicate effectively by asking appropriate questions, appropriately articulating their thoughts and goals, and elaborating on their opinions.

Finally, the discussion questions were changed so that they required input from all collaborators. Shute et al. (2000) maintained that collaborative activities improve learning when they are "true" group tasks, requiring information that no one person has and eliciting contributions from all group members. This change also reduces the likelihood of social loafing which may be more prevalent in TBI environments compared to classroom environments because learners often feel that they are not being personally monitored (Koller et al., 2005).

After the completion of Study 1, these changes were implemented and a small follow-up study (n =12) was conducted to determine whether or not participants were perceiving and responding to the new features. Results of the follow-up study revealed that participants did indeed perceive these changes. Specifically, these modifications accentuated differences between older and younger adults in terms of their reactions to the chatroom learning experience. While most of the interaction results were not significant (this was expected given the very small sample size of the Study 2 pilot study), the results were generally in the expected direction. For example, compared to the response differences between older and younger adults in Study 1, older adults were even *less* likely than younger adults to agree that the chatroom: 1) Triggered the recall of new information, 2) re-exposed them to information that they had forgotten, 3) empowered them, 4) helped them learn, 5) helped them evaluate where they stood relative to their learning goals, 6) afforded them enough discussion time, and 7) gave them the freedom to challenge others' ideas. Additionally, compared to Study 1, older adults were even *more* likely than younger adults to agree that: 1) Input from others disrupted their own ability to recall information, 2) others provided information too quickly that it was hard to keep up, 3) it was difficult to synthesize all of the information in the chatroom, 4) they would have performed better if they reviewed the questions on their own, and 5) felt overwhelmed by the amount of information in the chatroom. Based on these results, I expect that the modified chatroom environment will be particularly detrimental to the learning outcomes of older adults and perhaps widen the age-related performance gap in the control collaboration condition of Study 2.

While the Study 1 results did not confirm an age by treatment interaction, the data pattern was consistent with expectations - older adults performed slightly worse in the collaboration condition compared to the control condition whereas younger adults performed slightly better in the collaboration condition compared to the control condition.

In sum, Study 1 showed that older adults performed worse on transfer measures compared to younger adults, and older adults generally perceived the chatroom experience to be less positive compared to younger adults.

STUDY 2

In Study 2, I attempt to strengthen the collaborative learning manipulation, re-assess the relationship between chatroom-based collaboration and learning across age groups, and explore turn-taking as a method of compensating for the added challenges of the chatroom experience with older learners.

Re-assessing the Effect of Age and Online Collaboration on Learning Outcomes

After Study 1, I made several modifications to the chatroom to strengthen the collaboration manipulation, reduce within-cell variability, and increase the likelihood that hypotheses 1 and 2 from Study 1 will be supported. Specifically, I: 1) Eliminated training material on which participants are not directly tested, 2) added avatars and an icebreaker activity to the chatroom (to increase social presence), 3) gave participants more detailed instructions about how to effectively communicate, 4) modified the questions such that they require input from all group members, and 5) placed the learners in larger groups (groups of 4-7). After implementing the changes in a small follow-up study to Study 1, results indicated that participants did indeed perceive these changes and that these modifications tended to accentuate differences between older and younger adults in terms of their reaction to the chatroom learning experience. That is, compared to the response differences between older and younger adults in Study 1, the follow-up revealed that older adults were *even less* likely than younger adults to agree that the chatroom afforded them benefits *and even more* likely than younger adults to agree that the chatroom hindered their learning in various respects.

In Study 2, I used a larger sample and sought to determine whether these changes had implications for learning performance across age groups. Given that participants responded to the collaboration modifications in the follow-up study, it is expected that hypotheses 1 and 2 from Study 1 will now be supported.

Hypothesis 1: There will be a main effect of age on learning outcomes such that older adults will perform worse than younger adults.

Hypothesis 2: The performance gap between older and younger adults will widen in the chatroom condition compared to the individual review condition.

Within this study, I also investigated turn-taking as a way of addressing the added challenges of chatroom interaction, improving learning performance, and lessening age-related performance differences. If collaboration in fact creates a wider gap between younger and older learners, could turn-taking aid older learners and reverse that effect?

Taking Turns

One way to diminish age effects in a chatroom is by asking participants to take turns contributing to the conversation. For the purposes of this study, turn-taking can be defined as a process whereby learners alternate turns providing input about a discussion question. Below I outline costs and benefits of turn-taking, giving attention to both cognitive and affective issues. Cognitive issues relate to information processing and problem solving while affective issues relate to motivation and attitudes. Both of these factors are important to consider because they have been shown to enhance learning performance (Kettanurak, Ramamurthy, & Haseman, 2001; Mayer, 2001; Mayer, Dow, & Mayer, 2003; Mayer, Heiser, & Lonn, 2001; Shih & Gamon, 2001). Overall, I expect the benefits of turn-taking in this computer-based context will outweigh the costs. I then discuss how turn-taking accommodates age-related changes and bolsters learning, particularly for older adults.

Turn-taking aligns with what we know about optimal TBI design and cognitive load theory. To begin, turn-taking is a way of incorporating structure into a discussion. In general, many theorists have proposed that meaningful structure is a key feature of effective computer-based training programs, encouraging motivation, mastery orientation, and mindfulness (e.g., Brown & Ford, 2002; Wolfson, Cavanagh, & Kraiger, in press).

Cognitive load theory and cognitive theory of multimedia learning are two applied instructional theories based on our understanding of individuals' cognitive structure and they represent powerful tools for predicting the effect of turn-taking on learning outcomes. CLT suggests that humans have a cognitive architecture of limited capacity and care should be taken to ensure that it is not overtaxed during learning. Briefly, the theory proposes that working memory can only filter a limited number of units of information and their relations into long-term memory at each moment. In order to optimize learning, then, instructional designers should include content directly germane to the learning goal and minimize embellishments such as tangentially-related text, pictures, and videos. The CTML is closely related to CLT but its derived principles focus in particular on how individuals allocate their attention and interact with multimedia presentations consisting of text and pictures. CMLT is based on three assumptions: 1) dual-processing (learners have two independent channels for processing visual and verbal information), 2) limited processing capacity (WM can hold and manipulate a limited amount of information during multimedia instruction), and 3) generative processing (learning is a three-step process that involves a) attending to relevant information, b) mentally organizing the selected information into coherent mental models, and c) integrating these mental models with existing knowledge) (Mayer, 2005).

These theories have generated a host of specific instructional principles (e.g., segmentation principle, signaling principle, redundancy principle) that are intended to diminish cognitive load. Importantly, one can see how a turn-taking protocol serves a similar function as many of these principles, supporting the notion that turn-taking bolsters learning. For example, the segmentation principle refers to enhanced learning if the learner can self-pace through each step of multimedia instruction (Mayer & Chandler, 2001; Mayer et al., 2003) and turn-taking promotes segmentation in the sense that learners can control the amount of time they devote to thinking and responding to the material. The signaling principle refers to the notion that learning is fostered when essential information (e.g., key words, critical components of a graphic) is highlighted or cued. Likewise, with turn-taking, learners' attention is drawn to what each individual has to say, rather than allowing learners to talk/type over one another. Taken together, CLT and CTML suggest that a turn-taking protocol would reduce the amount of cognitive load placed on learners and in turn, improve learning outcomes.

Turn-taking is also expected to improve learners' attitudinal and motivational states by creating a relatively equal distribution of control amongst learners. That is, with turn-taking, learners know that they can express their knowledge and opinions and take control of the conversation once it is their turn. Research shows that distribution of control is a critical motivational variable in collaborative learning environments (Eals, Hall, & Bannon, 2002; Issroff & Soldato, 1996; Keller, 1987). For example, Hakkarainen, Lipponen, Jarvela, and Niemivirta (1999) argued that individuals should approach collaborative tasks with the perception that they will not dominate discussion, but work together with others. Similarly, Isroff and del Soldato proposed that distribution of control (the extent to which learners have a balance of control) is one of six key factors for promoting motivation in collaborative learning contexts.

In a technology-based learning context, control can be distributed to learners either through instruction or through the design of the software. TMC offers two correlated but distinct forms of control: control of the tool and control of the learning process (Jones & Isroff, 2005). Turn-taking encourages both by allowing each learner a chance to solely manipulate the chat tool and determine the type of information rehearsed and conveyed to other learners. Taken together, these studies indicate that turn-taking can improve collaborators' affect and motivation for learning. These affective and motivational factors are important because they facilitate learning performance (e.g., Kettanurak, Ramamurthy, & Haseman, 2001; Shih & Gamon, 2001).

Nunamaker et al. (1991) outlined a series of group process losses (i.e., aspects of group interaction that diminish learning compared to individual learning) and, arguably, turn-taking accommodates these losses. Group process losses include: 1) One or more individuals monopolizing discussion, 2) fear of judgment and negative feedback from other group members, causing learners to go into a self-protective mode and withdraw from the discussion, 3) cognitive overload from the amount of information exchanged in a group setting, 4) and a disjointed discussion in which learners speak over one another. It is quite clear that turn-taking makes it less likely that these process losses will occur. For example, turn-taking allows learners to contribute to a relatively equal degree, reducing the likelihood that certain individuals will monopolize discussion or withdraw from the group.

Research also shows that there are some disadvantages and inefficiencies associated with taking turns in a collaborative learning context. For example, using a basic recall paradigm, Harris, Barnier, and Sutton (2012) compared the costs and benefits of a turn-taking procedure (where participants had to recall as many words from a study list as possible, with each individual remembering a word in turn) versus a consensus procedure (where participants had to reach a consensus about each word) and found that turn-taking reduced recall accuracy (i.e., words recalled in error). As indicated in a post-experiment inquiry, the constrained nature of a turn-taking environment likely did not allow learners to correct the errors in others' thinking and therefore reduced recall accuracy.

Another potential cost of turn-taking in a chatroom environment is that it does not allow learners the flexibility to implement idiosyncratic strategies to coordinate and cue group recall (see Meade, Nokes, & Morrow, 2009). For example, Sundararajan (2009) found that within a computer-supported collaborative learning system, peer "Most Knowledgeable Others" (MKOs) emerged and seemed to affect not only how information and knowledge was transferred within class networks, but also the effectiveness of the learning system and students' perception of knowledge gained. By implementing a turn-taking procedure in the chatroom, instructional designers might prevent the emergence of these kinds of peer MKOs who seem to be critical in facilitating knowledge formation. What is more, by asking learners to respond to each discussion question in turn, learners may have greater difficulty building upon another learner's comment and jointly constructing unified responses.

While turn-taking has been examined in face-to-face (Harris et al., 2012; Lobel, Neubauer, & Swedburg, 2005) and online collaborative environments (Akpinar & Turan, 2012; Erkens et al., 2004), to my knowledge, researchers have not directly manipulated turn-taking in an online chatroom and have not compared its effects on older and younger learners. Evidently there are costs and benefits to a turn-taking strategy, but I expect the advantages to outweigh the costs in an online chatroom context by compensating for its cognitive demands. In the follow-up to Study 1, participants indicated that they felt overwhelmed by the amount of information in the chatroom, the conversation was often irrelevant to the discussion questions, and they did not have adequate time to discuss the questions. In other words, many of the complaints of participants about the chatroom revolved around its cognitive demands. Turn-taking is expected to reduce the load imposed on learners and in this way, enhance learning.

Moreover, previous research indicates that turn-taking tends to produce positive learning outcomes in an online collaborative context. For example, Akpinar and Turan (2012) found that students who engaged in a collaborative learning game with a well-scripted turn-taking control scheme scored significantly higher on a post-test compared to students who played individually. Soller (1997) found that students in effective collaborative teams took turns speaking. Drawing from this finding, Soller, Linton, Goodman, and Gaiman (1998) suggested that intelligent collaborative learning systems should establish an environment in which each student has the opportunity to contribute in turn without others interrupting. Accordingly, I expect that the advantages will overwhelm the disadvantages.

Hypothesis 3: Participants who take turns while in the chatroom will perform significantly better on learning outcome measures compared to participants in the control collaboration condition.

I expect turn-taking will be disproportionately beneficial to older learners because this kind of protocol compensates for age-related reductions in in cognitive speed, WM capacity, and executive functioning. For example, turn-taking reduces some of the difficulty involved in coordinating and synthesizing comments in a chatroom. Also, turn-taking allows learners to focus on each individual comment, reducing the need for learners to process and integrate multiple comments quickly. Indeed, there is evidence that older adults structure information less spontaneously compared to their younger counterparts and show significant learning benefits in individual and collaborative environments when the organization of information is facilitated (Blackburn, Papalia-Finlay, Foye, & Serlin, 1988; Sauzéon, Claverie, & N’Kaoua, 2006; Witte, Freund, & Sebby, 1990). With turn-taking, learners tend to engage in autonomous action and this might be beneficial for older adults who, as indicated in Study 1, had a slight (though non-significant) performance enhancement in the individual TBI condition. Accordingly, it is expected that:

Hypothesis 4: There will be an interaction between age and turn-taking such that older adults will benefit significantly more from them compared to younger adults, diminishing the age-related performance gap in collaborative TBI environment.

METHODS: STUDY 2

Participants

Participants consisted of 92 younger adults and 91 older adults. Younger adults were recruited mostly from the psychology research pool at Colorado State University and took part in exchange for research credit. Seventeen younger adults, however, who were friends, university students, or recruits from Craigslist, were given $25 for their participation. Older adults were either nominated by participants, friends, and colleagues or recruited from various sources including Craigslist, Facebook.com, Meetup.com, volunteer organizations, senior activity centers, and churches in Colorado. For their participation, older adults either received $25 directly or donated their money to a charity of their choice.

Two subjects were eliminated from the analyses due to the fact that they experienced severe technical problems (i.e., the training session did not appear for them) and 1 subject was eliminated because he did not proceed through the training properly and ultimately did not experience any manipulation. Additionally, three subjects were dropped from the analysis based on extreme multivariate outlier scores. Demographic information about the final sample with 91 younger adults (M_{age} = 21.4, SD = 3.9) and 86 older adults (M_{age} = 65.0, SD = 5.5) (n = 177) is provided in Table 7.

Design

This experiment used a 2 (young adult, older adult) by 2 (individual/control, collaboration) between-subjects design with turn-taking collaboration (yes or no) nested within the collaboration condition. This design was chosen over a 2 (young adult, older adult) X 3 (individual, collaboration, collaboration + turn-taking) design because it diminished my sample size requirement (and older adults are very difficult to recruit), and because of the exploratory nature of my hypotheses. As in Study 1, all older participants were screened for cognitive impairment using the Short Blessed Test (all subjects passed). Potential control variables measured were identical to those in Study 1 and included online chatroom experience, training-related self-efficacy, computer experience, computer anxiety, mental and physical health, personality, and working memory capacity. Potential mediating variables measured included self-efficacy for performance, cognitive load, metacognition, and training motivation.

