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GETTING BETTER WITH AGE

Toward a Psychological Science of Advanced Technology Design for Older Adults

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Objectives. Technology represents advances in knowledge that change the way humans perform tasks. Ideally, technology will make the task easier, more efficient, safer, or perhaps more pleasurable. Unfortunately, new technologies can sometimes make a task more difficult, slower, dangerous, or perhaps more frustrating. Older adults interact with a variety of technologies in the course of their daily activities and thus products should be designed to be used by people of varying ages.

Methods. In this article, we provide an overview of what psychology has to offer to the design of technology—from understanding what people need, to identifying their preferences for design characteristics, and to defining their capabilities and limitations that will influence technology interactions.

Results. We identify how research in the field of psychology and aging has advanced understanding of technology interactions and how research on technology interactions can inform theories of aging.

Discussion. Design for aging involves understanding the unique capabilities and limitations of older adults; identifying their needs, preferences, and desires for technology in their lives; and involving them in the design process.

Key Words: Aging—Human factors—Technology design.

TECHNOLOGY represents advances in knowledge that change the way humans perform tasks. Ideally, technology will make the task easier, more efficient, safer, or perhaps more pleasurable. Unfortunately, new technologies can sometimes make a task more difficult, slower, dangerous, or perhaps more frustrating.

Older adults interact with a variety of technologies in the course of their daily activities. In a diary study wherein older adults logged all of their interactions with technology for a 10 day period, O'Brien (2009) found that the average number of technology interactions reported by individuals aged 65–75 years was 190 for individuals preclassified as "low-technology users" (i.e., who self-reported using a low number of common technologies). The average number of technology interactions was 301 for a preclassified group of older individuals who were "high-technology users." Participants were asked to focus on technology interactions that involved electronics in some way; their reports included radios, microwave ovens, computers, exercise equipment, home security, answering machines, and more. They also reported frustrations, failures, and coping strategies—this is where psychological science can have an impact.

Psychology has much to offer to the design of technology —from understanding what people need, to identifying their preferences for design characteristics, and to defining their capabilities and limitations that will influence technology interactions. Our goal in this article is to identify how research in the field of psychology and aging has advanced understanding of technology interactions. We describe technology use by older adults to elucidate myths and realities. We discuss recent trends in the field and the current "state-of-the-science" regarding aging and technology interactions. Finally, we introduce the future—technologies on the horizon that are very different from desk-top computers. These developments must be informed by psychological science if they are going to improve the lives of older adults. Throughout we highlight future research needs.

Older Adults Use Technology

Age does not necessarily limit the number of products used. The assumption that older adults wish to avoid new technology is largely a fallacy. However, studies of technology use, attitudes, and abilities do show that older adults are less likely to use technology compared with younger adults (Czaja et al., 2006). For example, from a list of 17 common technologies, older adults reportedly used an average of 12 of them compared with an average of 15 reportedly used by younger adults. Although the range of technologies used may differ, once older adults adopt a particular technology they may use it as frequently as younger adults (O'Brien et al., 2008).

Age-related differences in the number of different technologies used may be mediated by age-related income disparities, perception of actual need to use the technology, products being too difficult to learn to use, cognitive and perceptual abilities, and other factors such as attitudes and beliefs (Charness & Boot, 2009). Moreover, the technology's perceived usefulness is a key variable in standard models of technology acceptance as its importance has been

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shown repeatedly for younger adults (e.g., Davis, 1989). The "need to use" or rather the benefits of use must be made clear before older adults will voluntarily adopt a technology. Evidence suggests, however, that when there is a perceived benefit of use for a particular type of technology, older adults will use it.

Four examples make the point: (a) Although fewer older adults are yet to use the Internet, the biggest increase in Internet use between 2005 and 2009 was for the age group 70–75 (an increase from 26% to 45%; Pew Internet & American Life Project, 2009); (b) Cell phone use between 1998 and 2005 increased the most for the group more than age 65, from 19% to 46% (U.S. Census Bureau, 2009); (c) A report on in-vehicle Global Positioning Systems revealed that a segment of "active" older adults were more likely than younger groups to either have or plan to acquire the systems (Ness, 2005); and (d) Internet use for adults more than age 50 is positively related to the strength of social networks (Hogeboom, McDermott, Perrin, Osman, & Bell-Ellison, 2010).

