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Attitudes Toward Computers Across Adulthood From 1994 to 2013

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Abstract

Background and Objectives: Regardless of the increased deployment of technologies in everyday living domains, barriers remain that hamper technology adoption by older adults. Understanding barriers to adoption such as individual differences in attitudes toward computers is important to the design of strategies to reduce age-related digital disparities.
Research Design and Methods: This article reports a time-sequential analysis of data from the Edward R. Roybal Center on Human Factors and Aging Research and the Center for Research and Education on Aging and Technology Enhancement (CREATE) on computer attitudes among a large (N = 3,917), diverse sample of community-dwelling adults aged from 18 to 98 years. The data were gathered from 1994 to 2013.
Results: The findings indicated that there are still age disparities in attitudes; older adults report less comfort with and less efficacy about using computers than younger people. We also found a cohort (birth year) effect; attitudes are generally more positive among more recent birth cohorts. Those who have more education and experience with computers also have more positive attitudes. Males generally have more positive attitudes than females; however, the gender difference decreases with increased age.
Discussion and Implications: Technology affords potential benefits for older people, but lack of uptake in technology clearly puts older adults at a disadvantage in terms of negotiating today's digital world. This article provides insight into attitudinal barriers that may affect on technology uptake among older adults. The findings have implications for the design of technology training programs, design of technology systems, and policy.

Keywords: Computer comfort, Computer self-efficacy, Technology adoption

In the past two decades, the use of computers and the Internet has substantially increased in the U.S. population and most developed countries of the world. The increased deployment of computers in schools, homes, business, and industry began in the late 1980s. In 1989, about 15% of all households in the U.S. owned a personal computer. In contrast, currently 75% of U.S. households have a desktop or laptop; 77% of adults in the United States have a handheld device such as a smartphone; and 51% have a computer tablet. Access to the Internet has also increased considerably. In 2016, 88% of adults in the United States used the Internet, about a 32% increase since 2000 (Andersen & Perrin, 2017; U.S. Census Bureau, 2005, 2017).

Despite the increase of computer and mobile device ownership and Internet use in the overall population, older adults still lag behind. In 2015, only about 65% of persons aged 65+ owned a computer, as compared with about 82% of those aged 45–64 years and 85% aged 35–44 (U.S. Census Bureau, 2017). Currently, only 42% of people aged 65+ own a smartphone, and 32% own a computer tablet (Andersen & Perrin, 2017). Further, about 67% of adults aged 65+ go online as compared with 96% of those aged 30–49 years and 87% of those aged 50–64 years. There are also significant differences in use of the Internet among subpopulations of older adults, with those in the older cohorts using the Internet less and having less broadband access than younger older adults. This pattern holds as well for those who are less educated and have lower household incomes.

Technology holds great potential in terms of increasing the quality of life of older adults. The Internet provides opportunities to lessen problems with social isolation, foster communication, facilitate the performance of everyday tasks, and enhance educational opportunities (e.g., Czaja, Boot, Charness, Rogers, & Sharit, 2017). Technology also plays an important role in work, communication, entertainment, and within health care. The rapid emergence and deployment of technology will continue and "meaningful access" to technology will increasingly be an essential component of independent living. For older adults to successfully use technology and fully appreciate the benefits of technology, it is important to understand factors that influence the decisions older adults make regarding technology adoption.

Different theories and models have emerged in an effort to understand technology adoption and acceptance. For example, the technology acceptance model (TAM; Davis, 1989) showed that adoption of technology is largely influenced by three factors: the perceived usefulness of the technology, the perceived ease of use of the technology, and overall attitudes toward the technology. The unified theory of acceptance and use of technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003), another common model of technology adoption, proposed that four factors are important in technology adoption: facilitating conditions, social influence, effort expectancy, and performance expectancy. The UTAUT model also indicated the importance of individual characteristics such as gender. The UTAUT model has been used to explain technology adoption primarily in organizational contexts. The UTAUT2 model tailored the UTAUT model to the consumer use context and incorporated three new constructs: hedonic motivation (enjoyment), price/value, and habit. The model also poses new theoretical relationships. For example, age, gender, and experience are viewed as moderators of facilitating conditions (Venkatesh, Thong, & Xu, 2012). Another recent model, the senior technology acceptance model (Chen & Chan, 2014) extended other models of technology acceptance by including age-related health and ability characteristics as factors influencing technology acceptance.

Attitudes toward a technology may also greatly influence a person's willingness to accept and adopt the technology, as attitudes tend to guide behavior (e.g., Regan & Fazio, 1977). With respect to older adults, we (Czaja & Sharit, 1998) found that older adults had less comfort with computers and computer efficacy, and felt they had less control over computers than younger people. However, we also found that attitudes are modifiable and that direct experience with computers can lead to more positive attitudes. Morrell, Mayhorn, and Bennett (2000) found that adults in the oldest-old cohort had less interest in using the web than middle-aged and older adults. Similarly, the findings from Morris, Goodman, and Brading (2007) from two surveys of computer and Internet use among participants aged 55+ in the United Kingdom, found that among those in the older cohorts a major reason for nonuse of computers and the Internet was lack of interest, which was in turn related to perceptions that they were too old to use computers/Internet and lack of perceived usefulness. Our group (Czaja et al., 2006) also found that older adults used computers and technology less than younger people and that attitudinal variables, such as computer anxiety and cognitive abilities, were important factors in predicting technology use. Likewise, Mitzner and colleagues (2016) found that attitudes such as computer self-efficacy, comfort, and interest predicted perceptions of usefulness and ease of use for a computer system specifically designed for older adults.

In this article, we examine age differences in computer attitudes among a large and diverse sample of community-dwelling adults, over the past 20 years (1994–2013). These decades represent an important transition period in human–computer interaction as they encompass the Internet revolution and the penetration of digital devices into society. The article is unique as we are able to examine both differences in attitudes as a function of age, time period, and cohort. Analysis of the time period effects allows us to examine if the attitudes of older adults toward computers have changed in the past two decades. The availability of this large data set also allows examination of interactions such as age and cohort to examine interactions such as the age and time period interaction and the cohort and time period interaction, that can help to disentangle age and cohort effects. Thus, we can examine the extent to which age and cohort differences exist over time. Another unique feature of this article is that we include individuals from a broad age range, including the "oldest old." We hypothesized that, given the broad infusion of computers and the Internet into society, over time attitudes would become more positive. Given the diversity of our sample, we also examined the differences in attitudes related to gender and racial/ethnic groups. Understanding differences in attitudes according to gender and race/ethnicity can provide insight into how perceptions of the value of technology and technology efficacy vary according to demographic characteristics, which in turn may inform understanding of differences in technology adoption. Currently, there are limited data on racial/ethnic differences in attitudes toward technology.