Training Content and Independent Variables

Training Content.

The training content used in this study was identical to the content used in Study 1, except it was shortened by approximately 4 minutes. Some of the learning content was eliminated because it was not relevant to the material on which participants were tested. The 18-minute presentation included information about the benefits of effective communication as well as barriers to and strategies for effective communication.

Chatroom Discussion and Individual Review Questions.

In groups of four to seven, participants discussed and came to a consensus regarding four discussion questions. These questions were modified from Study 1 so that they were age-neutral. For example, question #4 in Study 1 concerning communication in a classroom involved a central character, Max, who was likely young. Arguably, this question could be biased in favor of young adults; therefore it was replaced with a question about communication in a car repair shop. The central figure in this scenario was not clearly associated with any age group. Across conditions, questions were identical and presented in the following order:

1) In this training, you were presented with many barriers to effective communication. In your opinion, what is the most destructive barrier to communication? Please A) provide your opinion, B) describe how this barrier would be evident in daily life, and C) explain why this barrier is most destructive in at least 2 sentences.

2) In this training, you were presented with many strategies for communication. In your opinion, what is the most effective strategy for communication? Please A) provide your opinion, B) describe how this strategy would be evident in daily life and C) explain why this strategy is most effective in at least 2 sentences.

3) Richard and Carolyn, a couple, are discussing chores around the apartment. Carolyn wants Richard to contribute more around the apartment but Richard says his style is to be more nonchalant about cleaning up because it simply isn't important. Richard feels that he doesn't have time for chores and he thinks Carolyn is trying to control him. The more frustrated Carolyn gets, the louder her voice becomes and the quieter Richard becomes. What can both Richard and Carolyn do to improve communication?

4) Imagine the following scenario: Bill is waiting to get service at a car repair shop. After about 20 minutes of waiting, he reaches the front of the line. As he prepares to explain his car troubles, he realizes that the customer service representative is having a personal conversation on the phone, cleaning the desk, chatting with fellow coworkers, and completely ignoring his presence. After about 10 more minutes of waiting for the representative to give him attention, Bill is boiling with anger and decides to take an aggressive approach to the conversation. He screams at the agent, tells him he is terrible at his job, curses, throws a plant on the ground, and demands free service.

- Persons 1 and 2 (i.e., a random selection of chatroom participants)- each describe at least 2 effective strategies that Bill used.
- Persons 3 and 4 (i.e., the remainder of the chatroom participants)- each describe at least 2 barriers to communication that Bill used.

Overall, how would you rate the effectiveness of his communication on a scale of 1 (extremely ineffective) to 5 (extremely effective)? As a team, please come to a consensus.

Measures

The measures used in this experiment were identical to those used in Study 1 with the exception that one of the transfer outcome measures (the barriers to communication video) was eliminated (for time efficiency) and several assessments were added as either mediating variables or outcome measures. Appendices G - I list all of the new mediating assessments, except for the cognitive load scale, which consists of one item and is presented below. Appendices J - M list all of the new learning outcome measures. Mediating variables were added so that I might gain greater insight into *why* collaboration and turn-taking affect learning outcomes across age groups. Additional outcome measures (e.g., transfer, reactions to training, intentions to transfer, and recognition) were included so that I could assess a wider domain of training-related outcomes.

Screening Tools and Potential Covariates.

The screening tool (i.e., the Short Blessed Test) and the potential covariates were identical to those used in Study 1. See Appendix A – F for a list of these variables.

Mediating Variables.

Self-efficacy for Performance. Four items were selected and adapted from the "self-efficacy for learning and performance" component of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1993). I specifically selected items related to self-efficacy for *performance*, not learning, because when learners complete this assessment, the learning portion of the study will have concluded and they will be approaching the test. Example items include, “I believe I will receive an excellent score on this test” and “Considering the difficulty of this training program and my skills, I think I will do well on the upcoming test.” Cronbach’s alpha for this measure was .95.

Cognitive Load. As an estimate of cognitive load, participants will complete a one-item questionnaire based on Paas’ (1992) measure. Specifically, participants will rate their level of invested mental effort on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). This scale is the most widely-used measure of working memory load within the CLT literature, largely because of its ease of use, reliability, and sensitivity (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

Metacognitive Activity. A 12-item scale adapted from Ford, Smith, Weissbein, Gully, and Salas (1998) will be used to assess the extent to which learners engaged in metacognitive processes during the collaboration. Using a scale of (1) strongly disagree to (5) strongly agree, participants responded to questions such as “As I used the chatroom, I evaluated how well I was learning the training content,” and “I tried to monitor closely the areas where I needed the most review.” I found a coefficient alpha of .85 for this scale.

Learning Motivation. Motivation to learn was assessed using an eight-item scale adapted from Noe and Schmitt (1986). Example items include, “I was motivated to learn the information presented in the training program” and “I got more from this training than most people.” All items will be rated on a scale of 1 (strongly disagree) to 5 (strongly agree). Cronbach’s alpha for these eight items was .82.

Learning Outcome Measures.

Recall. Subjects were asked three questions to assess memory of units of information presented in the training. These recall questions were identical to those from Study 1 and the same scoring protocol was used.

Transfer. Subjects were given two tasks to assess their transfer performance (i.e., the extent to which they could apply what they learned in the training to real-world situations).

First, participants were asked to watch a video of an employee interacting with his boss and identify all of the strategies for effective communication depicted in the video. This video was transfer video 2 from Study 1 and the same scoring protocol was used.

Second, participants were asked to list the barriers to communication depicted in the following scenario:

Barbara notices that her sister, Ann, has been acting strangely toward her lately. They typically go out to lunch or dinner a few times per week and now Ann has been ignoring Barbara's calls and acting cold. Barbara learned that Ann is planning a move out of the city and she asked Ann why she hadn't told her. Ann simply said she was busy and forgot.

In reality, Ann was upset that Barbara had told their mutual friend a piece of very personal and private information that was meant to be kept between the two of them. Ann assumed that Barbara didn't care about her feelings and didn't value their relationship enough to keep the information to herself. Meanwhile, Barbara had assumed that the information was not a secret. Every time Barbara asks Ann about her distant behavior, Ann brushes off the question. Barbara wants to mend the relationship while Ann has already moved on and doesn't see how her sister can restore her trust. What kinds of barriers to communication do you see illustrated in this example?

Participants were awarded points based on how many barriers they accurately recognized. One point was awarded for each of seven possible answers including “lack of information or incomplete information,” “not trusting the other person,” “different goals for communication,” and “emotions.”

Recognition. Recognition is different from recall in the sense that learners do not have to generate answers themselves, but identify the correct answers among a list of possible responses. Participants were presented with a list of 32 barriers to effective communication and a separate list of 41 strategies for effective communication. Their task was to look at these two lists and identify those barriers and strategies presented in the audiovisual training and to do so within three to six minutes. Each participant was given a score based on the number of hits (correctly endorsing a studied item) and false alarms (incorrectly endorsing an item that was not studied). These data were used to calculate discriminability, an index indicating subjects’ ability to discriminate between old and new items.

Reactions to Training. A seven-item measure adapted from Brown (2005) was used to assess learners’ reactions to training. Brown (2005) found that overall training satisfaction was composed of three distinct reaction facets: enjoyment, relevance, and technology satisfaction. Example items were “Learning this material was fun,” “This training was relevant to my daily life,” and “The technology interface was easy to use” for the enjoyment, relevance, and technology satisfaction dimensions, respectively. Cronbach’s alpha for the overall trainee reactions measure was .84.

Intentions to Transfer. According to Foxon (1993), transfer intentions refer to trainees’ motivation to use knowledge and skills acquired in the training in the work environment. Transfer intentions is an important variable to measure because, as suggested by the Theory of

Planned Behavior (Azjen, 1991), it is the most proximal antecedent of transfer behavior. Intentions to transfer were evaluated using a measure adapted from Clemenz (2001) and Al-Eisa, Furayyan, and Alhemoud (2009). Example items included, “I intend to use the knowledge I acquired from this program in my daily life” and “The knowledge I learned in this program will be useful in improving my life.” These items were adapted to capture the extent to which participants applied what they learned in daily life, rather than specifically on the job. Cronbach’s alpha for this three-item measure was .91.

Two undergraduate research assistants served as raters for all of the subjective learning outcome measures – the three recall measures and the transfer measures listed above. They were trained in two 1-hour sessions using a scoring protocol developed for this study. The intraclass correlation between rater 1 and rater 2 was acceptable for the first 32% of responses (for recall question 1, the ICC was .92; for recall question 2, the ICC was .96; for recall question 3, the ICC was .94; for transfer question 1, the ICC was .82; and for transfer question 2, the ICC was .80). Given that the raters had a sufficient level of correspondence in terms of scoring, they split the remaining responses and rated them separately.

Procedure

The entire study was completed online. Before beginning the study, older and younger participants were randomly assigned to one of three conditions: individual (control), chatroom, and chatroom with turn-taking. For part 1, participants completed an online survey assessing online chatroom experience, training self-efficacy, computer understanding and experience, computer anxiety, physical and mental health, personality (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism), and working memory capacity.

For part 2, participants watched an audiovisual online presentation about the basics of communication. Following the presentation, participants reviewed training concepts either individually or collaboratively (with learners from their own age group) using the review questions listed in the *Training Content and Independent Variables* section. Those in the individual condition were given a minimum of four minutes to answer each of four applied questions on their own while those in the collaboration condition discussed these same questions in a chatroom setting without a minimum or maximum time restriction. Within the collaboration condition, participants either discussed their thoughts freely or took turns providing input upon prompting by the secretary. As in Study 1, the secretary was responsible for observing the chatroom conversation, directing the discussion using Paul's (1993) Taxonomy of Socratic Questions, determining the order in which participants speak (in the turn-taking condition), and synthesizing everyone's input to generate a group answer for each question on behalf of the group.

The procedure after the chatroom discussion was identical to the procedure in Study 1, with several differences. After the review activity (individual or collaborative) and before they complete the learning outcome measures, participants were given several additional measures to assess their self-efficacy for performance, cognitive load, metacognition, and motivation for learning. These constructs are expected to mediate the relationship between collaboration as well as turn-taking and learning performance. A handful of participants in Study 1 mentioned that they could have used more time on the test so participants were given two extra minutes to complete all learning outcome measures. After the test, participants completed a survey about their individual review or chatroom review experience. The entire experiment took participants approximately 2.5 hours to complete.

RESULTS: STUDY 2

Table 8 shows the correlation among all learning outcome variables. This table demonstrates that recall and transfer were moderately correlated (r =.54), technology satisfaction, training enjoyment, training relevance, and transfer intentions were moderately to highly correlated (correlations ranged from .37 to .73), and recognition was mildly to moderately correlated with the other training outcomes (correlations ranged from -.05 to .42). As in Study 1, potential covariates had relatively weak correlations with the outcome variables (correlations ranged from to -.28 to .28) and therefore, they were dropped from the analyses.

Based on the pattern of training outcome correlations, two MANOVAs were conducted – one with recall and transfer as the dependent variables and another with technology satisfaction, training enjoyment, and relevance as the dependent variables. The latter set of outcome variables were clustered together not only based on results of the data, but also because they are conceptually linked as separate facets of trainee reactions (Brown, 2005). Transfer intentions was eliminated from the analysis because this variable was very highly correlated with relevance and therefore, was considered redundant with this outcome. Because the recognition outcome generally exhibited weak correlations with the other learning outcomes, a separate ANOVA was conducted for this dependent variable.

Tables 9, 10, 11, 12, 13, and 14 show the cell means and standard deviations for the outcome variables - recall, transfer, recognition, technology satisfaction, training enjoyment, and training relevance, respectively. Tables 15 and 16 show participants' time for review across conditions and learning scores by chatroom group size, respectively.

Part 1: Evaluating the efficacy of individual learning and collaborative learning across age groups

In this section, I address Hypotheses 1 and 2. That is, I sought to determine whether older adults would generally perform worse than younger adults (Hypothesis 1) and whether the performance gap between older and younger adults would widen in the chatroom condition compared to the individual condition (Hypothesis 2).

To test these hypotheses, I examined the overall effect of technology-based collaboration (vs. individual learning) on training outcomes across age groups, combining the free-for-all collaboration condition and collaboration with turn-taking conditions.

Recall and Transfer Outcomes.

I first conducted a MANOVA with age and collaboration as the independent variables and recall and transfer as the dependent variables. Results indicated that the multivariate effect of age on learning outcomes was not significant ($\lambda = .98$, F $(2, 172) = 2.17$, $n_p^2 = .03$, $p = .12$), nor was the effect of collaboration on learning outcomes ($\lambda = .99$, F $(2, 172) = .92$, $n_p^2 = .01$, $p = .40$). The interaction between age group and collaboration, however, was significant ($\lambda = .94$, F $(2, 172) = 5.94$, $n_p^2 = .07$, $p = .00$). Univariate between-subjects tests showed that age and collaboration condition interacted to predict transfer performance (F $(1, 173) = 11.83$, p=.00, $n_p^2 = .06$), but not recall performance (F $(1, 173) = 2.46$, p =.12, $n_p^2 = .01$). Follow-up univariate post hoc comparisons using Bonferroni t-tests revealed that, in terms of transfer performance, older adults benefited from online collaboration ($p = .01$) while younger adults did not ($p = .53$) (compared to the individual condition). Furthermore, collaboration diminished the age-related performance gap, as there was a significant difference between young and old adults in the individual condition (*p* = .01) (younger adults did better than older adults here), but not in the collaboration condition (*p* = .46). (Hypothesis 2 was not supported). See Figure 1.

As there was a significant relationship between online collaboration and transfer for older adults, Preacher and Hayes' (2004; 2008) bootstrapping technique was conducted to determine whether self-efficacy, metacognition, or training motivation mediated this relationship. To support a significant mediation model, a significant relationship should exist between: 1) The independent variable (IV) and the mediator (M) (a-path), 2) the M and dependent variable (DV) (b-path), and 3) the IV and the DV (c-path). Further, with the mediator in the model, the strength of the relationship between the IV and the DV should diminish (indicating partial mediation) or become non-significant (indicating full mediation) (c'-path). Finally, the 95% confidence interval for the indirect effect must not include zero.

Multiple regression analyses were performed for each potential mediator to evaluate each component of the mediation model. I began with self-efficacy. I found that while collaboration (IV) was significantly related to transfer performance (DV) among older adults (B = 2.90, *t* (84) = 2.94, *p* = .00) (significant c-path), collaboration (as opposed to individual learning) was not related to self-efficacy (M) (B = -.29, *t* (84) = -1.13, *p* = .26) (non-significant a-path). Therefore, conditions for the mediation were not met. Results of the bootstrapping technique with 5000 bootstrap resamples further confirmed the non-significant mediating role of self-efficacy in the relationship between online collaboration and transfer performance (B = -.20; CI = -1.03 to .11).