The importance of understanding the potential benefits of technology was illustrated further in a small-group structured interview study exploring older adults' use of and attitudes toward technology (Mitzner et al., in press). Older adults reported using a variety of technologies and had many opinions about them. Participants were asked about technology use at home, work, and in health care. Technology was defined as electronic or digital products and services. Each group was asked, *"What technologies do you use"?* and *"For those of you who have used [each technology item], what do you like and dislike about using this technology"?*

In Mitzner et al. (in press), participants reported using many technology items, particularly in their homes, and they expressed both positive and negative attitudes about them. However, contrary to stereotypes of older adults holding negatively biased attitudes about technology, participants' attitudes were mostly positive in nature. Of all the attitudes expressed, 62% were "likes" whereas 38% were "dislikes." These findings confirm that older adults are using technology, and they perceive the benefits of that use as outweighing the costs.

Toward Understanding Advanced Technology and Aging

The goal of research on aging and technology is to replace the age variable with an understanding of the source of the age-related differences. In other words, chronological age may be predictive of usage patterns, difficulties, or preferences, but it is not an explanatory variable—it does not explain why the differences occur. Consequently, the research goal is to identify mediating variables such as working memory, perceptual ability, training, or experience. These variables are often well studied in the general area of psychology and aging; hence the fundamental research provides the basis for hypotheses about the most likely mediating variables. Moreover, evaluating the role of these variables in the context of technology use provides a test-bed for understanding generality of theories of aging (see Charness, 2008).

Matching Psychological Needs With Technology Design Features

Figure 1 illustrates a model we have developed to elucidate the many potentially relevant variables that influence successful technology use (Fisk, Rogers, Charness, Czaja, & Sharit, 2009). This model builds from ideas proposed by Lawton and Nahemow (1973) that successful performance depends on the demands imposed by the environment relative to the capabilities of the individual (i.e., the environmental press). Likewise, successful design of technology will depend on the match between the capabilities of the user and the demands imposed by the system as well as by the task being performed (e.g., playing a game vs. using a medical device). An additional important dimension is the context of use that may impede or support successful interactions (e.g., at home or in a moving vehicle). This model is not meant to be a predictive model but rather to illustrate the range and type of variables that must be considered in the study of technology interactions for older adults.

The importance of matching technology characteristics with user needs can be illustrated with the example of multimedia. It is sometimes assumed that individuals will learn better from a multimedia presentation of information (e.g., video plus audio vs. audio only). However, McLaughlin, Rogers, Sierra, and Fisk (2007) reported that for certain tasks, the video information can actually interfere with learning. Moreover, the match between the characteristics of the technology and the learner's goals was more critical for older compared with younger adults.

Guidance for Design

The literature on the psychology of aging provides much guidance for design—the challenge is in the translation. A concerted effort must be placed on bringing relevant psychological literature in a usable form to the design community. When done properly, the effort can have a real impact on practice. For example, the U.S. National Institute on Aging (National Institutes of Health) developed a tip sheet for designing senior-friendly Web sites that was specifically based on research on aging, cognition, and computer use. This valuable resource is available online http://www.nia.nih.gov/HealthInformation/Publications/website.htm.

In "*Designing for older adults*," Fisk, Rogers, Charness, Czaja, and Sharit (2004; Fisk, et al., 2009) provided guidelines for system designers that were explicitly based on the research literature. Fundamental understanding of age-related changes in motor control, perceptual function, and cognitive ability was translated into design guidelines for