Design and Methods

The data presented are from a series of studies conducted by the Edward. R. Roybal Center on Human Factors and Aging Research (1994–1999) and the Center for Research and Education on Aging and Technology Enhancement (CREATE) (1999–2013). The studies included in the analyses involved community-dwelling adults who interacted with some form of technology, and who also completed a battery of measures that included a demographic questionnaire, an assessment of prior computer experience (see Czaja et al., 2006 for a description of the common core battery), and the Attitudes Toward Computers Questionnaire (ATCQ; Jay & Willis, 1992). The research was conducted across three cities in the United States (Miami, FL, Tallahassee, FL, and Atlanta, GA). The site Institutional Review Boards approved all of the research protocols, and all research participants provided written informed consent.

Data Sources

Edward R. Roybal Center for Research on Human Factors and Aging Research

The Edward R. Roybal Center for Research on Human Factors and Aging Research focused on applying human factors principles to the design work activities and training for older adults with an emphasis on technology. The data included in these analyses are from a series of studies that focused on computer-based work tasks (e.g., Czaja, Sharit, & Nair, 1995; Czaja, Sharit, Nair, & Rubert, 1999; Sharit & Czaja, 1999) and age-related differences in performing basic computer activities such as use of a mouse (Smith, Sharit, & Czaja, 1999).

CREATE

CREATE is a multisite center, funded by the National Institutes of Health/National Institute on Aging (NIH/NIA). CREATE's focus is on older adults' interactions with technology systems to ensure that diverse populations of older adults can successfully use technology and realize its potential benefits. CREATE examined issues associated with aging and technology use across a broad range of technologies. Below, we summarize studies from which the computer attitude data were gathered for the analysis of this article.

The focus of CREATE I (1999–2004) was on training/instructional support, the design of input devices, interfaces, and the design of support aids. For these analyses, data were included from studies that examined telephone voice menu systems (Sharit, Czaja, Lee, & Nair, 2003); database search (Mead, Sit, Rogers, Jamieson, & Rousseau, 2010); skill acquisition for computer-based tasks (Nair, Czaja, & Sharit, 2007); input device design and selection (Charness, Holley, Feddon, & Jastrzembski, 2004; Jastrzembski, Harness, Holley, & Feddon, 2005; Pak, McLaughlin, Lin, Rogers, & Fisk, 2002; Rogers, Fisk, McLaughlin, & Pak, 2005); teleworkers (Sharit, Czaja, Hernandez, & Nair, 2009); and design of glucose monitors (McLaughlin, Rogers, & Fisk, 2004).

CREATE II (2004–2009) focused on health care applications, work/employment, use of technology within the home, and training, privacy, and trust. For these analyses, data were included from studies that examined the usability of the Medicare health website (Czaja, Sharit, & Nair, 2008); eHealth websites (Czaja et al., 2013); age-related differences in learning incidental and environmental information (Caine, Nichols, Fisk, Rogers, & Meyer, 2011); Internet health information seeking (Czaja, Sharit, Hernandez, Nair, & Loewenstein, 2010); strategies used during web-based information search and retrieval (Stronge, Rogers, & Fisk, 2006); stress experienced by older adults while interacting with technology (Dijkstra, Charness, Yordon, & Fox, 2009); synthetic speech (Roring, Hines, & Charness, 2007); and workload in human–automation interaction (McBride, Rogers, & Fisk, 2011).

In CREATE III (2009–2014), we examined applications of technology within living, work, and health care settings. For this article, we included data from a cross-site randomized field trial which evaluated the benefits of access to the Personalized Reminder Information and Social Management System (PRISM), a software application designed for older adults to support social connectivity, memory, knowledge about topics and resources, and leisure activities (Czaja et al., 2015; Czaja, Boot, et al., 2017). Data are also included from studies that examined the use of e-learning formats to train older adults (Taha, Czaja, & Sharit, 2016); online health information seeking (Sharit, Taha, Berkowsky, Profita, & Czaja, 2015); and everyday task performance using a technology-based functional assessment battery among noncognitively impaired older adults and older adults diagnosed with mild cognitive impairment (Czaja, Loewenstein, et al., 2017).

Sample

The sample for these analyses included 3,917 adults (1,472 male and 2,445 female) ranging in age from 18 to 98 years (M = 50.37; SD = 22.74). Race/ethnicity was self-identified by participants. The sample was relatively well educated, and primarily non-Hispanic white Caucasian (64%; Table 1). Figure 1 shows a smoothed scatter density plot which reflects the number of study participants of different ages as a function of year of testing. As shown, in later years we included more people from the "oldest old" categories.

With the exception of the study that evaluated everyday activity performance and included older adults with MCI (Czaja, Loewenstein, et al., 2017), all other study participants were noncognitively impaired (score on the Mini-Mental Status Examination [MMSE; Folstein, Folstein, & McHugh, 1975] ≥ 26 with the Mungus corrected score).

The sample was drawn from the community using various methods of recruitment such as media advertisement, participant registries, presentations at churches and senior centers, flyers advertising the studies, and word of mouth.

Table 1. Descriptive Statistics of Sample Used in the Analysis (n = 3,917; except for Race where n = 3,325)

Variable	*n*	Percent	*SE* (%)	Mean	SEM
Gender					
Male	1,472	37.58	0.77		
Female	2,445	62.42	0.77		
Education					
High school or less	899	22.95	0.68		
Some college	1,763	45.00	0.79		
College graduate	627	16.01	0.59		
Graduate school	628	16.03	0.59		
Race					
Black/African American	634	19.07	0.98		
White/Caucasian	1,926	57.92	0.86		
Hispanic/Latino	471	14.17	0.60		
Other	294	8.84	0.56		
Computer experience					
No	474	12.10	0.52		
Yes	3,443	87.90	0.52		
Age				50.36	0.37
Year of birth (YOB)				1953.47	0.36
Year of testing (YOT)				2004.25	0.08
Computer interest				18.57	0.07
Computer efficacy				21.11	0.04
Computer comfort				20.84	0.04

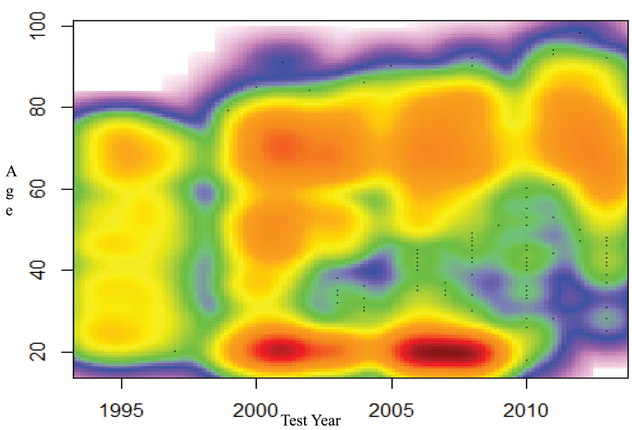

Figure 1. Smoothed color scatter density plot. The colors follow the color spectrum going from violet for areas with the least data to dark red for areas with the most data.