I then sought to determine whether metacognition mediated the relationship between online collaboration and transfer for older adults. Again, collaboration (as opposed to individual learning) did not significantly predict metacognition (B = -.13, *t* (84) = -1.15, *p* = .25) (non-significant a-path). One of the necessary conditions for mediation was not met. Additionally, the bootstrapping method with 5000 resamples affirmed that metacognition did not mediate the relationship between online collaboration and transfer performance (B =.07; CI =-.16 to .71).

Finally, I examined whether training motivation mediated the relationship between online collaboration and transfer for older adults. This analysis also did not yield significant results. Collaboration did not significantly predict training motivation (B = -.14, *t* (84) = -1.38, *p* = .17) (non-significant a-path) and the bootstrapping technique corroborated this non-significant mediation effect, as the confidence interval included zero (B =-.10; CI = -.77 to .17). In sum, none of the following variables – self-efficacy, metacognition, or training motivation – mediated the relationship between collaboration and transfer performance.

Recognition Outcome.

I then conducted an ANOVA with recognition as the outcome variable. Results showed that there was a main effect of age on recognition, F (1, 153) = 4.01, p =.05, n_p^2 = .03 – younger adults (M = 1.47) performed better than older adults (M = 1.12) (Hypothesis 1 supported). The effect of collaboration, however, was not significant, F (1, 153) = 2.52, p = .11, n_p^2 = .02, and neither was the interaction between age and collaboration, F (1, 153) = 1.15, p = .29, n_p^2 = .01. Because the significance level of the two latter findings was rather low, I took a look at the pattern of effects for these variables. Results showed that the effect size for collaboration among younger adults was d = .08 ($M_{individual}$ = 1.42, $M_{collaboration}$ = 1.51) and the effect size for collaboration among older adults was d = .43 ($M_{individual}$ = .90, $M_{collaboration}$ = 1.35). This pattern of results mirrors what I found with the transfer outcome – that younger adults performed similarly in the individual and collaboration condition whereas older adults experienced a boost in the collaboration condition compared to the individual condition. (Hypothesis 2 was not supported). See Figure 2 for a representation of pattern of results for the recognition outcome.

Training Reaction Outcomes.

Finally, I performed an MANOVA with age and collaboration condition as the independent variables and the three reaction variables (technology satisfaction, training enjoyment, and training relevance) as the dependent variables. Analyses revealed that there was a multivariate effect of age on trainee reactions (λ = .90, F (3, 171) = 6.19, n_p^2 = .10, p = .00). At the univariate level, age influenced technology satisfaction (p = .02) and training enjoyment (p = .03). Results showed that younger adults (M = 4.0) reported higher levels of technology satisfaction compared to their older counterparts (M = 3.7). Interestingly however, older adults reported higher levels of training enjoyment (M = 3.7) compared to their younger counterparts (M = 3.4). Figures 3 and 4 depict the main effect of age on technology satisfaction and enjoyment, respectively. The univariate effect of age on perceptions of training relevance was not significant (p = .37) but the data pattern was such that older adults (M = 4.05) were *slightly* more likely to endorse the relevance of the training compared to younger adults (M = 3.97).

The multivariate effect of collaboration condition (individual vs. collaboration) on trainee reactions was non-significant (λ = .98, F (3, 171) = 1.47, n_p^2 = .03, p = .22) and the multivariate interaction between age and collaboration was non-significant as well (λ = .97, F (3, 171) = 1.79, n_p^2 = .03, p = .15).

Results of analyses for Part 1 indicated that, consistent with previous research, younger adults demonstrated better performance on the recognition learning outcome measure compared to older adults. Contrary to expectations, technology-based collaboration had a facilitative effect on the transfer performance of older adults but did not influence transfer performance for younger adults. Essentially, TMC eliminated the learning gap between older and younger trainees. Though not significant, this same pattern of results emerged on the recognition outcome; that is, effect sizes suggested that younger adults performed similarly in the individual and collaboration condition while older adults experienced a small performance boost in the collaboration condition. Finally, older and younger adults differed with respect to their reactions to the training. While younger adults reported higher technology satisfaction, older adults reported greater enjoyment of the training.

Part 2: Evaluating the efficacy of collaborative turn-taking and free-for-all collaboration across age groups

In this section, I addressed Hypotheses 3 and 4. That is, I sought to determine whether participants who take turns in the chatroom would perform significantly better on learning outcomes compared to participants in the free-for-all collaboration condition (Hypothesis 3) and whether older adults would benefit significantly more from turn-taking compared to their younger counterparts (Hypothesis 4). For this second set of analyses, I eliminated the individual condition to again form a 2 (young, old) X 2 (free-for-all collaboration, turn-taking collaboration) design.

As in the previous set of analyses, I conducted two MANOVAs – one with recall and transfer as the dependent variables and another with technology satisfaction, training enjoyment, and relevance as the dependent variables. I also conducted a separate ANOVA with recognition as the dependent variable.

Recall and Transfer Outcomes.

For the first MANOVA, with age (young, old) and collaboration type (regular/free-for-all collaboration, collaboration plus turn-taking) as the independent variables and recall and transfer as the dependent variables, results were the following: The effect of age on learning outcomes was not significant (λ = .95, F (2, 81) = 2.26, n_p^2 = .05, p = .11). The effect of collaboration type (free-for-all collaboration, collaboration with turn-taking) was marginally significant ($\lambda = .94$, F $(2, 81) = 2.64$, $n_p^2 = .06$, $p = .08$). Univariate analyses revealed that this effect occurred on the recall outcome (p=.09, $n_p^2 = .04$), not the transfer outcome (p=.90, $n_p^2 = .00$). In terms of recall, turn-taking ($M = 14.7$) was slightly *worse* for performance than free-for-all collaboration (M = 18.5). (Hypothesis 3 was not supported) See Figure 5 for a depiction of this effect. An independent samples t-test revealed that those in the turn-taking groups produced significantly fewer words per minute compared to those in the free-for-all groups, $t(16) = 2.12$, $p = 0.05$, $M_{freeforall} = 65.57$ words per minute, $M_{turntaking} = 59.13$ words per minute. The diminished efficiency in communication may explain why turn-taking hurt certain aspects of learning performance.

Finally, the age by collaboration type interaction was not significant ($\lambda = .97$, F $(2, 81) = 1.48$, $n_p^2 = .04$, $p = .23$). Because the partial eta squared was not completely insubstantial, out of curiosity, I looked at the univariate results. These results showed that this slight effect was largely due to the transfer measure, though the effect is very marginal (p=.11, $n_p^2 = .03$). Follow-up Bonferroni t-tests indicated that, while there was not a significant difference between older ($M = 6.8$) and younger adults ($M = 6.6$) in the free-for-all collaboration condition (p=1.0*)*, there was a widening of performance differences between the two age groups in the turn-taking condition ($p = .13$) such that older adults ($M = 8.6$) tended to perform slightly better that young adults ($M = 5.1$), $d = .75$. (Hypothesis 4 was not supported, though there is some pattern of evidence to suggest that turn-taking facilitates transfer performance more so for older adults than younger adults).

Recognition Outcome.

I then conducted an ANOVA with age and collaboration type (free-for-all vs. turn-taking) as the independent variables and recognition as the dependent variable. Results showed that the effect of age on recognition was non-significant, F (1, 72) =.43, p = .51. Further, the effect of collaboration type (free-for-all vs. turn-taking) was non-significant (F (1, 72) =.01, p =.92), and the interaction between age and collaboration type was non-significant, F (1, 72) =.80, p =.37.

Training Reaction Outcomes.

For the second MANOVA, with age (young, old) and collaboration type (free-for-all collaboration, collaboration plus turn-taking) as the independent variables and technology satisfaction, training enjoyment, and relevance as the dependent variables, I found the following: The effect of age on training outcomes was significant (λ = .88, F (3, 80) = 3.80, n_p^2 = .13, p = .01). Univariate between-subjects tests showed that age influenced technology satisfaction specifically (p = .02, n_p^2 = .06) and younger adults were more satisfied with the technology (M = 3.9) compared to their older counterparts (M = 3.4). See Figure 6 for a visual representation of the main effect of age on technology satisfaction within the collaboration conditions. Secondly, the effect of collaboration type (free-for-all collaboration vs. collaboration with turn-taking) was not significant (λ = .97, F (3, 80) = .73, n_p^2 = .03, p = .54). Finally, the interaction between age and collaboration type was not significant (λ = .98, F (3, 80) = .68, n_p^2 = .03, p = .56).

With these Part 2 analyses, I looked within collaboration conditions to examine the effect of collaboration type (turn-taking versus free-for-all collaboration) on learning outcomes for older and younger adults. These analyses yielded two main findings. First, there was a marginally significant effect of collaboration type (free-for-all collaboration vs. turn-taking) on recall performance. Contrary to expectations, turn-taking led to worse performance compared to regular/free-for-all collaboration. Second, across both collaboration conditions, younger adults were more satisfied with the technology compared to older adults.

Chatroom Survey Results at the Item Level

A series of ANOVAs were conducted to see whether perceptions of the chatroom varied by age group, collaboration type, or the interaction between these two variables. Results of these analyses are presented below according to the chatroom perception item.

(1) *"The information other participants presented triggered the recall of new information that would not have been available to me if I was answering questions on my own."*

Results showed that there was a significant effect of age on item rating, $F (1, 81) = 5.44$, $p = .02$. Younger adults ($M = 4.0$) were more likely to endorse this item compared to older adults ($M = 3.6$). There was also a non-significant effect of collaboration condition, $F (1, 81) = 1.71$, $p = .19$, as well as a non-significant interaction between age and collaboration condition in predicting item rating, $F (1, 81) = .18$, $p = .67$.

(2) *"Feedback from others in the chatroom helped to curtail errors in my own thinking."*

There was a main effect of age on item rating, $F (1, 81) = 9.47$, $p = .00$. Younger adults were more likely to endorse this item compared to older adults ($M_{younger} = 3.6$, $M_{older} = 3.1$). There was a non-significant effect of collaboration condition on item rating, $F (1, 81) = 1.86$, $p = .18$. Finally, the interaction between age and collaboration condition in predicting item rating was not significant, $F (1, 81) = .03$, $p = .87$.

(3) *"During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom."*

Age significantly influenced item rating, $F (1, 81) = 7.81$, $p = .01$. Younger adults rated this item more highly compared to older adults ($M_{younger} = 3.9$, $M_{older} = 3.4$). There was a non-significant effect of collaboration condition, F (1, 81) = 1.20, p = .28, as well as a non-significant interaction between age and collaboration condition in predicting item rating, F (1, 81) = .64, p = .43.

(4) "During the online chat, the input of other group members disrupted my own ability to recall information."

Age did not significantly influence item rating, F (1, 81) = .22, p = .64, $M_{younger}$ = 2.3, M_{older} = 2.4. Collaboration condition was not significantly related to item rating, F (1, 81) = .04, p =.85, nor was the interaction between age and collaboration condition, F (1, 81) = .18, p = .67.

(5) "I felt empowered during the chatroom discussion."

Age did not significantly influence item rating, F (1, 81) = .00, p = .96, $M_{younger}$ = 3.2, M_{older} = 3.1. Collaboration condition was not significantly related to item rating, F (1, 81) = .98, p = .33. Finally, the interaction between age and collaboration condition in predicting item rating was not significant, F (1, 81) = .72, p = .40.

(6) "I felt accountable for participating in the chatroom discussion."

Results showed that the effect of age on item rating was not significant, F (1, 81) = 1.79, p = .19 ($M_{younger}$ = 3.9, M_{older} = 4.1). There was a non-significant effect of collaboration condition on item rating, F (1, 81) = 1.70, p = .20. Finally, the interaction between age and collaboration condition in predicting item rating was significant, F (1, 81) = 6.54, p = .01. Follow-up Bonferroni t-tests indicated that younger adults reported significantly lower accountability in the turn-taking condition (M = 3.7) compared to the free-for-all collaboration condition (M = 4.2) (p = .04) while older adults reported similar levels of accountability in the turn-taking condition (M =4.2) and the free-for-all collaboration condition (M = 4.0) (*p = 1.00).* Furthermore, older adults in the turn-taking condition reported marginally higher levels of accountability compared to younger adults in the turn-taking condition (*p* =.06).

(7) "Discussing the material in the online chatroom helped me learn"

Age did not significantly affect item rating, F (1, 81) = 1.08, *p* = .30, $M_{younger}$ = 3.8, M_{older} = 3.6. Collaboration condition was related to item rating, F (1, 81) = 5.14, *p* = .03. Those in the free-for-all collaboration condition (*M* = 3.9) were more likely to agree with this statement than those in the turn-taking condition (*M* = 3.5). Finally, the interaction between age and collaboration condition in predicting item rating was not significant, F (1, 81) = .00, *p* = .98.

(8) "I withheld ideas in the chatroom because I was worried others would think I was stupid."

Age influenced item rating marginally such that younger adults were slightly more likely to agree with this statement than older adults, F (1, 81) =3.59, *p* = .06, $M_{younger =}$ 2.1, M_{older} = 1.8. Collaboration condition was not related to item rating, F (1, 81) = .31, *p* = .58. Finally, the interaction between age and collaboration condition in predicting item rating was not significant, F (1, 81) = .78, *p* = .38.

(9) "I felt free to challenge others' ideas in the chatroom."

This question did not produce any significant differences across experimental groups. Age was not related to item rating, F (1, 81) = .19, *p* = .66. Collaboration condition was not related to item rating, F (1, 81) = .21, *p* = .58, and the interaction between age and collaboration condition did not significantly predict item rating, F (1, 81) = .00, *p* = .97.

(10) "I was motivated to learn from others in the chatroom."

Experimental groups did not rate this item significantly differently. Age was not related to item response, F (1, 81) = 2.25, *p* = .14, collaboration condition did not predict item response, F (1, 81) = 1.10, *p* = .30, and the interaction between age and collaboration condition did not significantly predict item response, F (1, 81) = .01, *p* = .93.

(11) "Others provided their input too quickly, so it was hard for me to keep up with the conversation in the chatroom."

Age did not significantly predict endorsement rates, F(1, 81) = .56, *p* = .46. Collaboration condition marginally predicted item response, F(1, 81) = 2.75, *p* = .10. Those in the free-for-all collaboration condition (*M* = 2.5) were slightly more likely to agree with this statement compared to those in the turn-taking condition (*M* = 2.1). Additionally, the interaction between age group and collaboration condition was not significant, F(1, 81) = 2.43, *p* = .12.