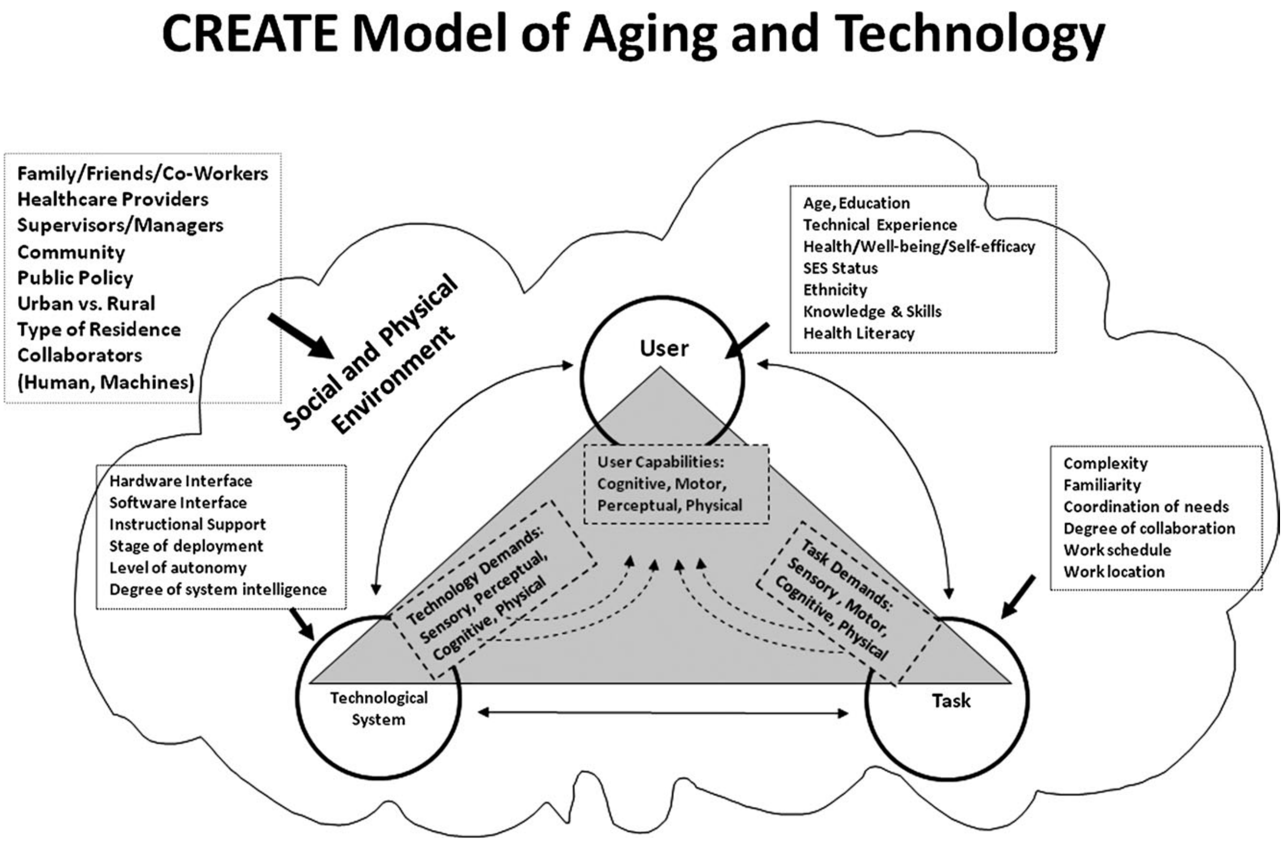

Figure 1. The Center for Research and Education on Aging and Technology Enhancement (CREATE; www.create-center.org) perspective on designing technology for older adults (reprinted with permission from Fisk et al., 2009).

input devices, output devices, human–computer interfaces, and training programs. Clearly, the years of focused research on understanding aging have direct implications for design and in turn the safety, health, and well-being of older adults.

A third example involves the use of data from research on aging to estimate parameters that will enable modeling and prediction of age-related performance differences. For example, Jastrzembski and Charness (2008) estimated performance variables such as eye-fixation duration, movement time, verbal working memory span, and the power law of practice for younger and older adults, based on the research literature. They then successfully used this information in a model that well-predicted age-related performance differences in the use of a cell phone. This approach was quite valuable but also revealed areas where insufficient information was available for parameter estimation and more research is needed (e.g., many estimates were based on small or select samples of older adults).