Materials

Background and Demographic Questionnaire

This questionnaire gathered basic demographic data such as gender, age, ethnicity, education level, and health information. It also included a question on prior computer experience (yes vs no).

The Attitudes Towards Computers Questionnaire (ATCQ) was used to collect attitudinal data (Jay & Willis, 1992). The ATCQ is a 35-item scale assessing seven dimensions of computer attitudes: comfort (feelings of comfort with computers); efficacy (feelings of competence with the computer); gender equality (computers are important to men and women); control (people control computers); interest (interest in learning about and using computers); dehumanization (the belief that computers are dehumanizing); and utility (the belief that computers are useful). There are five items for each dimension, which are rated on a 5-point Likert-type scale (*strongly agree* to *strongly disagree*). Scores for each dimension range from 5 to 25 with a higher score indicating more positive attitudes. Individuals who participated in the research before 2005 were administered the complete 35-item version of the ATCQ. Those who participated in later studies completed an adapted version of the ATCQ, which contains 15 items that assess comfort, efficacy, and interest (outdated scales were removed). The focus in this article is on comfort, efficacy, and interest as these subscales were present in both the 35-item and the 15-item ATCQ. The scores for the dimensions were z-scored to allow for a clearer interpretation of the data.

Results

A multilevel modeling technique was used for the analyses. The random effects variables tested were site (UM, GT, FSU) and study. The fixed effects variables tested were gender, education (an ordinal variable coded as high school or less, some college, college graduate, some graduate school or more), prior computer experience (yes or no), time period (year of testing), either age or cohort (year of birth), and several interactions. The effects of time period (year of testing), cohort (year of birth), and age, can only be described using 2 degrees of freedom; thus, the independent effects of all three variables cannot be fully disentangled as the value of any one of these variables can be identified by the combination of the other two (Bell & Jones, 2013). For example, if an individual completed the measures in 2010 and was born in 1940, that person must be either 69 or 70 years old.

A unique feature of this study is that the data are from a 20-year period, enabling the data to be examined from the perspectives of age, time period, and cohort. In the model that includes age (here on in referred to as the age model), we needed to ignore the effect cohort (year of birth), and in the cohort model, we needed to ignore the effect of age. In the age model, we examined age differences in attitudes and if attitudes changed over the time period. In the cohort model, we examine if individuals born, for example, in 1930, and who turned 65 in 1994, had different attitudes than individuals born in 1950 who turned 65 in 2013. We tested the three dimensions of the ATCQ in separate models for both age and cohort.

In the age and cohort models, we examined the following variables: gender (1 = *male*, 0 = *female*), education (1 = *high school or less*, 2 = *some college*, 3 = *college graduate*, 4 = *some graduate school or more*) and (personal) computer experience (1 = *no experience*, 0 = *experience*). The effect of these variables is essentially the same in both models, so we only discuss findings for these variables in the age models. Time period and the interaction of gender and time period was also tested in both models, but this parameter varies between the models and so is discussed in both models. All degrees of freedom reported reflect the Satterthwaite approximation.

Age Models

For each of the three dimensions in the ATCQ, we tested the following effects: age, time period, the age and gender interaction, the age and time period interaction, and the three-way interaction of age, gender, and time period. All continuous variables were centered at 0. In this model, a negative coefficient for age means that in general older adults had more negative attitudes than younger people. A positive effect of time period means that people included in the studies who were assessed more recently have more positive attitudes. A positive coefficient for gender means that males have more positive attitudes than females. A negative coefficient for PC experience means that people without computer (PC) experience had more negative attitudes about computers. An interaction of gender and time period means that across the 20 years that these studies took place the effect of gender changed. An interaction of age and gender means that gender differences were not the same for older adults as they were for younger adults. An interaction of age and time period implies that the effect of age changed over the 20 years that these studies took place. The three-way interaction of gender, age, and time period would mean that the change in the effect of age across the 20 years of the study was different between males and females. Model coefficients are reported in Table 2.

Table 2. Results of Multilevel Models on Dimensions of ATCQ Across Time

	Aging model			Cohort model		
	Interest	Efficacy	Comfort	Interest	Efficacy	Comfort
Variable	Coeff (*SE*)	Coeff (*SE*)	Coeff (*SE*)	Coeff (*SE*)	Coeff (*SE*)	Coeff (*SE*)
Fixed effects						
Intercept	−.15 (.22)	.03 (.06)	−.05 (.06)	−.13 (.22)	.04 (.06)	−.04 (.06)
Male	.11 (.03)**	.08 (.03)*	.22 (.03)**	.11 (.03)**	.08 (.03)*	.20 (.03)**
Education	.08 (.02)**	.13 (.02)**	.04 (.02)*	.08 (.02)**	.13 (.02)**	.04 (.02)*
No PC experience	−.44 (.05)**	−.40 (.05)**	−.47 (.05)**	−.44 (.05)**	−.40 (.05)**	−.47 (.05)**
Time period (TP)	.02 (.01)	.02 (.006)**	.03 (.004)*	.02 (.01)	.01 (.006)	.01 (.004)
Male × TP	.01 (.01)	.002 (.006)	−.005 (.006)	.005 (.007)	<.−.01 (.006)	−.003 (.006)
Age	<.01 (<.01)	−.01 (<.01)**	−.02 (<.01)**			
Male × Age	−.004 (.001)*	−.003 (.001)*	.002 (.001)			
Age × TP	<−.01(<.01)	−.01 (<.01)	<.01 (<.01)			
Gender × Age × TP	<.01 (<.01)	<.01 (<.01)	<.01 (<.01)			
Cohort (C)				<−.01 (<.01)	.01 (<.01)**	.02 (<.01)**
Male × C				.004 (.001)*	.003 (.001)*	−.001 (.001)
TP × C				<−.01 (<.01)	<−.01 (<.01)	<−.01 (<.01)
Gender × Age × C				<.01 (<.01)	<.01 (<.01)	<.01 (<.01)
Random effect						
Residual	.92 (.02)**	.88 (.02)**	.81 (.02)**	.92 (.02)**	.88 (.01)**	.81 (.02)**
Study	.24 (.15)	.005 (.006)	<.01 (.004)	.24 (.15)	.007 (.008)	<.01 (.003)
Site	.03 (.03)	.007 (.008)	.008 (.009)	.03 (.03)	.005 (.006)	.008 (.009)

Note: For each dimension, one analysis is presented showing the effects of age and another showing the effect of year of birth. n = 3,908. Coeff = coefficient (beta).
*p < .05. **p < .01.

Figure 2a plots the estimated values for all three variables across time at representative ages.