(12) "It was difficult to synthesize all of the information presented in the chatroom."

Age did not significantly predict item responses, F(1, 81) = .00, *p* = .97. Collaboration condition predicted item responses, F(1, 81) = 5.06, p = .03. Those in the free-for-all collaboration condition (*M* = 2.8) rated this item more highly than those in the turn-taking condition (*M* = 2.2). Finally, the interaction between age group and collaboration condition was marginally significant, F(1, 81) = 2.74, *p* =.10. Follow-up Bonferroni t-tests indicated that younger adults endorsed this item similarly in the free-for-all condition (M = 2.6) and turn-taking condition (M = 2.4) (*p* = 1.0), while older adults were less likely to endorse this item in the turn-taking condition (M = 2.1) compared to the free-for-all condition (M = 3.0) (*p* = .05).

(13) "My experience in the chatroom helped me to better evaluate where I stood relative to my learning goals"

Age was marginally related to item response, F(1, 81) = 2.70, *p* = .10. Younger adults were slightly more likely to agree with this item compared to their older counterparts ($M_{younger}$ = 3.5, M_{older} = 3.2). Collaboration condition was also marginally related to item response, F(1, 81)

= 3.72, *p* = .06. Those in the free-for-all collaboration condition (*M* = 3.5) rated this item slightly higher than those in the collaboration with turn-taking condition (*M* = 3.2). The interaction between age group and collaboration condition, however, did not significantly affect item responses, F(1, 81) = .83, *p* = .26.

(14) "The conversation in the chatroom was often irrelevant to the discussion questions."

The effect of age group was significant, F(1, 81) = 4.35, p = .04. Older adults (*M* = 2.3) were more likely to agree with this item than younger adults (*M* = 1.9). However, the effect of collaboration condition (F(1, 81) = 2.43, *p* = .12) and the age by collaboration condition interaction (F(1, 81) = 1.17, *p* = .28) were not significant.

(15) "I would have performed better on the test if I had reviewed the material by answering discussion questions on my own."

Responses to this question did not differ by age group (F(1, 81) = .00, *p* =.96), collaboration condition (F(1, 81) = 1.70, *p* =.20), or the interaction between the two variables (F(1, 81) = 1.50, *p* =.22).

(16) "We had adequate time to discuss the questions."

Responses were the same across experimental groups. Younger and older adults were equally likely to endorse this item, (F(1, 81) = 1.25, *p* = .27). Those in the free-for-all collaboration and collaboration with turn-taking condition responded similarly (F(1, 81) = 1.31, *p* = .26). Finally, the interaction between age group and collaboration condition did not predict item response, (F(1, 81) = 1.42, *p* = .24

(17) "I would have benefited more from the chatroom if we had gotten more time to discuss the material."

For this item, age ($F(1, 81) = .65$, $p = .42$), collaboration condition ($F(1, 81) = .07$, $p = .79$), and the age by collaboration condition interaction ($F(1, 81) = 1.56$, $p = .22$) did not influence responses.

(18) "I felt overwhelmed by the amount of information exchanged in the chatroom."

There were not any significant differences across experimental groups in terms of their response to this item. Younger and older learners ($F(1, 81) = .09$, $p = .76$), those in the free-for-all collaboration condition and those in the collaboration plus turn-taking condition ($F(1, 81) = .15$, $p = .70$) responded similarly. Additionally, the interaction between age group and collaboration condition did not affect item ratings ($F(1, 81) = 1.73$, $p = .19$). See Table 17 for a summary of these results.

This survey provided an indication of how subjects' chatroom experience varied depending on their age and collaboration condition (free-for-all collaboration vs. collaboration with turn-taking). From these analyses, I gleaned the following conclusions: 1) Overall, older adults had a more negative perception of the chatroom experience compared to their younger counterparts. For example, older adults were less likely to endorse statements such as, *"Feedback from others in the chatroom helped to curtail errors in my own thinking,"* and *"During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom."* 2) The turn-taking protocol yielded advantages as well as disadvantages to learners. For example, while learners in the turn-taking condition were less likely to report that they had difficulty synthesizing material in the chatroom, they also less likely to report that the chatroom helped them learn. These results might explain why, on balance, turn-taking did not influence most learning outcomes and only had a marginally negative effect on one learning outcome. 3) There was an interaction between age and collaboration condition such that younger adults reported significantly lower accountability in the turn-taking condition compared to the free-for-all collaboration condition while older adults reported similar levels of accountability in both collaboration conditions. Furthermore, older adults in the turn-taking condition reported marginally higher levels of accountability compared to younger adults in the turn-taking condition. There was also a marginally significant interaction between age group and collaboration condition in terms of how participants much difficulty participants had synthesizing the material. The interaction was such that younger adults reported similar levels of difficulty across both collaboration conditions and older adults reported less difficulty in the turn-taking condition compared to the free-for-all condition.

Factor Analysis on Chatroom Survey

After investigating age and collaboration condition effects on item-level responses, I sought to determine the overall factor structure of the chatroom survey. Combining survey data from Study 1 and Study 2, I assessed whether there were one or more common factors underlying responses to individual items. I first conducted a Maximum likelihood extraction with oblimin rotation on all 18 items. An oblimin rotation was appropriate because the factors were mildly to moderately correlated. Results indicated that there was a 4-factor solution based on the scree plot, the cumulative variance explained (49.5%), the pattern of item loadings, and dimension interpretability. The emergent dimensions were 1) time to discuss in the chatroom, 2) cognitive load, 3) memory cues, and 4) engagement. However, I identified four problematic items that loaded below .4 and/or increased subscale reliability when deleted. These 4 items were deleted, yielding a 14-item scale. Below I present descriptive statistics, reliability, and validity evidence for the final 14-item scale.

Descriptive Statistics.

Table 18 shows the range, mean, standard deviation, and sample size for each of the subscales. The means were not extreme (ranging from 2.24 and 3.60 on a 5 point scale) and there was considerable variance within scales (standard deviations ranged from .63 to .87).

Reliability.

Results generally supported the internal consistency and precision of the subscales. Cronbach's alphas were .64 (2 items), .81 (4 items), .80 (3 items), and .81 (5 items), for the time to discuss, cognitive load, memory cues, and engagement subscales, respectively. Item-total correlations within the subscales ranged from .47 to .75. Table 19 shows the internal consistencies and inter-subscale correlations.

Validity.

Maximum likelihood extraction with oblimin rotation and four fixed factors yielded psychometrically sound and interpretable results. Cumulative variance explained with this 4-factor solution was 57.7%. A pattern matrix with individual item loadings is presented in Table 20.

Chatroom Survey Results at the Subscale Level

After solidifying the structure of the scale, I examined the influence of age and collaboration condition on perceptions of the chatroom learning experience in Study 2. Results were as follows:

Adequate Time to Discuss.

This factor did not produce any differences across experimental groups. The effect of age was non-significant, $F(1, 81) = 1.23$, $p = .27$, the effect of collaboration condition was not significant, $F(1, 81) = .62$, $p = .43$, and the age by collaboration condition interaction ($F(1, 81) = 2.02$, $p = .16$) was not significant.

Cognitive Load.

Here, the effect of age was not significant $F(1, 81) = .09$, $p = .76$ and neither was the effect of collaboration condition, $F(1, 81) = 2.57$, $p = .11$. There was, however, a marginally significant interaction of age and collaboration condition on cognitive load, $F(1, 81) = 2.85$, $p = .10$. Follow-up Bonferroni t-test revealed that, while there was not a significant difference in terms of how younger adults rated this item across collaboration conditions ($p = 1.0$) ($M_{free\ for\ all} = 2.27$; $M_{turntaking} = 2.29$), older adults rated this item *slightly* lower in the turn-taking condition compared to the free-for-all condition ($p = .15$) ($M_{free\ for\ all} = 2.50$; $M_{turntaking} = 1.96$). This *p* value did not reach significance, but the pattern of data suggests older adults reported slightly less cognitive load in the turn-taking condition compared to the free-for-all condition.

Memory Cues.

There was a main effect of age such that younger adults were more likely to endorse this item ($M_{younger} = 3.85$) compared to older adults ($M_{older} = 3.38$), $F(1, 81) = 11.68$, $p = .00$. The effect of collaboration condition, $F(1, 81) = 2.44$, $p = .12$, and interaction between age and collaboration condition, $F(1, 81) = .06$, $p = .81$, however, were not significant.

Engagement.

Analyses revealed that there was not a significant difference between age groups in terms of their engagement, $F(1, 81) = .01$, $p = .94$. A main effect of collaboration condition did emerge, $F(1, 81) = 3.90$, $p = .05$, such that those in the turn-taking condition were significantly less engaged ($M_{turn\text{-}taking}$ = 3.45) compared to those in the free-for-all collaboration condition ($M_{free\ for\ all}$= 3.71). The interaction between age group and collaboration condition was non-significant, $F(1, 81) = .00$, p =.99.

In summary, the survey analysis revealed the following: First, there was a marginally significant interaction between age and collaboration condition indicating that, while younger adults reported similar levels of cognitive load across collaboration conditions, older adults experienced slightly less cognitive load in the turn-taking condition compared to the free for all condition. Second, compared to older adults, younger adults were more likely to report that the collaboration intervention cued their memory for training content. Finally, analyses revealed that those in the turn-taking condition were significantly *less* engaged during learning compared to those in the free-for-all collaboration condition.

GENERAL DISCUSSION

The purpose of this study was to examine the effect of technology-supported collaboration on learning outcomes of older and younger adults, with an intent toward answering the broader question: Do we need to design computer-based training differently for older adults compared to younger adults? I expected that technology-mediated collaboration would sustain or facilitate learning for younger adults and hinder learning for older adults. I was also interested in turn-taking as a strategy for bolstering learning in the chatroom. I expected that turn-taking would improve learning outcomes for both age groups, but benefit older adults to a greater extent, lessening age-related performance differences after collaboration.

In Study 1, older and younger adults listened to an audiovisual training and then reviewed concepts either individually or in a chatroom with other trainees. Consistent with findings in the existing literature (Kubeck et al., 1996), analyses revealed that older adults performed worse on the transfer measure compared to their younger counterparts. Additionally, older adults reported more negative perceptions of the chatroom environment. The age by instructional design manipulation interaction was not significant.

With Study 2, I modified the TMC context to strengthen the manipulation by, for example, adding instructions about how to effectively communicate and incorporating avatars into the chatroom. I then re-investigated the relationship between computer-supported collaboration and learning outcomes across age groups. I also examined turn-taking as a method for improving learning performance in the chatroom and closing the performance gap between older and younger adults. I first examined the effect of age group and instructional design manipulation (individual vs. collaboration with free-for-all collaboration and turn-taking combined into one collaborative condition) on training outcomes. Results were the following:

1) Younger adults demonstrated superior performance on the recognition outcome measure compared to older adults. This finding of an age-related training performance decrement has been persistent in the literature (Elias et al., 1987; Kubeck et al., 1996). For example, Kubeck et al.'s meta-analytic review showed that, across a wide variety of occupations and training tasks, older adults required more time to complete training programs and exhibited worse performance on training-related outcome measures compared to younger adults. This is presumably because older adults experience a host of cognitive declines (e.g., slower processing speed, decreased working memory capacity, increased distractibility (Connelly et al., 1991; Salthouse, 2004), and therefore, struggle to efficiently select, organize, and integrate novel, especially complex, information into memory.

2) TMC had a *facilitative* effect on the transfer performance of older adults but did not influence transfer performance for younger adults. In effect, TMC reduced the learning gap between older and younger trainees. Though not significant, the same pattern of effects emerged on the recognition outcome. This finding certainly did not align with expectations but could have emerged for a variety of reasons.

First, the topic was relatively simple in that learners had to remember singular pieces of information rather than coordinate and integrate information. Initially, I argued that the chatroom would exacerbate age-related cognitive and motivational changes and therefore, hurt learning among older adults. However, if the material is straightforward and learners simply need to repeat units of information, the challenges inherent in the chat tool might be less likely to have a debilitating effect. For example, research shows that older adults have more difficulty forging connections between units of memory (Naveh-Benjamin, 2000) and therefore, might struggle in a chatroom environment where they are required to integrate a series of disjointed comments into a coherent knowledge structure. However, if the training content itself is simple, regardless of how incoherent the discussion thread is, learners can extract the information they need to perform well on the test. Furthermore, if learners are not required to integrate information in a sophisticated manner, then they have more time to rehearse. In effect, it may be that the simplicity of the material afforded them more time to transfer information into long term memory.

Second, because communication is a central part of life, it is probable that older participants, simply by virtue of their age and life experience, had higher levels of prior knowledge about the training topic compared to younger participants. In a chatroom forum where learners can share new information and experiences, this background knowledge likely provided a foundation for the integration and meaningful processing of new material, helping older adults to assimilate more information into memory. There is ample research showing that experience and prior knowledge are strong positive predictors of knowledge acquisition (e.g., Beier & Ackerman, 2005; Charness et al., 2001; Chase & Simon, 1973). For example, Charness et al. conducted a study of training for word processing software and found that the extensiveness of experience with software strongly and positively influenced learning. Chase and Simon compared expert and novice chess players in terms of their memory for the placement of chess pieces on a chessboard. They found that while experts and novices did not differ with respect to their memory for randomly-placed pieces, experts significantly outperformed novices when pieces were placed strategically, in a way that they might appear during a regular chess game. The idea here is that those with more prior information can more effectively "chunk" new information and in this way, incorporate more information into their existing knowledge structure. For older adults, this prior knowledge might not have been brought into conscious awareness when they were in the individual condition, but with the right learning aid, surfaced and facilitated the anchoring of information in memory. Future researchers should attempt to replicate this study using a topic with which participants do not have a lot of experience.

Third, this interaction effect might have emerged because there were certain key training features providing social and instructional support that may have been particularly helpful for older adults. These features include a moderator, who was present in the chatroom to help direct discussion and integrate material on behalf of the group members. Furthermore, Study 2 added avatars, an icebreaker activity, a shortened, more concise training program, and detailed instructions on how to effectively communicate. These instructional features target the needs of older populations, in particular, who require more structure (Beier, Teachout, & Cox, 2012; Wolfson et al. in press;) and instructional support (Craik, 1986), and feel less efficacious in their ability to operate technology compared to younger adults (Charness & Czaja, 2006). Future researchers might consider eliminating these features and re-assessing the relationship among age, online collaboration, and learning performance to see if the same findings re-surface.