One caveat to mention is that, although technology may be designed as a form of environmental support, intended to off-load demands from users, the technology itself may impose demands (Morrow & Rogers, 2008). For example, search engines often allow use of Boolean operators to constrain searches (e.g., “and”; “or”). However, younger adults benefited more from the availability of these search tools because they used them more frequently and had a better understanding of how they functioned (Mead, Sit, Rogers, Rousseau, & Jamieson, 2000). Technology can be a successful form of environmental support; as illustrated with an in-vehicle navigation system that used a synthetic voice to augment instructions displayed onscreen and thereby improved performance of older adults more than younger adults (Dingus et al., 1997).

Usability, Training, and Needs Assessment for Technology Development

Despite advances in technology design and efforts to make technologies usable and useful, older adults remain slower to adopt new technologies and more likely to report anxiety about using new systems or frustrations when using technologies (e.g., Czaja et al., 2006; Ellis & Allaire, 1999; O’Brien et al., 2008). Note that usability problems are not restricted to older adults—younger adults also report frustrations and difficulties using technologies. However, it is generally the case that improving design to enhance usability for older adults improves the usability for other user groups as well.

Where do existing technologies fail and what do future technologies need to do? Research efforts have addressed three facets of improving technologies used by older adults: (a) identifying the source of usability difficulties for current technologies, (b) assessing the adequacy of current training and instruction materials, and (c) understanding the needs of older adults not met by current technologies. Together these efforts will enhance use of current devices and systems, provide guidance for refining future iterations of those systems , and stimulate ideas for next generations of product design.

Usability Assessment

Empirical studies have identified the nature of the usability problems older adults have with input devices (e.g., Charness, Holley, Feddon, & Jastrzembski, 2004; Rogers, Fisk, McLaughlin, & Pak, 2005; Walker, Philbin, & Fisk, 1997); computers (e.g., Charness. Kelly, Bosman, & Mottaram, 2001; Kelley & Charness, 1995; Sharit et al., 2004); and the Internet (e.g., Czaja, Sharit, Ownby, Roth, & Nair, 2001; Hudson, Scialfa, Diaz-Marino, Laberge, & MacKillop, 2008; Sharit, Hernandez, Czaja, & Pirolli, 2009; Stronge, Rogers, & Fisk, 2006). Studies have also provided insights about age-related difficulties with specific technologies such as automatic teller machines (Rogers & Fisk, 1997), online library systems (Mead et al., 2000; Rousseau, Jamieson, Rogers, Mead, & Sit, 1998), cell phones (Jastrzembski & Charness, 2008), and more (for reviews, see Nichols, Rogers, & Fisk, 2006; Rogers, Stronge, & Fisk, 2006). These studies have provided a wealth of data about the nature of the difficulties older users have and the age-related changes in movement control, perception, cognition, and attitudes that are predictive of such changes.

Understanding age-related capabilities and limitations should also guide the usability assessments themselves. For example, cognitive impairments may impede understanding task instructions, hearing impairments may impede comprehending auditory feedback, and visual impairments may impede reading information on a computer screen (for further discussion, see Fisk et al., 2009).

The next steps are to learn more about use of technologies by older adults in context; for example, to assess long-term usage of technologies to understand how or if they support everyday activities. Similarly, direct observation of technology use difficulties for a wide-range of user-experience levels would be informative about the nature of errors that are made under various circumstances. These studies will enable us to refine our model of aging and technology use to guide training and design.

Training and Instruction

General guidelines are available to enhance older adults' ability to learn to use new technologies (e.g., Czaja & Lee, 2003; Fisk et al., 2009; Rogers et al., 2006). However, numerous open questions regarding training remain to be answered in the context of aging and technology: What is the optimal type and format of feedback for immediate learning versus long-term retention (McLaughlin, Rogers, & Fisk, 2008)? How should training components be sequenced for technology training (Hickman, Rogers, & Fisk, 2007)? How do user preferences for training methods interact with the success of training (Mitzner et al., 2008)? How should multimedia training be developed to capitalize on age-related strengths and minimize the effects of age-related deficits in perceptual and cognitive functioning (Fisk et al., 2009)? These are just a few of the questions that will benefit from systematic study of psychological mechanisms such as working memory limitations and selective attention deficits that mediate the benefits of training for younger and older adults.