Computer Interest

Overall, males [$t(3,896) = 3.29$, $p = .001$], and people with higher levels of education [$t(3,899) = 4.77$, $p < .001$] and with computer experience [$t(3,899) = -8.44$, $p < .001$] showed significantly more interest in computers. There was no significant main effect of time period [$t(156) = 1.44$, $p = .15$], or age [$t(3,887) = -0.66$, $p = .51$). The interactions of age and time period [$t(3,850) = 1.61$, $p = .11$] and gender and time period [$t(3,894) = 1.31$, $p = .19$], and the three-way interaction of age, gender, and time period [$t(3,895) = -0.41$, $p = .68$] were not significant. However, there was a significant age by gender interaction [$t(3,894) = -2.53$, $p = .01$] such that the greater interest in computers among males compared with females decreased in later ages (Figure 3).

Computer Efficacy

Males [$t(3,898) = 2.56$, $p = .011$], people with higher levels of education [$t(3,687) = 8.02$, $p < .001$], and people

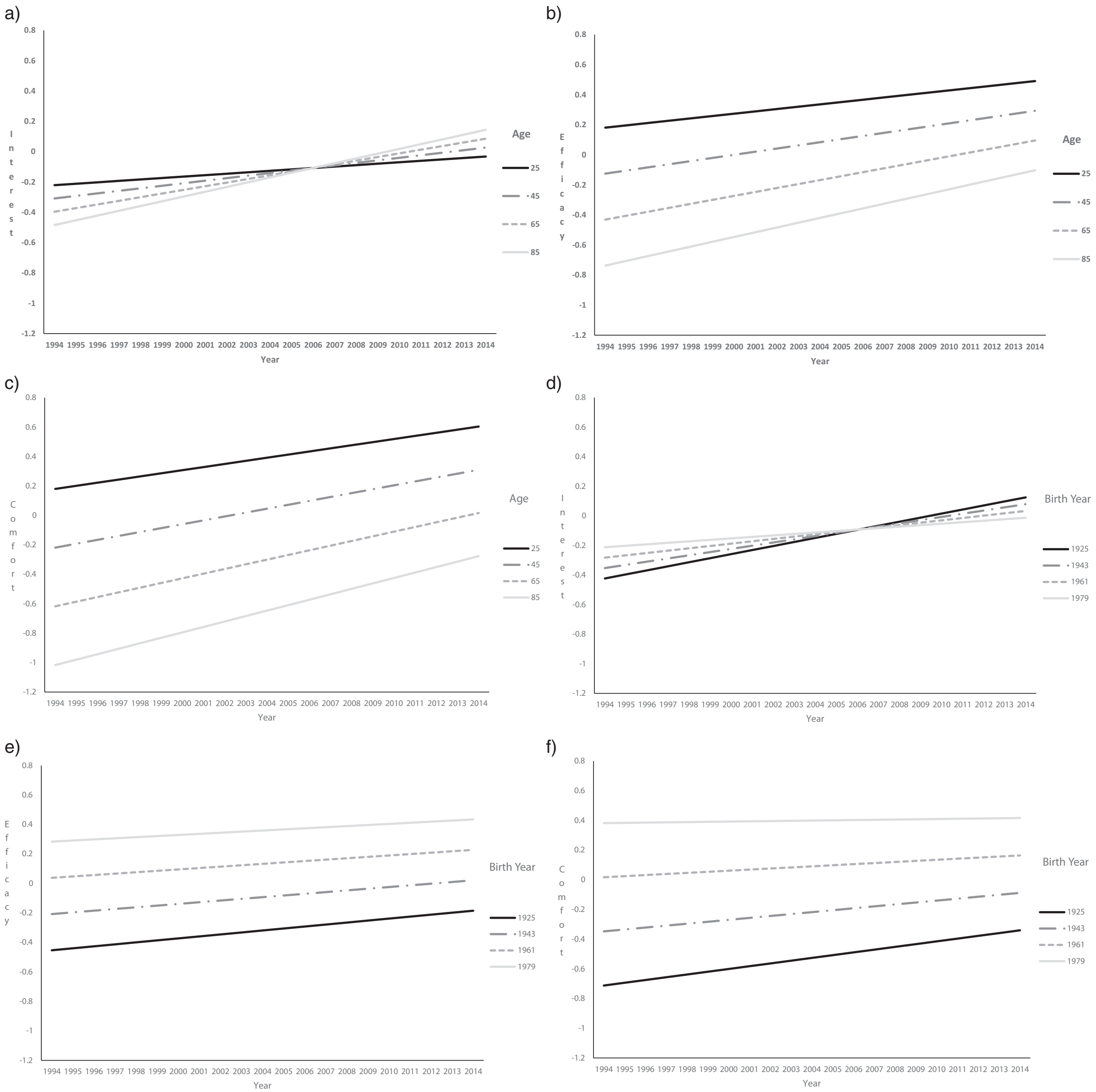

Figure 2. (a) Age changes in computer attitudes across time based on the results of the multilevel models. From left to right are computer interest, computer efficacy, and computer comfort. (b) Changes within birth cohort in computer attitudes across time based on the results of the multilevel models. From left to right are computer interest, computer efficacy, and computer comfort.

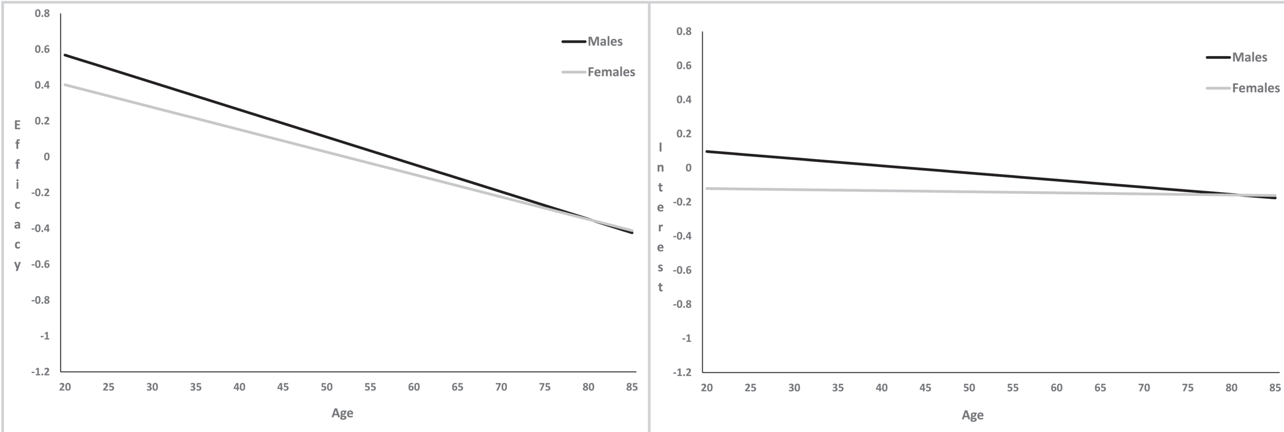

Figure 3. Interaction of gender and age on computer efficacy (left) and computer interest (right).

with computer experience [$t(2,387) = -8.08$, $p < .001$] reported significantly greater computer efficacy. Computer efficacy also increased significantly over time [$t(8) = 3.82$, $p = .01$]. There was also a significant age effect such that older adults had lower computer efficacy than younger people [$t(2,859) = -13.37$, $p < .001$]. The relationship between age and computer efficacy did not change over time [$t(615) = 1.19$, $p = .24$], However, there was a significant age by gender interaction [$t(3,998) = -1.99$, $p = .047$] such that the greater computer efficacy reported by males as compared with females decreased with age (Figure 3). The interaction of gender and time period [$t(3,894) = 0.40$, $p = .69$] and the three-way interaction of age, gender, and time period [$t(3,858) = -0.70$, $p = .48$] were not significant.