Finally, the chatroom experience of Study 2 was different from Study 1 in that learners were not given a time restriction for their discussion. The secretary ensured that learners had an opportunity to provide their input and were comfortable with the group response before they moved to the next question. In this way, participants could more effectively self-pace and maintain a sense of control over their learning. Research suggests that older adults require more time to complete training (Kubeck et al., 1996). When older trainees can control the amount of time spent on each portion of instruction, their performance enhances and age differences in learning performance may dissipate (Beier & Ackerman, 2005; Callahan, Kiker, & Cross, 2003; Meyer, 1987). In fact, Callahan et al.'s meta-analysis, which examined the impact of various instructional features on learning outcomes among older adults, found that self-pacing accounted for the greatest proportion of observed variance in training performance. Self-pacing accommodates cognitive deficits such as reduced cognitive speed and allows older learners to more effectively integrate incoming information into memory.

3) Learners' reactions to the training differed depending on their age and the reaction outcome of interest. Across both instructional design conditions, younger adults reported higher technology satisfaction and older adults reported greater enjoyment of the training. Given the existing literature which suggests that older adults feel less comfortable around technology and more negative about the amount of effort required to interact with technology (Czaja & Lee, 2003; Marquié et al., 2002), the age difference in technology satisfaction was expected. Older adults, however, reported greater enjoyment of the training as a whole. Socioemotional selectivity theory (Carstensen, 1995) suggests that older adults, because of their limited time perspective, will pursue emotional goals (e.g., strengthening their relationships) over cognitive goals (e.g., gaining knowledge). While the training content (communication) was designed to appeal to both of these goals, perhaps the relationship between communication and satisfaction in personal relationships was more immediately apparent and therefore, the topic became more inherently interesting to older adults.

<u>Within the collaboration conditions</u>, results were as follows:

4) Compared to free-for-all collaboration, turn-taking slightly hindered recall performance. This finding was contrary to expectations (and contrary to propositions by Soller et al., 1998). While my intent with the turn-taking protocol was to slow down communication and help learners more deeply encode training content into memory, turn-taking may have slowed communication down too much and actually hurt learning. Analyses revealed that those in the

turn-taking group produced significantly fewer words per minute in their chatroom conversation compared to those in the free-for-all collaboration condition. Cognitive load theory suggests that the relationship between cognitive load and learning takes on an inverse U shape; that is, very low levels of cognitive load produce low levels of learning and learning increases in relation to increases in load until learners reach their optimal level of load. After this point, learning diminishes with increased levels of load because the material begins to impose excessive demands on the learner (Brunken, Plass, & Moreno, 2010). Turn-taking may have reduced cognitive load to the point where it hampered learning.

5) Younger adults reported more satisfaction with the technology compared to older adults. This finding replicates previous research showing that older adults feel less comfort with and less interest in technology (Czaja & Lee, 2003; Ellis & Allaire, 1999; Marquié et al., 2002).

6) Despite the fact that the chatroom facilitated learning for older adults, they still reported more negative perceptions of this learning tool in a follow-up survey. For example, compared to younger adults, older adults were less likely to report that collaboration cued their memory for training content. Trainees often have only moderately accurate perceptions of their own learning (particularly when the assessment is close to the training event) and of what and how to best learn (Bell & Kozlowski, 2002; Falchikov & Boud, 1989; Kraiger & Jerden, 2007; Rhodes & Tauber, 2011). There is also evidence to suggest that older adults may be more sensitive to memory failures and overly negative when evaluating their memory performance (e.g., Cavanagh, Grady, & Perlmutter, 1983; Cavanagh & Morton, 1989). These survey results might reflect this disconnect between how much participants *actually* learned and how much they *think* they learned.

7) According to the follow-up survey, learners in the turn-taking condition reported *lower* engagement compared to those in the free-for-all condition. For example, they reported lower motivation, empowerment, and accountability compared to those in the free-for-all condition. As explained earlier, there is an inverse U relationship between cognitive load and learning such that moderate levels of load optimize learning performance. Results suggested that those in the turn-taking condition produced significantly fewer words per minute, and perhaps turn-taking diminished load too much. Furthermore, turn-taking encourages autonomous action, which may have increased learners' anxiety, and in turn, reduced their processing effectiveness and engagement. These survey results might explain why turn-taking had a mild negative impact on recall performance.

8) Finally, the survey revealed that, contrary to expectations, turn-taking in the online collaborative environment did not increase learners' sense of accountability and, for younger adults, actually decreased their reported sense of accountability. There was also a marginally significant interaction between age and collaboration condition in terms of how participants much difficulty participants had synthesizing the material. Younger adults reported similar levels of difficulty across both collaboration conditions and older adults reported less difficulty in the turn-taking condition compared to the free-for-all condition. These finding might explain why there was a trend toward older adults outperforming younger adults in the turn-taking condition on the transfer outcome. While this trend was not significant, the effect size of this difference was moderate (d =.75) according to Cohen's (1988) proposed rule of thumb.

Practical and Theoretical Implications

One of the most important and surprising contributions of this paper was the finding that, compared to individual instruction, chatroom-based collaboration helped learning for older adults while sustaining levels of learning for younger adults. Assuming that this age by design manipulation interaction is replicated in future research, this finding has important practical and theoretical implications. Practically, this result suggests that developers of computer-based training programs should consider the age composition of their trainees before they make decisions regarding instructional design. If trainees are mostly older adults, practitioners might find it worthwhile to implement a chat tool because this tool has been shown to improve performance for this age group. However, if trainees are mostly younger adults, the choice between individual training and group training is less significant and practitioners could simply choose the option that is most cost-effective.

This age by instructional design interaction also has implications for how researchers and practitioners utilize the existing body of training research findings. The vast majority of training studies within the past several decades have used college samples (see Sitzmann, Kraiger, Stewart, & Wisher’s 2006 training meta-analysis which found a mean age across participants of 24). However, based on the data trend of this study, researchers and practitioners should be careful about extrapolating the results of these studies to older learners (cf., Beier et al., 2012). Instead, researchers should continue to pursue and draw more heavily from this line of research comparing older and younger adults in a training environment.

From a theoretical perspective, the finding that computer-supported collaboration facilitated learning for older adults and sustained levels of learning for younger adults bolsters propositions by authors who suggest that age and design principle interact in an *ordinal* fashion to predict learning performance (Van Gerven et al., 2006). In other words, when older and younger adults respond differently to the same instructional feature, the difference is usually in terms of the magnitude of the effect rather than the direction. Even though the interaction between age group and instructional feature was ordinal, the fact that younger adults maintained levels of learning across conditions and older adults did not suggests that there is something fundamentally different about how older adults and younger adults process and integrate information while learning. Future researchers should pursue more research with older learners to determine which instructional principles have similar learning effects across age groups and which instructional principles vary in magnitude or direction across age groups (see Wolfson et al., in press.)

Another interesting finding of this study that ran contrary to predictions was that turn-taking slightly hurt recall performance. Even though those in the turn-taking condition had decreased efficiency of communication– i.e., learners produced fewer words per minute - suggesting that turn-taking decreased cognitive load, they reported less engagement during learning. Taken together, these findings indicate that reducing cognitive load may not always increase learning. While it is important to eliminate extraneous or irrelevant load as much as possible, instructional designers should work toward using working memory capacity to its full extent with relevant load. Practically, the turn-taking result suggests that instructional designers should be cautious about employing turn-taking protocols in chatrooms because it may have some negative implications for learning performance.

Lastly, the pattern of results in this study is consistent with more general findings that the effects of training interventions are often specific to certain learning outcomes (Ford, Kraiger, & Merritt, 2010). That is, in this study, different learning outcomes were differentially affected by instructional design manipulations or trainee characteristics. For example, the main effect of age emerged only with the recognition and trainee reaction outcomes and the interaction between age and collaboration predicted transfer, but not recall or recognition performance. Within the collaboration conditions, turn-taking only influenced recall performance of all six training outcomes. Future researchers should be prudent about choosing learning outcome measures that are sensitive and *related to the intervention*. That way, they will more likely detect effects of instructional principles when they do exist.

Limitations and Directions for Future Research

This study has limitations with regard to the participant sample, training content, outcome measures, and the design of the training itself. First, the sample raises generalizability concerns. I was able to gather employment data from a majority of both younger and older participants. Most of the younger participants were undergraduates or masters-level students and, while a significant proportion of them were employed, many of these positions were part-time and probably not career-oriented. It is worth mentioning that, according to Campbell (1986), students likely learn in a similar manner to employees, so the students' performance on the outcome measures was at least comparable to the performance of those in the working population. Similarly, the older adults in this study were not recruited directly from a working population and a significant proportion of them were retired. To increase confidence in the external validity of these findings, future researchers should attempt to repeat this study using a sample of younger and older adults who are employed. It might also be interesting to examine the effect of this kind of computer-based training program among younger and older employees with similar education levels. In this study, 34.9% of older adults had earned a master's or PhD, compared to 3.3% of younger adults. This difference between the two subject pools might explain why younger adults (who are perhaps not as adept at utilizing effective learning strategies or taking advantages of learning aids) did not benefit from collaboration and older adults did.

Second, the training content, while inherently interesting to most participants, has some limitations. As mentioned earlier, because communication is a central part of life, it can be assumed that most of the participants probably had high-levels of prior knowledge about the training topic (and arguably, that older adults had more prior knowledge than their younger counterparts). Kraiger and Jerden (2007) suggested that learners' level of task experience moderates the effectiveness of training design manipulations. Therefore, it could be the case that when learners have less experience with a training topic, they might rely more heavily on the learning aids and this is where we might see the effect of the learning tool accentuated. Future researchers should attempt to replicate this study using a topic with which participants do not have a lot of experience.

Another issue with the training content is that the material was simple. Learners simply had to remember distinct units of information rather than join up interrelated pieces of information into an intricate mental model. In future studies, researchers might explore a more complicated topic and see how performance varies by manipulation across age groups. We know that older adults have more difficulty building connections between units of memory. Therefore, it is reasonable to expect that complicated training material would pose greater cognitive load on the processing capacity of older adults, leaving them with fewer resources to overcome the challenges of a chatroom-based learning environment. With complicated training material, I might be more likely to find the results I was originally expecting. That is, unassisted (free-for-all) collaboration would aid learning for younger adults and diminish learning for older adults. Additionally, one might expect that because older adults have more room for improvement, that chatroom learning tools (such as a moderator, turn-taking, prompting, etc.) help older adults to a greater extent.

In terms of the training design itself, one limitation is the fact that the training was unproctored. An implication of this is that I could not control certain variables including participants' level of distraction, cheating, noise, etc. The assumption here was that these kinds of issues are relatively equivalent across instructional conditions, so they essentially wash out. In future research, however, experimenters might consider inserting "checks" or monitoring tools to insure that participants are completing the training according to specified guidelines. One example of such tools is a webcam enabling remote proctoring.

Furthermore, this study is limited in that I considered just one form of many potential collaborative technologies – chatrooms. Future researchers could examine the efficacy of different forms of collaborative technology across older and younger adults. Examples of different collaborative tools include mind mapping for creative thinking, video-based collaboration, collaborating in front of the same computer, computer system itself serving as the collaborating "partner". On a related note, future researchers could also consider the age composition of the group, pre-existing relationships among group members, as well as types of collaborative tasks that most enhance later individual performance. Hiltz and Turoff (2002) suggested that collaborative activities likely to enhance learning in an online context include debates, simulations, and collaborative writing exercises and it is worthwhile to determine the impact of these exercises across age groups. Through these efforts, we can get a more sophisticated understanding of the kind of collaborative training environment that is most well-suited for each age group.

The final limitation of this study is that learning was assessed using three of many potential learning measures. Researchers suggest that learning is multidimensional (Ford et al., 2010; Kraiger, 2002; Kraiger et al., 1993), and while I did focus on those learning outcomes which were highly relevant to the training program, future researchers could examine the effect of these instructional principles on different outcomes such as transfer behavior (perhaps assessed more objectively from the perspective of people with whom they've communicated) and long term retention. Schmidt and Bjork (1992) noted that there might be temporary effects of training manipulations such that performance differences arise immediately after training but dissipate or alter significantly after a period of time, once learners have been allowed to rest. By testing the relationship between age, instructional principles and different learning outcomes, researchers can gain a more fine-tuned understanding of how to design computer-based instruction depending on the age of the learner and the learning outcome of interest.

Future research might also consider testing new potential mediators to the relationship between collaboration-learning performance relationship across age groups. I tested metacognition, motivation, and self-efficacy to no avail. However, there are other potential mediators including state learning goal orientation or increased arousal. These kinds of studies are likely to shed light on the mechanisms underlying learning processes across age groups.

In this study, I used theory and logic to choose an instructional design manipulation that I thought might produce age-specific learning effects. Future researchers might also consider more innovative methodologies for determining how older adults interact with computer-based tools. One suggestion to propel the field forward is to operate in a reverse fashion and use grounded theory. That is, to allow the data to inform theory-building. This might involve an experimenter sitting with older adults and younger adults separately as they interact with new training programs or instructional tools. The experimenter might interview them or have them verbally report their questions or concerns as they progress through the program. This kind of process is similar to one originated by Roos, Dickinson, Goodman, Mival, Syme, and Tiwari (2003) of the

UTOPIA (Usable Technology for Older People: Inclusive and Appropriate) project called "mutual inspiration" and has the potential to spawn interesting new research questions. Another suggestion is to use neurocognitive measures such as EEG or fMRIs to see if older and younger adults activate different brain regions when they interact with particular computer-mediated learning tools. This kind of methodology is likely to lend insight into the question of whether there is something fundamentally different about how older and younger adults process and integrate computer-based training information.

Though not without limitations, this study generated some interesting (and at times, surprising!) findings. First, age significantly predicted recognition performance such that younger adults did better than older adults. Second, age and instructional design condition (individual vs. collaboration) interacted to predict transfer performance. While younger learners performed similarly in the individual and the collaboration condition, older adults achieved significant performance improvements in the collaboration condition compared to the individual condition. What is more, this collaborative tool helped eliminate age-related performance differences between older and younger adults that existed in the individual condition. While not significant, the same pattern of findings was evident on the recognition measure. Third, while younger adults reported more satisfaction with the technology, older adults reported greater enjoyment of the training. Fourth, within the collaboration conditions, turn-taking was slightly detrimental to recall performance. Finally, there was a disconnect between learners' *actual* learning in the chatroom and their *perception* of their learning in the chatroom. That is, compared to individual learning, computer-supported collaboration improved performance for older adults and only sustained levels of learning for younger adults, yet older adults were less likely to report that collaboration cued their memory for training content. Perhaps the most important implication of this study is it bolsters the proposition that older and younger adults may require different instructional formats.