Understanding Unmet Needs

Designers must develop technologies for which there is a need. For example, if technologies are to be successful in supporting memory needs of older adults, the technology must be designed with such specific needs in mind. "Needs arise from the ways in which people perceive their everyday world and how they decide and act upon their own self-determined priorities. The ways in which needs arise thus depend upon the individual, but are also driven by the norms shared with other people within their social group . . . technological solutions must adequately account for the full complexity of human experience if they are to be useful (Sixsmith & Sixsmith, 2000, p. 192)."

"Needs assessment and requirements analysis are the most important activities for initiating system improvement because, done well, they are the foundation upon which all other activities build (Beith, 2001, p. 14)." Concern must focus on what technology should do, rather than what it can do.

Consider the case of technology to support memory. In self-reports of memory functioning in large-sample studies, older adults reported various types of memory difficulties (e.g., Gilewski, Zelinski, & Schaie, 1990). For example, they reported sometimes having difficulty remembering names, faces, appointments, and phone numbers; they also perceived that when they did forget such things it was a problem. Moreover, Boron, Rogers, and Fisk (2006) found that even high-functioning older adults reported forgetting to take their medications with a sufficient frequency for it to be considered a problem.

Understanding everyday cognitive competence (e.g., Willis, 1996) provides information about the needs of older adults that might be well-supported by technology. Task simplification through cognitive supports holds promise to facilitate older adults' daily living activities involving multiple components (Mynatt, Melenhorst, Fisk, & Rogers, 2004; Rogers & Fisk, 2001). For example, automated reminder messages can support memory for appointments (Morrow & Leirer, 2001) and reminder cues at the appropriate time can improve medication adherence (Park, Morrell, Frieske, & Kincaid, 1992).

Technology that can maintain perceptual and cognitive abilities is another arena that is of interest to many older individuals. Some recent evidence suggests that playing commercial video games can lead to cognitive engagement and improve perceptual and cognitive abilities, such as memory, reasoning ability, and multitasking performance (e.g., Basak, Boot, Voss, & Kramer, 2008; Green & Bavelier, 2008).

Robotics and Ambient Technologies

Technologies Are Changing

Advanced-technology systems in the near future will move beyond the personal computers that sit on a desk. Already, hand-held computers have tremendous power and are multi functional. Moreover, robotic technologies are being developed that will change the way people interact with automated systems and the way they perform various tasks (if they perform them at all). The phrase "ambient technology" is being used more frequently in reference to technologies in the environment such as sensors and other types of ubiquitous computing. In short, technologies of the near future will be mobile, increasingly interactive, embedded in the environment, and adaptive to individuals' changing needs, capabilities, and preferences. Such developments have great potential for supporting the needs of older adults (e.g., Mynatt & Rogers, 2002) by assisting with medication management and enabling social connectivity, for example. Advancements can be developed based on knowledge from psychological science such as models of technology acceptance (e.g., Park, Fisk, & Rogers, 2010).

How do designers ensure that these new systems will be usable and used by older adults? It is critical to involve older adults in the design process—early and iteratively. Older adults should be a part of formative evaluation studies (when needs are being assessed), summative evaluation studies (when testing prototypes), and long-term use studies to determine how (or if) technologies are integrated into everyday activities. Guidance for involving older adults in the various phases of technology development is provided in Fisk et al. (2009).

Potential for Technology to Enable Independence

One way to increase usability of technology supports for older adults is to minimize the required interaction between the person and the system. For example, an ambient technology might be a system in the environment that monitors one's activities and provides guidance where needed.

The potential of this type of cognitive augmentation system was assessed in the form of a technology "coach" that could support older adults learning to use a medical device (Rogers, Essa, & Fisk, 2007). The system used computer vision to track use of a blood glucose meter and provided users with feedback if they made an error. The development of the technology coach required guidance from psychology as well as computer science. Challenges were to (a) identify task demands; (b) understand needs and capabilities of the target user population, namely older adults; (c) develop a system that could capture information from the environment in an unobtrusive manner; (d) use the information captured to recognize actions; (e) interpret activities being performed and identify whether an error had been made; and (f) provide feedback to support task performance and learning.