Computer Comfort

Males [$t(3,888) = 7.06$, $p < .001$), people with higher levels of education [$t(2,758) = 2.51$, $p = .012$], and people with computer experience [$t(544) = -10.02$, $p < .001$] reported significantly more comfort with computers. Comfort with computers also significantly increased over time [$t(2) = 6.24$, $p = .02$]. Further, older adults reported significantly less comfort with computers than younger adults [$t(499) = -19.24$, $p < .001$]. The relationship of age and computer comfort did not change over time [$t(42) = 1.52$, $p = .14$]. The interactions of age and gender [$t(3,898) = -1.57$, $p = .12$] and gender and time period [$t(3,824) = -0.88$, $p = .38$], and the three-way interaction of age, gender, and time period [$t(3,463) = -1.85$, $p = .06$] were not significant.

Cohort Models

For each dimension in the ATCQ, we tested the following effects: cohort (year of birth), time period, the cohort and gender and cohort and time period interactions, and the three-way interaction of cohort, gender, time period. For this model, a main effect of cohort means that people born at earlier dates differed from people born at later dates. A positive coefficient would mean that people born in 1950, for example, on average had more negative computer attitudes than people born in 1980. An interaction of cohort and time period implies that across the time period of these studies there was a change in the effect of the cohort. An interaction of gender and cohort would mean that the differences between males and females varied based on birth year. The three-way interaction of gender, cohort, and time period would mean that the change in the effect of the birth year across the 20 years of the study was different between males and females. The coefficients for the models are reported in Table 2. Figure 2b plots the estimated values for all three variables across time at representative birth years. The cohort models and the age models are linearly equivalent past rounding. Consequently, outside of the year of birth and time period variables, which allow us to view the data from a different perspective, we will not report main effects of gender, education, and no PC experience, which are redundant to that presented in the age models.

Computer Interest

There was no significant effect of time period [$t(159) = 1.36$, $p = .18$) or cohort [$t(3,887) = 0.61$, $p = .54$] for interest in computers. The cohort and time period [$t(3,890) = -1.40$, $p = .16$], gender and time period [$t(3,894) = 0.74$, $p = .47$] or cohort, gender, and time period [$t(3,894) = 0.20$, $p = .84$] interactions were also non-significant. However, there was a significant cohort by gender interaction [$t(3,894) = 2.53$, $p = .01$] such that the greater interest in computers among males as compared with females was greater among people born more recently.

Computer Efficacy

There was no main effect of the time period [$t(8) = 1.77$, $p = .11$]. However, we did find a main effect for cohort such that people born in later years reported significantly higher computer efficacy [$t(2,960) = 13.36$, $p < .001$]. The interactions of cohort and time period [$t(1,466) = -0.50$,

Table 3. Descriptive Statistics by Race and Gender

Group	*n*	Comfort	Interest	Efficacy	Year of testing	Age	Year of birth	Education	PC experience
Black/African American males	179	19.71 (3.57)	21.44 (2.85)	21.67 (2.93)	2006.20 (4.18)	47.50 (20.45)	1958.36 (19.52)	1.95 (0.86)	0.83 (0.38)
Black/African American females	455	19.15 (3.87)	21.18 (2.57)	21.35 (2.63)	2006.32 (4.19)	50.99 (21.70)	1954.88 (20.56)	1.92 (0.92)	0.85 (0.35)
White/Caucasian males	760	18.95 (4.24)	20.82 (3.09)	21.24 (2.81)	2005.17 (3.67)	53.31 (24.48)	1951.40 (24.30)	2.54 (1.04)	0.92 (0.28)
White/Caucasian females	1166	17.61 (4.35)	20.43 (2.81)	20.82 (2.75)	2005.29 (3.92)	54.19 (24.08)	1950.66 (23.47)	2.33 (0.97)	0.91 (0.29)
Hispanic/Latino males	141	19.67 (3.95)	21.31 (2.55)	21.65 (2.77)	2005.94 (4.56)	47.58 (21.80)	1958.09 (21.15)	2.21 (0.95)	0.90 (0.30)
Hispanic/Latino females	330	19.23 (4.21)	21.06 (2.71)	21.18 (2.94)	2006.59 (4.63)	49.58 (22.60)	1956.70 (20.84)	2.13 (0.98)	0.91 (0.29)
Other males	135	21.13 (3.16)	21.37 (2.69)	21.82 (2.80)	2005.00 (3.32)	29.96 (19.39)	1974.53 (19.28)	1.90 (0.78)	0.99 (0.09)
Other females	159	19.33 (3.99)	20.47 (2.45)	21.24 (2.65)	2005.19 (3.67)	36.08 (22.41)	1968.68 (21.65)	2.11 (0.87)	0.95 (0.22)

Note: $n = 3,325$.

p = .62], gender and year of testing [$t(3,880) = 0.14$, p = .88], and the three-way interaction of age, gender, and year of testing [$t(3,877) = .22$, p = .82] were not significant. However, there was a significant cohort by gender interaction [$t(3,897) = 2.02$, p = .04] such that gender difference in efficacy was greater among people born more recently.

Computer Comfort

There was no main effect of time period [$t(4) = 2.26$, p = .09]. However, people born in later cohorts reported significantly greater comfort with computers [$t(802) = 19.13$, p < .001]. There was no significant interactions of cohort and time period [$t(203) = -1.52$, p = .13], cohort and gender [$t(3,895) = -1.48$, p = .14], gender and time period [$t(3,615) = -0.51$, p = .61], or cohort, gender, and time period [$t(3,762) = 1.63$, p = .10].

Race/Ethnicity

The variable of race/ethnicity was not available for the participants involved in the Center on Human Factors and Aging Research (before 2000). We added the variable of race, the interaction of race and gender, the interaction of race and age, and the interaction of race and time period to the previously described models for the participants included in studies from 2000 to 2013. We only report a subset of the data for the age and cohort models for race. Descriptive statistics by race are in Table 3.