Table 1

Implications of Age-Related Changes for Performance in a Chatroom Training Context

Age-Related Cognitive or Socio-Emotional Change	**Implication for Older Adults in a Chatroom Context**
• Reduced cognitive speed (Salthouse, 2004)	Older adults need self-pacing to accommodate this decline. In chatrooms, individuals have minimal control over the discussion pace and therefore, it can be expected that older adults would struggle more than younger adults in this training context.
• Reduced working memory capacity (Bopp & Verhaeghen, 2005)	In a chatroom, learners need to extract meaning from often disjointed and tangential series of comments. Because learners need to hold information in memory as well as read new messages and compose responses, this requirement may impose excessive load on older learners who tend to have less working memory resources.
• Increased distractibility (Connelly, Hasher, & Zacks, 1991)	If group members recall false information, older learners might have difficulty screening this information out of consciousness. Ultimately, they may incorporate more errors into their thinking.
• Reduced ability to coordinate and integrate information. Included in this category is decreased ability to recollect the source of information (Dywan & Jacoby, 1990; Rabinowitz, 1989; Naveh-Banjamin, 2000).	Conversations are often more disjointed in a chatroom compared to an individual review or free-flowing conversation. Older adults will have particular difficulty integrating and coordinating information presented in a chatroom to form a cohesive mental representation of the training content. Also, because older adults exhibit reduced source monitoring, it might be expected that if chatroom collaborators recall false information, older adults may have difficulty remembering if this information was presented in the audiovisual presentation or erroneously recalled by another learner. There is potential here for older adults to integrate false information into their understanding of the material.

• Reduction in some forms of metacognition (Touron & Hertzog, 2004)	Research suggests that metacognitive learning aids such as chatroom discussions are effective among older adults if learners can self-pace throughout instruction (Dunlosky, Kubat-Silman, and Hertzog, 2003)). In chatrooms, individuals have minimal control over the discussion pace and therefore, it is expected that older adults will continue to exhibit reduced metacognition and this will hurt their learning.
• Heightened tendency to falsely recall and recognize items (Meade & Roediger, 2009)	This tendency to falsely recall items could worsen the social contagion of memory effect among older adults in a chatroom environment. The social contagion of memory effect occurs when group members incorporate others' erroneous thoughts into their own understanding of the material (Roediger, Meade, & Bergman, 2001).
• Pursuit of emotion-related goals (less likely to pursue knowledge-related goals) (Carstensen, 1995) • Heightened need to protect self-image (Kanfer & Ackerman, 2004)	Not only are older adults less likely to be interested in a chatroom discussion of training concepts, but they may also find this social learning environment more threatening to their self-image (compared to an individual review session). These two elements are likely to cause older learners to withdraw from discussion and reap less benefit from the interaction compared to younger adults.

Table 2

Demographic Information for Study Sample

	Younger Adults (n = 56)	Older Adults (n = 48)
Gender		
Men	48.2%	31.3%
Women	51.8%	66.7%
Education		
Did not complete High School		
High School Degree	94.6%	25.0%
Bachelor's Degree	5.4%	31.3%
Master's Degree		25.0%
Ph.D.		16.7%
Computer Use		
Hardly ever		
Once a month		
Once a week	1.8%	
Every day	98.2%	97.9%

Table 3

Descriptive Statistics and Intercorrelations among Study Variables

Variable	**M**	**SD**	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Online Chat Experience	2.90	1.30	___	.12	.27**	-.24*	-.08	.01	.09	.01	-.01	-.06	.16	.06	.21*
2. Training Self Efficacy	5.70	0.89		___	.28**	-.43**	.16	.18	.08	.19	-.14	.16	.08	-.02	03
3.Computer Usage and Experience	4.50	0.51			___	-.68**	.18	-.02	-.03	.08	-.22*	.07	15	-.10	.14
4.Computer Anxiety	2.01	0.50				___	-.19*	-.02	-.02	-.23	.17	-.22*	-.20*	-.02	-.12
5. Health	3.92	.48					___	.29**	.20*	.42**	-.48**	.05	.03	.07	-.06
6. Extraversion	3.39	.98						____	.07	19	-.22*	.26**	-.11	-.05	-.22*
7. Agreeableness	4.00	.59							___	.45**	-.47**	.37**	-.05	.15	-.16
8.Conscientiousness	4.06	.59								___	-.52**	.28**	.13	.17	-.07
9. Neuroticism	2.44	.85									___	-.26**	.02	-.01	.16
10. Openness to Experience	3.77	.66										___	.08	.17	-.12
11. Working Memory	8.13	4.12											___	.12	.34**
12. Recall	15.36	8.99												___	.47**
13. Transfer	9.16	5.99													___

Table 4

Cell Means and Standard Deviations for Dependent Variable, Recall

	Mean	SD	n
Young Learner			
No Collaboration,	13.3	10.1	26
Collaboration	16.0	9.7	30
Older Learner			
No Collaboration	16.6	8.7	25
Collaboration	15.4	6.9	23

Table 5

Cell Means and Standard Deviations for Dependent Variable, Transfer

	Mean	SD	n
Young Learner			
No Collaboration,	10.9	7.1	26
Collaboration	11.9	5.0	30
Older Learner			
No Collaboration	6.6	4.9	25
Collaboration	6.4	4.8	23

Table 6

Results of Independent Samples T-Test for Chatroom Survey at Item Level (Study 1)

Item	Younger Adult Mean	Younger Adult SD	Older Adult Mean	Older Adult SD	T-test
The information other participants presented triggered the recall of new information that would not have been available to me if I was answering questions on my own.	4.0	.8	3.4	.9	2.35**
Feedback from others in the chatroom helped to curtail errors in my own thinking.	3.5	1.0	3.0	.9	1.79*
During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom.	4.0	.9	3.3	.8	2.80**
My experience in the chatroom helped me to better evaluate where I stood relative to my learning goals.	3.5	.9	3.1	.8	1.74*
During the online chat, the input of other group members disrupted my own ability to recall information.	2.3	1.1	2.4	.9	*Ns*
I felt empowered during the chatroom discussion	3.3	1.0	3.4	.8	*ns*
I felt accountable for participating in the online discussion.	3.8	.9	4.1	.5	*ns*
Discussing the material in an online chatroom helped me learn.	3.6	.9	3.6	.9	*ns*
I withheld ideas in the chatroom because I was worried that others would think I was stupid.	2.0	.7	1.9	.7	*ns*

I felt free to challenge others' ideas in the chatroom.	3.5	.9	3.4	.8	*ns*
I was motivated to learn from others in the chatroom.	3.6	.8	3.6	.7	*ns*
Others provided their input too quickly, so it was hard for me to keep up with the conversation in the chatroom.	2.2	1.0	2.4	1.0	*ns*
It was difficult to synthesize all of the information presented in the chatroom.	2.5	1.0	2.4	.9	*ns*
I would have performed better on the test if I had reviewed the material by answering discussion questions on my own (rather than with others).	2.9	1.1	2.7	1.0	*ns*
I would have benefited more from the chatroom if we had gotten more time to discuss the material.	2.5	1.1	2.8	1.1	*ns*
I felt overwhelmed by the amount of information exchanged in the chatroom.	2.1	1.0	2.0	.7	*ns*
The conversation in the chatroom was often irrelevant to the discussion questions.	1.8	.7	2.1	.7	*ns*
We had adequate time to discuss the questions.	4.0	1.0	3.7	.9	*ns*

Note. ** = p level of less than .05; * = p level of less than .10; ns = not significant.

Table 7

Demographic Information for Sample in Study 2

	Younger Adults (*n* =*91*)	Older Adults (*n* =*86*)
Gender		
Men	36.3%	36.0%
Women	58.2%	60.5%
Education		
Did not complete High School	0.0%	2.3%
High School Degree	73.6%	31.4%
Bachelor's Degree	17.6%	27.9%
Master's Degree	3.3%	30.2%
Ph.D, JD, DDS, or MD (or equivalent)		4.7%
Computer Use		
Hardly ever	0.0%	1.2%
Once a month	2.2%	0.0%
Once a week	1.1%	4.7%
Every day	91.2%	90.7%
Employment Status		
Employed full time	8.8%	22.1%
Employed part time	35.2%	24.4%
Unemployed	13.2%	5.8%
Retired	0.0%	34.9%
Missing	42.9%	12.8%

Table 8

Descriptive Statistics and Intercorrelations among Study Variables with the Entire Sample (n =177)

Variable	Mean	SD	1	2	3	4	5	6	7
Recall	16.9	10.8	-						
Transfer	6.4	4.4	.54	-					
Recognition	1.3	1.1	.24	.42	-				
Tech Satisfaction	3.8	.9	-.03	-.09	.02	-			
Enjoyment	3.5	.8	.11	-.02	.05	.42	-		
Relevance	4.0	.6	.22	.16	.15	.37	.54	-	
Transfer Intentions	4.0	.6	.18	.10	.10	.42	.59	.73	-

Table 9

Cell Means and Standard Deviations for Dependent Variable, Recall

	Mean	SD	n
Young Learner			
Individual	17.4	11.0	46
Collaboration	17.0	10.6	24
Collaboration + Turn-taking	12.0	5.6	21
Older Learner			
Individual	16.7	11.6	45
Collaboration	20.1	10.6	23
Collaboration + Turn-taking	17.5	12.6	18

Table 10

Cell Means and Standard Deviations for Dependent Variable, Transfer

	Mean	SD	n
Young Learner			
Individual	7.5	4.3	46
Collaboration	6.6	4.2	24
Collaboration + Turn-taking	5.1	2.7	21
Older Learner			
Individual	4.7	3.7	45
Collaboration	6.8	4.1	23
Collaboration + Turn-taking	8.6	6.7	18

Table 11

Cell Means and Standard Deviations for Dependent Variable, Recognition

	Mean	SD	n
Young Learner			
Individual	1.4	1.1	40
Collaboration	1.4	1.2	20
Collaboration + Turn-taking	1.6	1.0	20
Older Learner			
Individual	0.9	0.9	41
Collaboration	1.4	1.2	20
Collaboration + Turn-taking	1.2	1.2	16

Note. d' cannot be calculated when there are hit or false alarm rates of 1 or 0 so data from 20 participants is missing for this variable.

Table 12

Cell Means and Standard Deviations for Dependent Variable, Technology Satisfaction

	Mean	SD	n
Young Learner			
Individual	4.0	.6	46
Collaboration	3.9	.8	24
Collaboration + Turn-taking	4.0	.9	21
Older Learner			
Individual	3.9	.8	45
Collaboration	3.6	1.1	23
Collaboration + Turn-taking	3.2	1.2	18

Table 13

Cell Means and Standard Deviations for Dependent Variable, Training Enjoyment

	Mean	SD	n
Young Learner			
Individual	3.4	.9	46
Collaboration	3.3	.9	24
Collaboration + Turn-taking	3.4	1.0	21
Older Learner			
Individual	3.8	.8	45
Collaboration	3.7	.6	23
Collaboration + Turn-taking	3.4	.8	18

Table 14

Cell Means and Standard Deviations for Dependent Variable, Training Relevance

	Mean	SD	n
Young Learner			
Individual	3.9	.6	46
Collaboration	4.0	.6	24
Collaboration + Turn-taking	4.1	.6	21
Older Learner			
Individual	4.1	.6	45
Collaboration	3.9	.6	23
Collaboration + Turn-taking	4.0	.6	18

Table 15

Mean Time for Review Per Condition

Condition	*Time for Review*
Younger, Individual	21.7 min
Younger, Free-for-all Collaboration	32.9 min
Younger, Turn-Taking Collaboration	40.6 min
Older, Individual	24.0 min
Older, Free-for-all Collaboration	34.5 min
Older, Turn-Taking Collaboration	43.9 min

Table 16

Mean Learning Scores By Group Size

Group Size	*Recall*	*Transfer*	*Recognition*
4	17.9	8.0	1.6
5	17.4	6.7	1.6
6	14.1	5.7	1.1
7	18.8	7.2	1.4

Table 17

Results of ANOVAs for Chatroom Survey at Item Level (Study 2)

Item		*Df*	*F*	n^2	*p*
The information other participants presented triggered the recall of new information that would not have been available to me if I was answering questions on my own.	(A) Age Group	1	5.43	.06	.02**
	(B) Collab. Type	1	1.71	.02	.19
	AXB (interaction)	1	.18	.00	.67
	Error	81			
Feedback from others in the chatroom helped to curtail errors in my own thinking.	(A) Age Group	1	9.47	.11	.00**
	(B) Collab. Type	1	1.86	.02	.18
	AXB (interaction)	1	.03	.00	.87
	Error	81			
During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom.	(A) Age Group	1	7.81	.09	.01**
	(B) Collab. Type	1	1.20	.02	.28
	AXB (interaction)	1	.64	.01	.43
	Error	81			
My experience in the chatroom helped me to better evaluate where I stood relative to my learning goals.	(A) Age Group	1	2.70	.03	.10*
	(B) Collab. Type	1	3.72	.04	.06*
	AXB (interaction)	1	1.31	.02	.26
	Error	81			
During the online chat, the input of other group members disrupted my own ability to recall information.	(A) Age Group	1	.22	.00	.64
	(B) Collab. Type	1	.04	.00	.85
	AXB (interaction)	1	.18	.00	.67
	Error	81			
I felt empowered during the chatroom discussion	(A) Age Group	1	.00	.00	.96
	(B) Collab. Type	1	.98	.01	.33
	AXB (interaction)	1	.72	.01	.40
	Error	81			
I felt accountable for participating in the online discussion.	(A) Age Group	1	1.79	.02	.19
	(B) Collab. Type	1	1.70	.02	.20
	AXB (interaction)	1	6.54	.08	.01**
	Error	81			
Discussing the material in an online chatroom helped me learn.	(A) Age Group	1	1.08	.01	.30
	(B) Collab. Type	1	5.14	.06	.03**
	AXB (interaction)	1	.00	.00	.98
	Error	81			

I withheld ideas in the chatroom because I was worried that others would think I was stupid.	1	3.59	.04	.06*
	1	.31	.00	.58
	1	.78	.01	.38
	81			
I felt free to challenge others' ideas in the chatroom.	1	.19	.00	.67
	1	.31	.00	.58
	1	.00	.00	.97
	81			
I was motivated to learn from others in the chatroom.	1	2.25	.03	.14
	1	1.10	.01	.30
	1	.01	.00	.93
	81			
Others provided their input too quickly, so it was hard for me to keep up with the conversation in the chatroom.	1	.56	.01	.45
	1	2.75	.03	.10*
	1	2.43	.03	.12
	81			
It was difficult to synthesize all of the information presented in the chatroom.	1	.00	.00	.97
	1	5.06	.06	.03**
	1	2.74	.03	.10*
	81			
I would have performed better on the test if I had reviewed the material by answering discussion questions on my own (rather than with others).	1	.00	.00	.96
	1	1.70	.02	.20
	1	1.51	.02	.22
	81			
I would have benefited more from the chatroom if we had gotten more time to discuss the material.	1	.65	.01	.42
	1	.07	.00	.79
	1	1.56	.02	.22
	81			
I felt overwhelmed by the amount of information exchanged in the chatroom.	1	.09	.00	.76
	1	.15	.00	.70
	1	1.73	.02	.19
	81			
The conversation in the chatroom was often irrelevant to the discussion questions.	1	4.35	.05	.04**
	1	2.43	.03	.12
	1	1.17	.01	.28
	81			