The technology coach was successful in supporting immediate performance and learning (assessed via 2 day retention); success was indexed by participants' ability to correct errors after feedback from the coach. However, the specificity of feedback influenced the success of the coach —nonspecific information (an error has occurred) yielded worse performance than either specific procedure feedback (turn the test strip over) or even specific conceptual feedback (the pink side must face up).

Future efforts must address remaining issues related to design of effective feedback systems—content, timing, amount, and optimal display format. In addition, it is important to determine whether feedback effectiveness differs as a function of user capabilities and experience. This research provides guidance for development of an in-home personal machine agent designed to coach individuals in tasks necessary for independent living. Such tasks might include use of medical devices, proper performance of rehabilitation exercises, or learning to use a home security system —tasks that are procedural in nature.

Intrusiveness of Advanced Technologies

With many technologies, designers must be concerned about the potential intrusiveness of the technology; will older adults want monitoring technologies in their homes? Optimizing use of advanced technologies while ensuring complete informed consent for technologies that can intrude into one's home is not a trivial problem. Many scientific questions concerning privacy must be addressed. For example, under what conditions will older adults allow intrusive technologies (e.g., cameras used by a technology coach) into their homes? Answers to such questions will ensure a given technology is represented such that the costs and benefits are fairly weighed.

In an interview study with older adults, participants were shown various technologies that might be installed in a "home of the future." These technologies were installed and operational in the Georgia Tech Aware Home (www.awarehome.gatech.edu; Mynatt et al., 2004) so the participants did not need to imagine what they would be like. Through a structured interview, the participants were asked about their concerns about these technologies (Melenhorst, Fisk, Mynatt, & Rogers, 2004). Of the nearly 3,000 comments made about pros and cons of the house or specific technologies within the home, only 19% were related to intrusiveness. Concerns about intrusiveness were related to physical issues about the technology design or interface display, privacy issues, or security issues.

With respect to privacy concerns, the older adults' comments were conditional: *If this [monitoring system] would keep me independent longer, I wouldn't mind as much; If it's only my daughter who monitors me, it's alright; If you really need it, privacy becomes secondary.* These comments suggest that although privacy is a concern, its importance may be weighed against potential benefits of technology (see also Caine, Fisk, & Rogers, 2006). Moreover, concerns may be alleviated by enhancing older adults' understanding of how the technology works and providing them with control over who has access to their information.

These findings were supported by a field trial wherein people were monitored with an aware home system by a family member for several months (Rowan & Mynatt, 2005). Consider one mother–son combination. Both mother and son were very enthusiastic about the system and privacy concerns were minimal, in this context. Moreover, with respect to social support, the mother reported feeling a level of support and connectedness with her son via the presence of the monitoring system even though the son lived quite a distance from his mother. Rather than feeling intruded upon by the technology, such technology can give comfort.

Older adults also reported that they would be open to the idea of having visual sensing devices in their home, including cameras (Caine, et al., 2006). They were more willing to have cameras if they were in a situation where their cognitive function had declined, their movement abilities had declined, or if they were facing a decision to move to an assisted living facility.

Needs for Research in Psychology and Aging

Ambient intelligence is a form of intelligent technology that is always present; often it involves the integration of technological devices into an environment such that the technology itself disappears from sight and only the user interface remains. Representative examples of ambient intelligence are collaborative machine assistants (CMAs), for example, in the form of a virtual agent or a robot (see e.g., Park et al., 2010). With such assistants, the user interaction moves to the foreground, making it critical to consider user characteristics (e.g., age, knowledge) and technology characteristics (e.g., perceived usefulness, ease of use) during the design.