With respect to computer interest, the effect of race/ethnicity was statistically significant $F(3, 3,284) = 16.70$, p < .001. As shown in Figure 4, black/African Americans reported significantly more interest in computers than white/Caucasians [$t(3,296) = 7.03$, p < .001, g = .32], Hispanics [$t(3,284) = 4.34$, p < .001, g = .26], and the other race category [$t(3,294) = 3.42$, p < .001, g = .24]. The interactions of race/ethnicity and gender [$F(3, 3,292) = 0.69$, p = .55], race/ethnicity and age [$F(3, 3,294) = 0.95$, p = .42], and race/ethnicity and year of testing [$F(3, 3,292) = 0.60$, p = .62) were not statistically significant. For computer efficacy, the effect of race/ethnicity was statistically significant [$F(3, 2,168) = 5.58$, p = .001]. Black/African Americans reported significantly more computer efficacy than white/Caucasians [$t(3,297) = 3.78$, p < .001, g = .17], Hispanics [$t(3,141) = 3.04$, p = .002, g = .19], and other races [$t(3,297) = 2.60$, p = .009, g = .18]. The interactions of race and gender [$F(3, 3,296) = 0.28$, p = .84], race and age [$F(3, 3,296) = 0.66$, p = .57], and race and time period [$F(3, 3,297) = 1.22$, p = .30] were not statistically significant. For computer comfort, the effect of race was statistically significant [$F(3, 2,939) = 15.52$, p < .001]. The white/Caucasians reported significantly less comfort with computers than black/African Americans [$t(3,296) = -6.39$, p < .001, g = −.29] or Hispanics [$t(2,009) = -3.61$, p < .001, g = −.22]. The interactions of race and gender [$F(3, 3,294) = 2.16$, p = .09], race and age [$F(3, 32,876) = 2.20$,

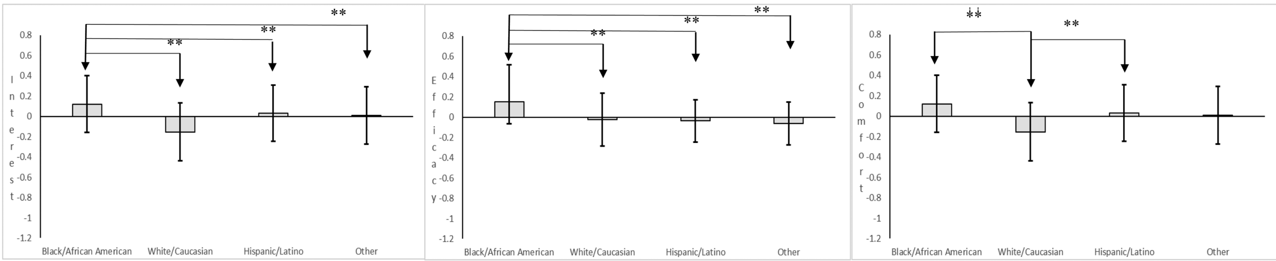

Figure 4. Racial differences in computer attitudes.

p = .09], and race and time period [F(3, 2981.79) = 0.93, p = .42] were not statistically significant.

Discussion

This article examined attitudes toward computers from a large, diverse sample of community-dwelling adults from the time period 1994–2013. These 20 years are significant in that the early 1990s marked the beginning of the modern Internet, which in turn generated rapid growth in the use of personal computers (Leiner et al., 1997). Further, across these 20 years, there has been a tremendous increase in the number of households with computers and Internet access as well as the emergence of new devices such as smartphones. Today, more than 80% of households in the United States have a computer and greater than 70% have broadband access to the Internet. However, despite the increase in uptake of technology and the Internet in the overall population there still exists an age-related digital divide, with older adults being less likely to own computers and digital devices and have access to the Internet.

Attitudes toward technology are important predictors of technology adoption. In fact, findings from a recent report from the Pew Research Center (Anderson & Perrin, 2017) indicate that one challenge that older adults face with respect to technology adoption is lack of confidence regarding their ability to learn to use the technology. In this study, we were able to examine age differences in attitudes toward computers as well as examine if age differences in attitudes have changed over time or as a function of cohort. Answers to these questions are important as they provide insight into barriers to technology adoption among older people. Given the diversity of our sample, we were also able to examine gender and racial/ethnic differences in attitudes.

With respect to age, despite the widespread proliferation of technology and the Internet, older adults still have less comfort with and efficacy toward computers, and these effects were found to be stable over time (i.e., no age by time period interaction). This is alarming given the ubiquitous infiltration of computers and the Internet into most aspects of life. Not being part of the digital revolution clearly puts older adults at a disadvantage in terms of successfully negotiating today's world. It also prevents older adults who are not "connected" to realize the potential benefits of technology such as opportunities for enhancing engagement and socialization and opportunities for employment and learning. These findings point to the need for product developers and marketers to develop strategies that can engender confidence among older adults that they will be able to master the use of new technologies. Underlying such strategies are designs that encompass the needs, preferences, and abilities of older users (Fisk, Rogers, Charness, Czaja, & Sharit, 2009). Technology training programs should also be structured to foster confidence in learning. Older adults often report the desire for more training to support their use of technology (Mitzner et al., 2008). We did not, however, find an age difference with respect to interest in computers. This finding may be due to the fact that the sample was a convenience sample interested in participating in research about computers and technology.

Our data also show that adults born at later birth cohorts reported more comfort and more computer efficacy. These effects did not change over time, which suggests that changes in attitudes are not changing within cohorts. The fact that adults born in later cohorts are becoming more comfortable with computer technology may be influencing the higher rate of Internet adoption rate among those who are currently aged 65–74 years as compared with those aged 75+ (Anderson & Perrin, 2017). It may also be that experience with technology is resulting in an increase with comfort toward technology and increased beliefs that one will be able to use the technology. Our data indicate that people with computer experience reported more comfort with computers and computer efficacy. Given the trends in technology diffusion, people born in later cohorts are more likely to have had experience with computers in work and perhaps learning contexts than those born in early cohorts. Further, although new technologies are likely to continue to emerge at a relatively rapid rate, given the ubiquitous deployment of technology we conjecture that attitudes toward technology will continue to be more positive and that over time age differences may diminish. The reductions in age differences in attitudes will also be more likely if older adults have access to technology and venues for obtaining technology skills, and if designers consider older adults as active users of systems.

We also found that being male and having higher levels of education were associated with greater interest in computers, comfort with computers, and computer efficacy. The UTAUT model of technology adoption recognized that gender is a significant factor with respect to technology adoption. In fact, a recent review (Goswami & Dutta, 2016) found that gender is an important predictor with respect to the acceptance of new technology. However, the impact of gender varied according to the technology application. Males were more likely to be accepting of technologies and applications such as computers, email, and electronic data management systems whereas for mobile or Internet banking, there were mixed findings and there was no gender difference with respect to social media.

Interestingly, the gender differences in computer interest and computer efficacy were found to decrease as people aged. This effect could be due to the fact that younger males have a disproportionately increased exposure to computer technologies in work settings. Currently, women are still underrepresented in technology-based jobs (U.S. Department of Labor, 2015). The age and gender interaction is also consistent with findings that males are more interested in things as opposed to people in comparison to females, and that this difference diminishes with age (Su, Rounds, & Armstrong, 2009). It should also be noted that attitudes among women were more age invariant.