We had adequate time to discuss the questions.	1 1 1 81	1.25 1.31 1.42	.02 .02 .02	.27 .26 .24

Note. ** = p level of less than or equal to .05; * = p level of less than or equal to .10

Table 18

Descriptive statistics for subscales

	Range	**Mean**	**SD**	**n**
Time to Discuss	4.0	3.4	.87	137
Cognitive Load	3.8	2.2	.74	137
Memory Cues	4.0	3.6	.72	137
Engagement	3.2	3.6	.63	137

Table 19

Internal consistencies and inter-subscale correlations

	F1	F2	F3	F4
Time to Discuss	*(.64)*			
Cognitive Load	-.20	*(.81)*		
Memory Cues	-.04	-.26	*(.80)*	
Engagement	.04	-.15	-.38	*(.81)*

Table 20

Exploratory Factor Analysis and Item-Subscale Correlations

Item	Item-Subscale Correlation	1	2	3	4
We had adequate time to discuss the questions.	.47	.80			
I would have benefited more from the chatroom if we had gotten more time to discuss the material.	.47	-.59			
Others provided their input too quickly, so it was hard for me to keep up with the conversation in the chatroom.	.75		.95		
It was difficult to synthesize all of the information presented in the chatroom.	.63		.70		
I felt overwhelmed by the amount of information exchanged in the chatroom.	.65		.62		
I withheld ideas in the chatroom because I was worried that others would think I was stupid	.53		.46	-.31	-.42
The information other participants presented triggered the recall of new information that would not have been available to me if I was answering questions on my own.	.71			-.84	
During the online discussion, I was re-exposed to information that I myself had forgotten prior to the chatroom	.66			-.81	
Feedback from others in the chatroom helped to curtail errors in my own thinking.	.57			-.52	

I was motivated to learn from others in the chatroom.	.73		.80
I felt accountable for participating in the online discussion.	.51		.72
I felt empowered during the chatroom discussion.	.59		.56
Discussing the material in an online chatroom helped me learn.	.69	-.42	.56
My experience in the chatroom helped me to better evaluate where I stood relative to my learning goals.	.50		.47

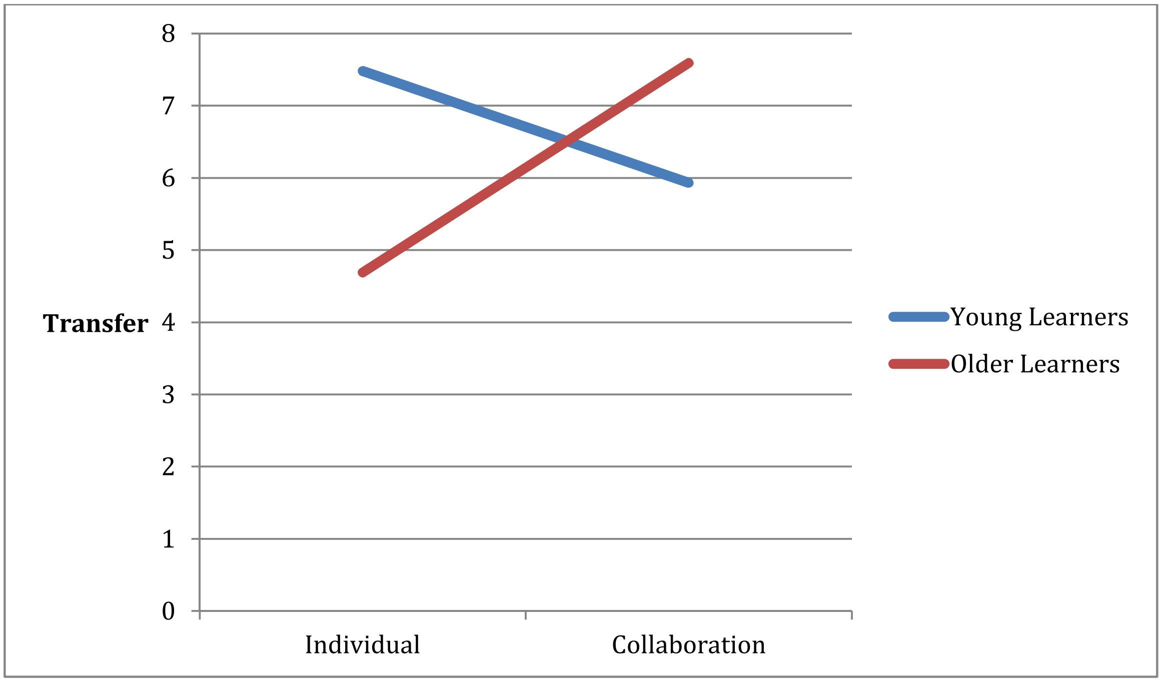

Figure 1
Interaction between age and instructional condition in predicting transfer performance (Study 2)

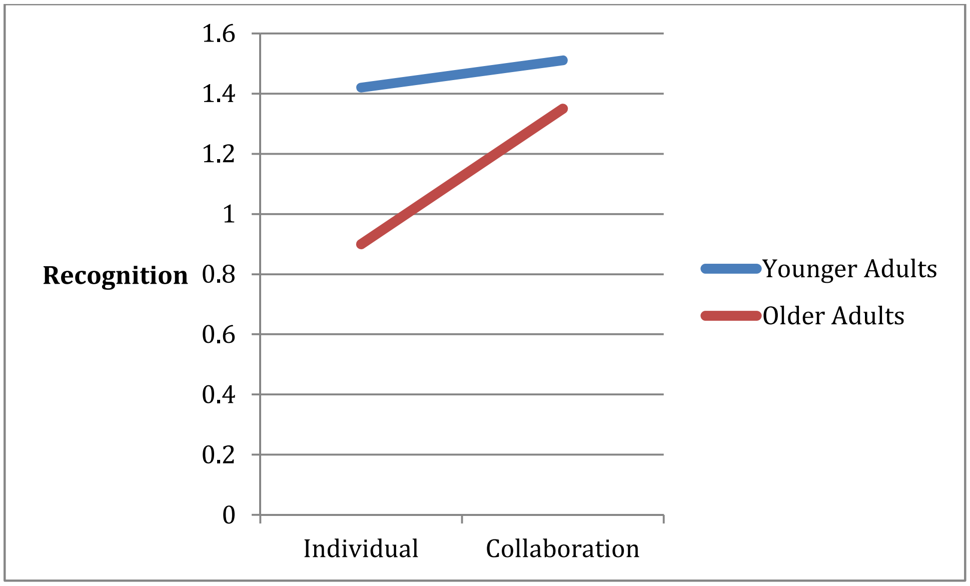

Figure 2
Main effect of age on recognition performance (Study 2)

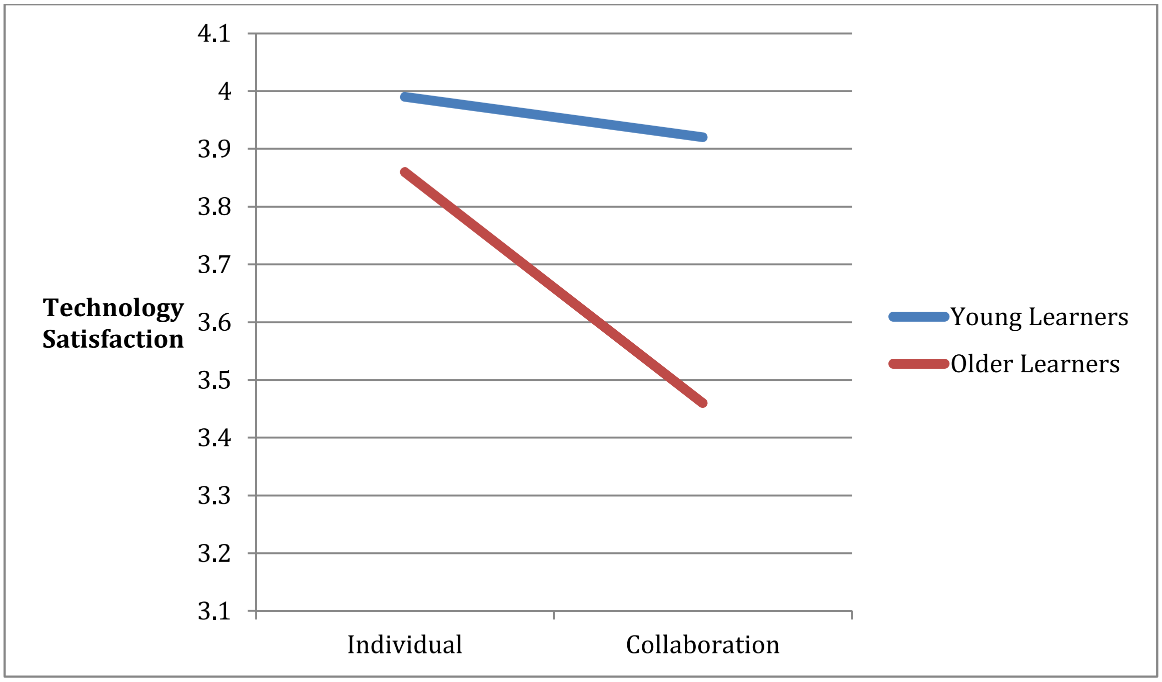

Figure 3
Main effect of age on technology satisfaction
(Study 2)

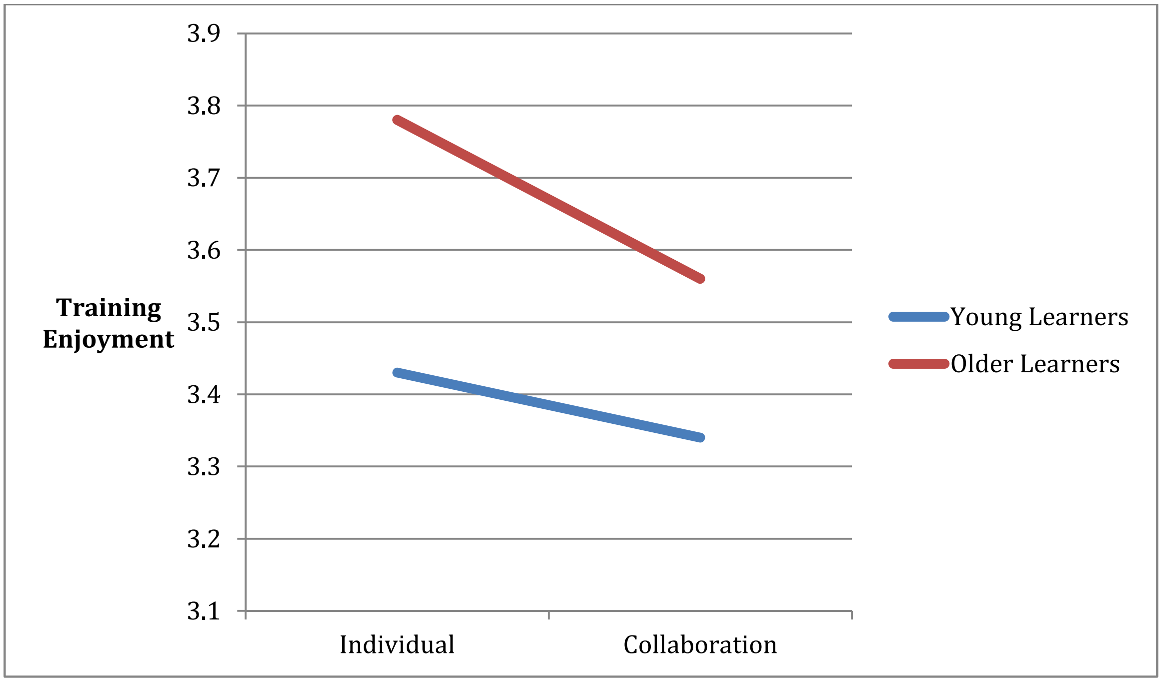

Figure 4
Main effect of age on training enjoyment
(Study 2)

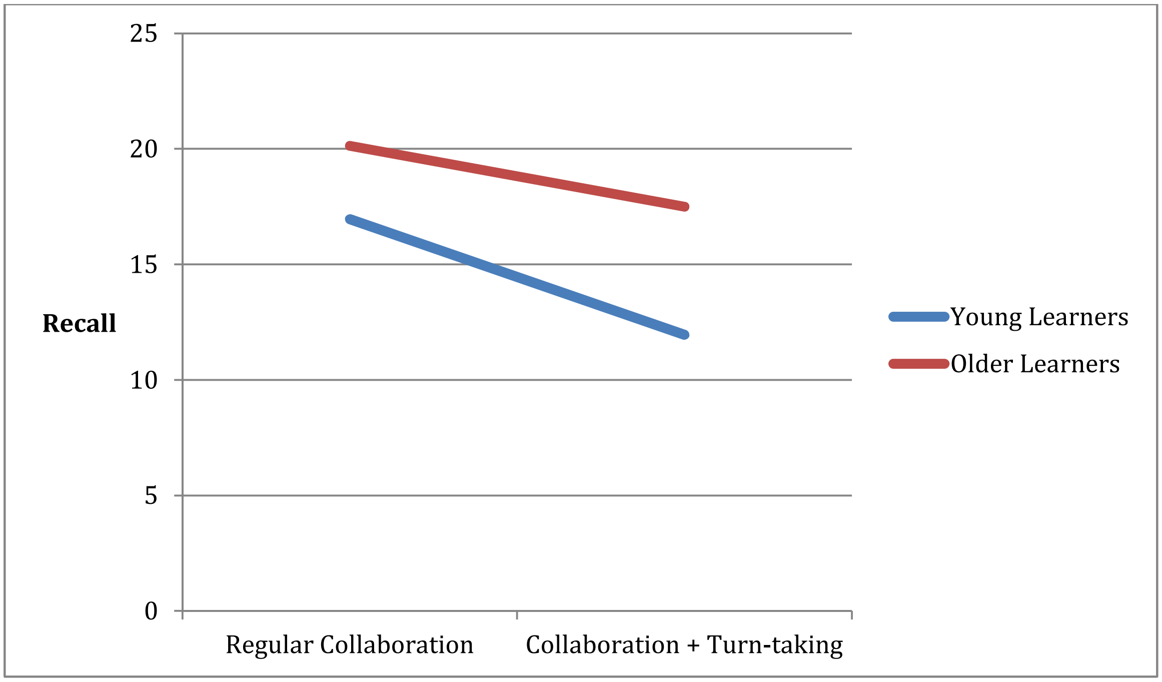

Figure 5
Marginally significant effect of turn-taking on recall performance within the collaboration conditions
(Study 2)