The main characteristics of CMAs (a) are collaborative —meaning they interact with the human user in some way, (b) involve some level of intelligent awareness, and (c) are assistive by supporting or enhancing the activities of the human. There are many potential benefits of a well-designed CMA: it is always there when it is needed, eminently patient; proactive rather than just reactive (can provide guiding information based on context and specific circumstances), understands its human team member and may have a social component whereby it can understand a person's situation, and be tailored to the task at hand—with consideration for task difficulty and individual preferences. CMAs may support a variety of everyday tasks such as medication management, home maintenance, entertainment, social engagement, and preventive health care tasks such as menu planning or exercise tracking. The potential for CMAs, and robotics more specifically, is illustrated by the following statement made by Bill Gates: "*I can envision a future in which robotic devices will become a nearly ubiquitous part of our day-to-day lives* (Gates, 2007, p. 62)."

Most work in this area has been focused on testing the technology—does it work—rather than on trying to understand how older adults will interact with the technology. Various questions need answers if CMAs are going to be successful in supporting older adults' needs (for more details, see Park et al., 2010). These questions include what does the CMA have to do (what is the nature of the support that needs to be provided, what kind of information is going to be useful), what types of support are older adults willing to accept (what characteristics should the CMA have), how important is it that it have a physical presence (as opposed to a virtual presence), and how might the context demands interact with the benefits of different CMA characteristics?

Figure 2 provides an overview of the aspects of human-CMA collaborations that must be understood if the potential of future technologies will be realized for the support of health, safety, and well-being of older adults. Three main categories of variables must be assessed, both independently and interactively: (a) user knowledge and beliefs, (b) context of the interaction, and (c) characteristics of the CMA.

User knowledge and beliefs.—User knowledge and beliefs include attitudes (about technology), experience (with technology or in the task domain), and the user's mental model both of the task and of the way the CMA functions (e.g., when it is likely to make an error and why specific types of errors occur). What do people want their CMA to look like, act like, and be able to do? Many individuals have opinions and expectations about CMAs. For example, Ezer, Fisk, and Rogers (2009a) conducted a survey study wherein younger (aged 18–25 years) and older (aged 65–86 years) adults were asked to describe the robot they might imagine in their home environment and answer a series of items about the characteristics of that robot. Respondents of both age groups were more willing to have robots perform infrequent but critical tasks that required little interaction with the human (e.g., warnings about emergencies) compared with service-type tasks with more required interaction (e.g., make meals or do housework). Respondents were least willing to have a robot perform noncritical tasks requiring extensive interaction between robot and human (e.g., play games or converse). Older adults reported more willingness

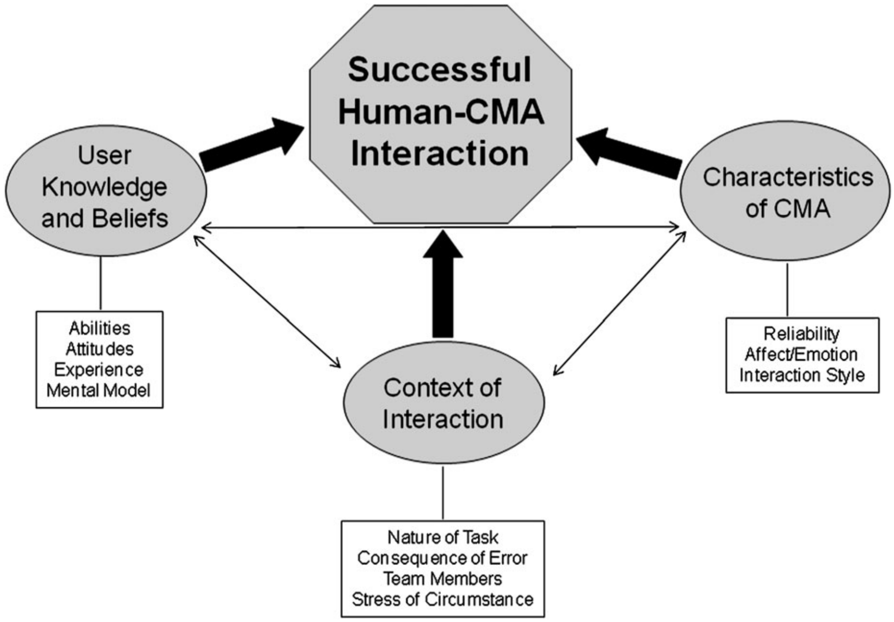

Figure 2. Factors contributing to successful interactions between human and collaborative machine assistants (CMA).

than younger adults in having a robot perform critical tasks in their home such as warning of an intruder.