Our findings also indicate that black/African Americans report significantly more computer interest and efficacy than other ethnic groups. This seems counterintuitive because, while the size of the digital divide between ethnic groups varies by age and education, on average African Americans have lower adoption rates than Whites (Smith, 2014). However, technological adoption and technological attitudes clearly are not identical concepts. An implication of this study is that the digital divide among ethnic groups is not being driven by attitudes but rather is more likely being influenced by access to the technology. In fact, data indicate (Porter & Donthu, 2006) that black/African Americans were more likely than whites to perceive access to the Internet as being costly. The investigators also found no ethnic group differences in perceived usefulness of the Internet; in fact, 87% of their minority sample perceived the Internet as useful. Future research should look more closely at differences in attitudes between ethnic groups and what variables might mediate the differences observed here. For example, recent data from the Pew Research Center (Perrin, 2017) indicate that although blacks and Hispanics are less likely than whites to own a computer and have high-speed Internet access at home, they are more likely than whites to access the Internet through smartphones. Perhaps phones are perceived as easier to use and thus generate greater feelings of self-efficacy. However, consistent with the findings of Porter and Donthu (2006), cost remains an issue. Blacks and Hispanic smartphone users are twice as likely as whites to cancel Internet smartphone service because of expense.

In summary, our findings, consistent with recent models of technology adoption such as the UTAUT2 model (Venkatesh et al., 2012), indicate that individual characteristics such as age, gender, race/ethnicity, and educational status, have an impact on attitudes toward technology. Further, despite the ubiquitous deployment of technology in society, the attitudes of older adults remain less positive than those of younger people. These findings underscore the importance of considering individual differences in the design of training programs and technology systems. A "one size fits all" approach is not feasible given the broad diversity of user groups. Also, what is clear from the human factors literature (e.g., Fisk et al., 2009) is that improved usability of a system or program will enhance market penetration of that system or program. The findings also have policy implications. As noted above, efforts should be directed toward ensuring that people across ages and SES status have meaningful access to technology.

Study Limitations

It is important to note some limitations to this study. First, we only included basic sociodemographic information such as age, gender, race/ethnicity, and computer experience in our multilevel modeling. As our research and that of others shows, there are other factors such as income, health status, and cognitive abilities which predict technology adoption among older adults. Second, our measure of computer experience was rather broad. Third, although we were able to examine time period and cohort, the data were not longitudinal. Fourth, even though we enrolled community-dwelling adults in our studies, the participants represented a convenience sample who took part in research studies which involved technology. They may have been predisposed to have an interest in computers and Internet-based activities, and thus their attitudes toward computers might be more positive than the general population.

Overall, technology adoption is a complex issue and is influenced greatly by attitudes toward computers and other factors such as sociodemographic factors, race/ethnicity, and cognitive abilities. Other important aspects of the technology adoption equation that need to be explored include environmental factors such as the availability of training and the usability of technology.

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Conflict of Interest

The authors report no conflict of interest.

References

Anderson, M., & Perrin, A. (2017). *Tech adoption climbs among older adults*. Pew Research Center. Retrieved from http://www.pewinternet.org/2017/05/17/tech-adoption-climbs-among-older-adults/

Bell, A., & Jones, K. (2013). The impossibility of separating age, period and cohort effects. *Social Science & Medicine (1982)*, **93**, 163–165. doi:10.1016/j.socscimed.2013.04.029

Caine, K. E., Nichols, T. A., Fisk, A. D., Rogers, W. A., & Meyer, B. (2011). Age-related differences in learning incidental, environmental information. *Experimental Aging Research*, **37**, 17–45. doi:10.1080/0361073X.2010.507429

Charness, N., Holley, P., Feddon, J., & Jastrzembski, T. (2004). Light pen use and practice minimize age and hand performance differences in pointing tasks. *Human Factors*, **46**, 373–384. doi:10.1518/hfes.46.3.373.50396

Chen, K., & Chan, A. H. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics*, **57**, 635–652. doi:10.1080/00140139.2014.895855

Czaja, S. J., Boot, W. R., Charness, N., Rogers, W. A., & Sharit, J. (2017). Improving social support for older adults through technology: Findings from the PRISM randomized controlled trial. *The Gerontologist*, **58**, 464–477. doi:10.1093/geront/gnw249

Czaja, S. J., Boot, W. R., Charness, N., Rogers, W. A., Sharit, J., Fisk, A. D.,…Nair, S. N. (2015). The personalized reminder information and social management system (PRISM) trial: Rationale, methods and baseline characteristics. *Contemporary Clinical Trials*, **40**, 35–46. doi:10.1016/j.cct.2014.11.004

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., & Sharit, J. (2006). Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging*, **21**, 333–352. doi:10.1037/0882-7974.21.2.333

Czaja, S. J., Loewenstein, D. A., Sabbag, S. A., Curiel, R. E., Crocco, E., & Harvey, P. D. (2017). A novel method for direct assessment of everyday competence among older adults. *Journal of Alzheimer's disease*, **57**, 1229–1238. doi:10.3233/JAD-161183

Czaja, S. J., & Sharit, J. (1998). Age differences in attitudes toward computers. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, **53**, 329–340.

Czaja, S. J., Sharit, J., Hernandez, M., Nair, S. N., & Loewenstein, D. A. (2010). Variability among older adults in Internet information seeking performance. *Gerontechnology*, **9**, 46–55. doi:10.4017/gt. 2010.09.01.004.00

Czaja, S. J., Sharit, J., Lee, C. C., Nair, S. N., Hernández, M. A., Arana, N., & Fu, S. H. (2013). Factors influencing use of an e-health website in a community sample of older adults. *Journal of the American Medical Informatics Association*, **20**, 277–284. doi:10.1136/amiajnl-2012-000876

Czaja, S. J., Sharit, J., & Nair, S. N. (1995). Age differences in perception of workload for a computer task. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, **39**, 129–133. doi:10.1177/154193129503900202

Czaja, S. J., Sharit, J., & Nair, S. N. (2008). Usability of the Medicare health web site. *JAMA*, **300**, 790–792. doi:10.1001/jama.300.7.790-b

Czaja, S. J., Sharit, J., Nair, S. N., & Rubert, M. (1999). Understanding sources of user variability in computer-based data entry performance. *Behaviour & Information Technology*, **17**, 282–293. doi:10.1080/014492998119355

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, **13**, 319–340. doi: 10.2307/249008

Dijkstra, K., Charness, N., Yordon, R., & Fox, M. (2009). Changes in physiological stress and self-reported mood in younger and older adults after exposure to a stressful task. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, **16**, 338–356. doi:10.1080/13825580902773859

Fisk, A. D., Rogers, W. A., Charness, N., Czaja, S. J., & Sharit, J. (2009). *Designing for older adults: Principles and creative human factors approach* (2nd ed.). Boca Raton, FL: CRC Press.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, **12**, 189–198.