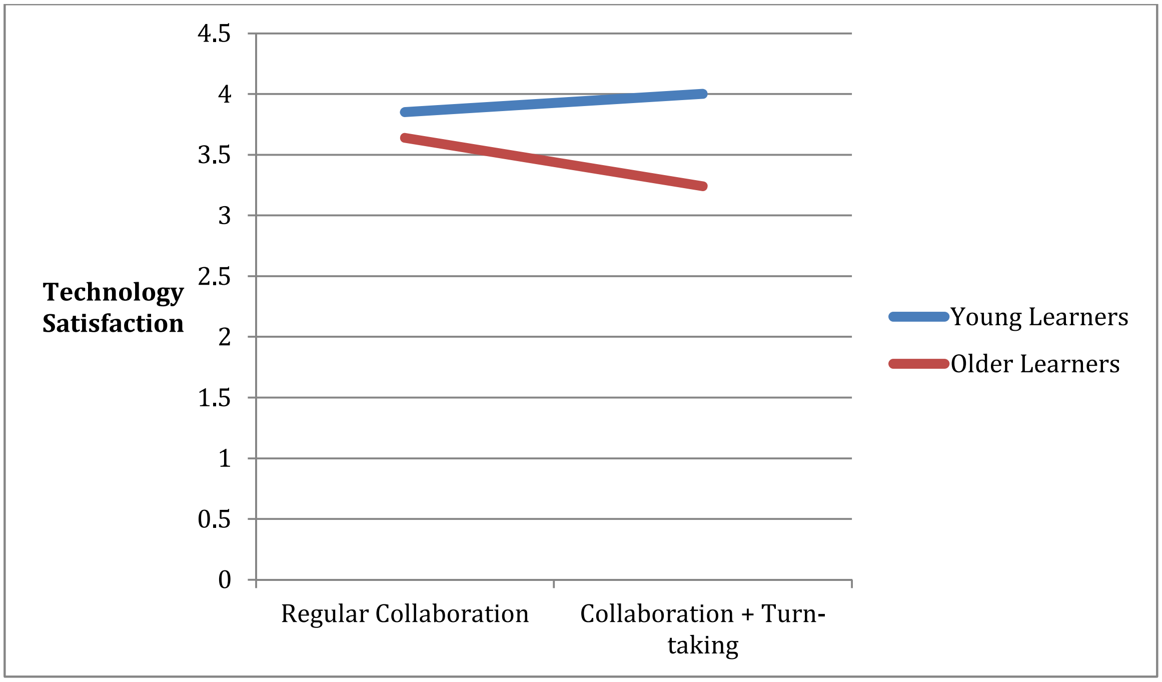

Figure 6
Main effect of age on technology satisfaction within the collaboration conditions (Study 2)

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APPENDICES

Appendix A

Short Blessed Test

1. What year is it now?
2. What month is it now?
3. Please repeat this name and address after me: John Brown, 42 Market Street, Chicago. (Good, now remember this name and address for a few minutes).
4. Without looking at your watch or clock, tell me about what time it is.
5. Count aloud backwards from 20 to 1.
6. Say the months of the year in reverse order.
7. Repeat the name and address I asked you to remember.

Appendix B

Training Self Efficacy

INSTRUCTIONS: Please indicate the extent to which you agree with the following questions. Think about how you feel and how you expect to perform with reference to this study's upcoming training.
1=Strongly disagree, 2= Moderately disagree, 3= Slightly disagree, 4= Neither agree nor disagree, 5=Slightly agree, 6 = Moderately agree, 7 = Strongly agree.

1. I am confident that I can succeed in the upcoming training.
2. I will do well in the upcoming training.
3. I will be able to learn information and skills in the upcoming training.
4. I will be able to apply skills used in the upcoming training.
5. I will be able to apply what I have learned in the upcoming training.

Appendix C

Computer Usage and Experience

INSTRUCTIONS: Please indicate the extent to which you agree with the following items.
Please circle your response.
1=Strongly disagree, 2= Disagree, 3= Neither Agree nor Disagree, 4= Agree, 5=Strongly Agree.

1. I know what email is.
2. I know what a database is.
3. I am computer literate.
4. I regularly use computers for word processing.
5. I often use computers.
6. I am good at using computers.

Appendix D

Computer Anxiety

INSTRUCTIONS: Please read each item below and respond to it by choosing one of the responses on the scale from (1) to (5), where (1) = strongly disagree and (5) = strongly agree.

1. I look forward to using a computer.
2. I do not think I would be able to learn a computer programming language.
3. The challenge of learning about computers is exciting.
4. I am confident that I can learn computer skills.
5. Anyone can learn to use a computer if they are patient and motivated.
6. Learning to operate computers is like learning any new skill—the more you practice, the better you become.
7. I am afraid that if I begin to use computers I will become dependent upon them and lose some of my reasoning skills.
8. I feel that I will be able to keep up with the advances happening in the computer field.
9. I dislike working with machines that are smarter than I am.
10. I feel apprehensive about using computers.
11. I have difficulty in understanding the technical aspects of computers.
12. It scares me to think that I could cause the computer to destroy a large amount of information by hitting the wrong key.
13. I hesitate to use a computer for fear of making mistakes that I cannot correct.
14. If given the opportunity, I would like to learn about and use computers.
15. I have avoided computers because they are unfamiliar and somewhat intimidating to me.
16. I feel computers are necessary tools in both educational and work settings.

Appendix E

Physical and Mental Health

1. In general, how would you rate your overall health?
2. Does your current health status now limit you in moderate activities, such as moving a table, pushing a vacuum cleaner, or playing golf?
3. Does your current health status limit you in climbing several flights of stairs?
4. During the past 4 weeks, how much did pain interfere with your normal work (including both outside the home and housework)?

   The following questions refer to your experiences during the PAST FOUR WEEKS. Please circle your response.

5. How often have you accomplished less than you would like with your work or other regular daily activities as a result of your physical health?
6. How often have you been limited in the kind of work you do or other activities as a result of your physical health status?
7. How often have you accomplished less than you would like with your work or other regular daily activities as a result of emotional problems (such as feeling depressed or anxious)?
8. How often have you done work or activities less carefully than usual as a result of any emotional problems (such as feeling depressed or anxious)?
9. How much of the time during the past 4 weeks have you felt calm and peaceful?
10. How much of the time during the past 4 weeks did you have a lot of energy?
11. How much of the time during the past 4 weeks have you felt downhearted and depressed?
12. How much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

Appendix F

Big Five Personality

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who *likes to spend time with others*? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement.

1	**2**	**3**	**4**	**5**
Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly

I am someone who…

1. Is talkative
2. Tends to find fault with others
3. Does a thorough job
4. Is depressed, blue
5. Is original, comes up with new ideas
6. Is reserved
7. Is helpful and unselfish with others
8. Can be somewhat careless
9. Is relaxed, handles stress well.
10. Is curious about many different things
11. Is full of energy
12. Starts quarrels with others
13. Is a reliable worker
14. Can be tense
15. Is ingenious, a deep thinker
16. Generates a lot of enthusiasm
17. Has a forgiving nature
18. Tends to be disorganized
19. Worries a lot
20. Has an active imagination
21. Tends to be quiet
22. Is generally trusting
23. Tends to be lazy
24. Is emotionally stable, not easily upset
25. Is inventive
26. Has an assertive personality
27. Can be cold and aloof
28. Perseveres until the task is finished
29. Can be moody
30. Values artistic, aesthetic experiences
31. Is sometimes shy, inhibited
32. Is considerate and kind to almost everyone
33. Does things efficiently
34. Remains calm in tense situations
35. Prefers work that is routine
36. Is outgoing, sociable
37. Is sometimes rude to others
38. Makes plans and follows through with them
39. Gets nervous easily
40. Likes to reflect, play with ideas
41. Has few artistic interests
42. Likes to cooperate with others
43. Is easily distracted
44. Is sophisticated in art, music, or literature

Appendix G

Self-efficacy for Performance

1. I believe I will receive an excellent score on this test.
2. I'm confident I can do an excellent job on the test at the end of this training program.
3. I expect to do well on the test at the end of the training program.
4. Considering the difficulty of this training program and my skills, I think I will do well on the upcoming test.

Appendix H

Metacognitive Activity

1. I used learning strategies in the chatroom (e.g., visualization, elaboration, seeking feedback, goal-setting) so that I could learn as much as I could.
2. While in the chatroom, I monitored how well I was learning the training content.
3. I thought carefully about what I knew and didn't know about the communication material before entering the chatroom.
4. As I used the chatroom, I evaluated how well I was learning the training content.
5. When I felt that the chatroom was not helping me learn, I experimented with different procedures for interacting with my peers in the chatroom (e.g., elaboration, seeking feedback, goal-setting).
6. I considered the knowledge that needed the most rehearsal when choosing how to best use the chatroom.
7. When answering the discussion questions, I considered how the question would help me to learn the training content.
8. While in the chatroom, I tried to implement strategies that would help me learn (e.g., visualization, goal-setting, elaboration, seeking feedback).
9. While in the chatroom, I tried to monitor closely the areas where I needed the most review.
10. I noticed where I needed the most help and focused on improving those areas while in the chatroom.
11. I used the chatroom to fill in gaps in learning.
12. I used the input of others in the chatroom to help me evaluate where I stood relative to my learning goals.

Appendix I

Learning Motivation

1. I was motivated to learn the information presented in the training program.
2. I tried to learn as much as I could from the training.
3. I got more from this training than most people.
4. The knowledge I gained in this training may advance my career and/or personal life.
5. I volunteered for this training program as soon as I could.
6. The reason I stuck with the training program was because I wanted to learn how to improve my knowledge and skills in communication.
7. I wanted to improve my knowledge and skills in communication.
8. If I didn’t understand some part of the training, I tried harder.

Appendix J

Transfer Measure

Please list the barriers to communication depicted in the following scenario:

Barbara notices that her sister, Ann, has been acting strangely toward her lately. They typically go out to lunch or dinner a few times per week and now Ann has been ignoring Barbara's calls and acting cold. Barbara learned that Ann is planning a move out of the city and she asked Ann why she hadn't told her. Ann simply said she was busy and forgot.

In reality, Ann was upset that Barbara had told their mutual friend a piece of very personal and private information that was meant to be kept between the two of them. Ann assumed that Barbara didn't care about her feelings and didn't value their relationship enough to keep the information to herself. Meanwhile, Barbara had assumed that the information was not a secret. Every time Barbara asks Ann about her distant behavior, Ann brushes off the question. Barbara wants to mend the relationship while Ann has already moved on and doesn't see how her sister can restore her trust. What kinds of barriers to communication do you see illustrated in this example?

Appendix K

Recognition Measure

Please indicate which barriers to communication were presented in the audiovisual lecture. If you think a particular barrier was presented in the lecture, click on the square to the left of the barrier.

1. Emotions (e.g., frustration, impatience)□
2. Saying the same thing in too many different ways.□
3. Lack of practice or experience□
4. Lying□
5. Failing to maintain eye contact□
6. Male and female communication differences□
7. No definition of words or terms used□
8. Using overly expressive gestures□
9. One-way communication (no opportunity to ask questions, make comments)□
10. Preconceptions□
11. Differing definition of terms□
12. Conveying inconsistent information□
13. Status differences□
14. No visual aid (i.e., only verbal or written communication)□
15. Fear of asking questions□
16. Being shy□
17. Being unfamiliar with the person□
18. Not trusting or feeling comfortable with the other person□
19. Avoiding difficult conversations□
20. Feelings of grandeur and self-importance□
21. Inaccurate information□
22. Distractions□
23. Physical distance between the two speakers□
24. Not knowing what questions to ask□
25. Time limit or feeling rushed□
26. Having different goals for communication□
27. Lack of interest in the topic of conversation□
28. Revealing secrets□
29. Lack of information or incomplete information□
30. No feedback on communication□
31. Inappropriate time or place□
32. Use of slang/profanity

Please indicate which strategies for communication were presented in the audiovisual lecture. If you think a particular strategy was presented in the lecture, click on the square to the left of the strategy.

1. Taking time to listen☐
2. Keep emotions out of the conversation☐
3. Make a good first impression☐
4. Write everything down☐
5. Maintain a sense of humor☐
6. Say things in multiple ways☐
7. Elaborate as much as you can☐
8. Ask questions even when you think you know☐
9. Be as extroverted as you can☐
10. Encourage others to ask questions☐
11. Know your audience (who they are, what social boundaries exist, etc.)☐
12. Consider all forms of feedback (what do the other person's verbal cues, body language indicate?)☐
13. Alter your intonation throughout the conversation☐
14. Be kind☐
15. Focus on the important issues☐
16. Empathize☐
17. Remain open to different points of view☐
18. Remove distractions☐
19. Provide context or background☐
20. Simplify complex topics☐
21. Thoroughly understand your own message☐
22. Be mindful of the other person's time☐
23. Find adequate time to have the conversation☐
24. Ask the other person to repeat things to ensure you understood☐
25. Be objective☐
26. Generate as many ideas as you can☐
27. Be sincere, honest, and precise☐
28. Use critical thinking☐
29. Focus on the positive side of everything☐
30. Create interpersonal safety or a safe, non-judgmental environment☐
31. Be patient☐
32. Defining terms☐
33. Use multiple types of communication (visual, verbal)☐
34. Reveal secrets☐
35. Use one mode of communication☐
36. Have a clear objective/purpose☐
37. Provide feedback to the speaker☐
38. Give the speaker the benefit of the doubt☐
39. Be consistent in the way you are communicating (avoid sudden changes in the way you are doing or saying things)☐
40. Agree to disagree☐
41. Be self-confident☐

Appendix L

Trainee Reactions

1. The technology interface was easy to use. *(Technology Satisfaction)*
2. The technology allowed for easy review. *(Technology Satisfaction)*
3. I am satisfied with the technology interface. *(Technology Satisfaction)*
4. I enjoyed the training. *(Training Enjoyment)*
5. Learning this material was fun. *(Training Enjoyment)*
6. This training was relevant to my daily life. *(Training Relevance)*
7. This training provided useful examples and illustrations. *(Training Relevance)*

Appendix M

Transfer Intentions

1. I intend to use the knowledge I acquired from this program in my daily life.
2. The knowledge I acquired from this program will be useful to me in my life.
3. The knowledge I learned in this program will be useful in improving my life.