People's attitudes and beliefs about robots may be limited by their experience and their imagination. It is difficult to imagine what a robot might be able to do. In our current research, we are providing illustrations and demonstrations of robot capabilities first and then assessing attitudes and openness to interacting with a personal robot in the home environment. This type of involvement by potential users early in the design process will be necessary for developing robots that will be accepted and embraced (at least figuratively).

Characteristics of the CMA.—Important features of the CMA include its reliability (and the nature of the errors it does make), the affective and emotional characteristics of the CMA (e.g., happy or playful), and its interaction style (e.g., directive or cooperative). Research on these variables is in its infancy but already the complexity of the human-collaborative system interaction is evident.

Task simulations have been designed to assess relationships between system variables (e.g., reliability, error type) and dependence on the guidance provided by the system (e.g., responding immediately to an alarm vs. requesting additional information). Both younger and older adults reduced trust and system reliance when system reliability was less than perfect, but older adults appeared to be more sensitive to such changes (Sanchez, Ezer, Rogers, & Fisk, 2006). Both age groups showed less reliance when a system made a false alarm (i.e., indicated a problem that did not exist) than a miss (i.e., did not alert the user to a problem); however, older adults showed the most overreliance on a system that tended to miss critical events (Johnson, Sanchez, Fisk, & Rogers, 2004). These studies indicate that many variables mediate the success of human-collaborative system interactions, and age may moderate these relationships.

Context of the interaction.—The interaction context refers to the nature of the task (e.g., educational, entertainment), the consequence of an error (e.g., annoyance or health impact), the number and nature of team members (e.g., multiple CMAs, family members), and the stress of the circumstances under which the interaction occurs.

Here too the research is just beginning, but evidence suggests the importance of attending both to age-related differences (e.g., in reliance on automation) and to the importance of the context. For example, younger and older adults could calibrate their dependence on a system depending on the consequence of making an error or the cost of double-checking the system recommendation, but older adults were less flexible in this calibration (Ezer, Fisk, & Rogers, 2009b).

Context effects have emerged when the benefits of an automated support system are investigated under normal versus stressful contexts. An adaptive computer assistant for the personalized supervision of diabetes patients' self-care was more effective if it changed the format of advice according to the task context (Blanson-Henkemans et al., 2008) than if it was not adaptive to context. The adaptive computer assistant was more effective in dealing with normal and health critical situations, and, generally, it led to more time efficiency. Use of an adaptive computer assistant facilitated diabetes patients' ability to integrate self-care activities in their daily life.

Needs for research.—User variables, contexts of use, and CMA characteristics are all going to contribute to the success or failure of the technologies of the future. Psychological science has much to offer in this realm by conducting the critical research that bridges the gap between fundamental theories of aging and practical, everyday living tasks of older adults. As illustrated in Figure 1, the overall research space of aging and technology is multifaceted and provides an overview of the ecology that will advance our understanding of the aging process as well as of individual differences and resilience of older adults.

Conclusions

Just as technologies have advanced, so has understanding of aging. Increased awareness of fundamental age-related changes in perception, movement control, cognitive capabilities, and attitudes has provided a foundation for design guidelines that are accommodative (e.g., Fisk et al., 2009). Fields devoted to design and development of advanced technology can learn much from the field of psychology and aging. Researchers in this field, in turn, have an opportunity to advance the scientific knowledge base because of the unique problem spaces arising from human interaction with this technology. Psychological scientists can advance further by attending to Broadbent's concept of practically relevant research (Broadbent, 1973). In his view, practically relevant research simultaneously advances both theory and the application of theory. In the context of aging and technology design, practically relevant research can advance the health, safety, and well-being of older adults by identifying the unique capabilities and limitations of older adults; understanding their needs, preferences, and desires for technology in their lives; and involving them in the design process. Such research can also provide a context within which to test the boundaries of theories of aging.

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