Goswami, A., & Dutta, S. (2016). Gender differences in technology usage—A literature review. *Open Journal of Business and Management*, **4**, 51–59. doi:10.4236/ojbm.2016.41006

Jastrzembski, T., Charness, N., Holley, P., & Feddon, J. (2005). Input devices for web browsing: Age and hand effects. *Universal Access in the Information Society*, **46**: 39. doi:10.1007/s10209-003-0083-5

Jay, G. M., & Willis, S. L. (1992). Influence of direct computer experience on older adults' attitudes toward computers. *Journal of Gerontology*, **47**, P250–P257.

Leiner, B. M., Cerf, V. G., Clark, D. D., Kahn, R. E., Kleinrock, L., Lynch, D. C.,…Wolff, S. S. (1997). The past and future history of the Internet. *Communications of the ACM*, **40**, 102–108. doi:10.1145/253671.253741

McBride, S. E., Rogers, W. A., & Fisk, A. D. (2011). Understanding the effect of workload on automation use for younger and older adults. *Human Factors*, **53**, 672–686. doi:10.1177/0018720811421909

McLaughlin, A. C., Rogers, W. A., & Fisk, A. D. (2004). Age-related glucometer design and selection: Tools and principles for optimal solutions. *Diabetes Technology & Therapeutics*, **6**, 319–325. doi:10.1089/152091504774198007

Mead, S. E., Sit, R. A., Rogers, W. A., Jamieson, B. A., & Rousseau, G. K. (2010). Influences of general computer experience and age on library database search performance. *Behaviour & Information Technology*, **19**, 107–123. doi:10.1080/014492900118713

Mitzner, T. L., Rogers, W. A., Fistk, A. D., Boot, W. R., Charness, N., Czaja, S. J., & Sharit, J. (2016). Predicting older adults' perceptions about a computer system designed for seniors. *Universal Access in the Information Society*, **15**, 271–280. doi:10.1007/s10209-014-0383-y

Mitzner, T. L., Fausset, C. B., Boron, J. B., Adams, A. E., Dijkstra, K., Lee, C. C.,…Fisk, A. D. (2008). Older adults' training preferences for learning to use technology. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, **52**, 2047–2051.

Morrell, R. W., Mayhorn, C. B., & Bennett, J. (2000). A survey of World Wide Web use in middle-aged and older adults. *Human Factors*, **42**, 175–182. doi:10.1518/001872000779656444

Morris, A., Goodman, J., & Brading, H. (2007). Internet use and non-use: Views of older users. *Universal Access in the Information Society*, **6**, 43–57. doi:10.1007/s10209-006-0057-5

Nair, S. N., Czaja, S. J., & Sharit, J. (2007). A multilevel modeling approach to examining individual differences in skill acquisition for a computer-based task. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, **62**(Spec. No. 1), 85–96.

Pak, R., McLaughlin, A. C., Lin, C. C., Rogers, W. A., & Fisk, A. D. (2002). An age-related comparison of a touchscreen and a novel input device. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, **46**, 189–192. doi:10.1177/154193120204600204

Perrin, A. (2017). *Smartphones help blacks, Hispanics bridge some—But not all—Digital gaps with whites*. Pew Research Center. Retrieved from http://www.pewresearch.org/fact-tank/2017/08/31/smartphones-help-blacks-hispanics-bridge-some-but-not-all-digital-gaps-with-whites/

Pew Research Center. (2018). *Internet/Broadband factsheet*. ***Retrieved from http://www.pewinternet.org/fact-sheet/internet-broadband/

Porter, C. E., & Donthu, N. (2006). Using the technology acceptance model to explain how attitudes determine Internet use: The role of perceived access barriers and demographics. *Journal of Business Research*, **59**, 999–1007. doi:10.1016/j.jbusres.2006.06.003

Regan, D. T., & Fazio, R. (1977). On the consistency between attitudes and behavior: Look to the method of attitude formation. *Journal of Experimental and Social Psychology*, **13**, 28–45. doi:10.1016/0022-1031(77)90011–7

Rogers, W. A., Fisk, A. D., McLaughlin, A. C., & Pak, R. (2005). Touch a screen or turn a knob: Choosing the best device for the job. *Human Factors*, **47**, 271–288. doi:10.1518/0018720054679452

Roring, R. W., Hines, F. G., & Charness, N. (2007). Age differences in identifying words in synthetic speech. *Human Factors*, **49**, 25–31. doi:10.1518/001872007779598055

Sharit, J., & Czaja, S. J. (1999). Performance of a computer-based troubleshooting task in the banking industry: Examining the effects of age, task experience, and cognitive abilities. *Internal Journal of Cognitive Ergonomics*, **3**, 1–22. doi:10.1207/s15327566ijce0301_1

Sharit, J., Czaja, S. J., Hernandez, M. A., & Nair, S. N. (2009). The employability of older workers as teleworkers: An appraisal of issues and an empirical study. *Human Factors and Ergonomics in Manufacturing*, **19**, 457–477. doi:10.1002/hfm.20138

Sharit, J., Czaja, S. J., Nair, S., & Lee, C. C. (2003). Effects of age, speech rate, and environmental support in using telephone voice menu systems. *Human Factors*, **45**, 234–251. doi:10.1518/hfes.45.2.234.27245

Sharit, J., Taha, J., Berkowsky, R. W., Profita, H., & Czaja, S. J. (2015). Online information search performance and search strategies in a health problem-solving scenario. *Journal of Cognitive Engineering and Decision Making*, **9**, 211–228. doi:10.1177/1555343415583747

Smith, A. (2014). *African Americans and technology use: A demographic portrait*. Pew Research Center. Retrieved from http://pewinternet.org/reports/2014/African-American-Tech-Use.aspx

Smith, M. W., Sharit, J., & Czaja, S. J. (1999). Aging, motor control, and the performance of computer mouse tasks. *Human Factors*, **41**, 389–396. doi:10.1518/001872099779611102

Stronge, A. J., Rogers, W. A., & Fisk, A. D. (2006). Web-based information search and retrieval: Effects of strategy use and age on search success. *Human Factors*, **48**, 434–446. doi:10.1518/001872006778606804

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin*, **135**, 859–884. doi:10.1037/a0017364

Taha, J., Czaja, S. J., & Sharit, J. (2016). Technology training for older job-seeking adults: The efficacy of a program offered through a university-community collaboration. *Educational Gerontology*, **42**, 276–287. doi:10.1080/03601277.2015.1109405

U.S. Census Bureau. (2005). *Computer and Internet use in the United States: 2003*. Retrieved from https://www.census.gov/prod/2005pubs/p23-208.pdf

U.S. Census Bureau. (2017). *Computer and Internet use in the United States: 2015*. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2017/acs/acs-37.pdf

U.S. Department of Labor. (2015). *Computer and information technology occupations*. Retrieved from https://www.dol.gov/wb/stats/Computer_information_technology_2014.htm

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, **27**, 425–478.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly*, **36**, 1.