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Review

Computer use by older adults: A multi-disciplinary review

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ABSTRACT

As the populations of most of the world's developed nations experience an increase in average age, a similar trend is being observed in the population of computer and Internet users. In many cases, older adults are the fastest growing computer and Internet user group in both personal and workplace contexts. However, the needs and concerns of older adults as computer users differ from those of younger users as a result of the natural changes associated with the aging process. Much research has been conducted in a variety of fields in order to understand how these changes experienced by older adults impact their use of computers and the Internet. This article reviews this existing research and provides a holistic view of the field. Since the study of computer use by older adults is a multi-disciplinary topic by nature, we provide a synthesis of the findings across these many disciplines, and attempt to highlight any gaps that exist. We use Social Cognitive Theory as a lens to view and organize the literature, as well as illustrate means through which computer use by this user group can be encouraged. Finally, suggestions for future research are proposed, and implications for research and practice are discussed.

1. Introduction

Most of the world's developed nations are experiencing an increase in the average age of their population (OECD, 2006). A similar trend has been observed among users of computers and the Internet, both for personal and professional purposes. Older adults now make up the fastest growing consumer segment of Internet users (Hart, Chaparro, & Halcomb, 2008). They are enhancing their independence by accessing online services such as banking, shopping, or healthcare management, and pursuing leisure activities, including recreation and communication (Vuori & Holmlund-Rytkönen, 2005). Further, adults over 50 years of age make up the fastest growing segment of the workforce (Kooij, deLange, Jansen, & Dikkers, 2008), where workers are often using computers on a daily basis to perform their jobs (Nord, McCubbins, & Nord, 2006). As computers become an increasingly integral part of the lives of older adults, the study of computer use by older adults is becoming an increasingly relevant field of study. In order to encourage and facilitate computer use by this important group, for both personal and professional benefit, it is necessary to understand how older computer users differ from their younger counterparts, and what the implications of these differences are for computer use.

The term older adult has been defined in a variety of ways. In the papers reviewed for this article, a wide age range was observed with "over 40" on the lower end of the scale and "over 75" on the higher end of the scale. The distinction of "older" depends partially upon the context under consideration. In a workplace context, older typically refers to workers over the age of 50 or 55 since this is the age range where a decline in labor market participation rate tends to be observed (Kooij et al., 2008). In a more general context, the minimum age describing older tends to be higher since the upper limit on age is much higher outside of the workplace.

When it comes to using computers, older adults have different needs and concerns compared to younger adults resulting from the natural physical and cognitive changes that come with aging, which tend to become more noticeable at approximately 45 years of age (Hawthorn, 2000). Each of these changes has important implications for the use of computers by older adults. For example, physical changes associated with aging include declines in vision, hearing, and psychomotor coordination (Hawthorn, 2000). Thus, computer and web interfaces will be more appropriate for older users if they make use of features like larger fonts, sounds within certain frequency ranges, and layouts that require less precise mouse movement. Similarly, cognitive changes such as reduced attention span, declines in memory, and changes in spatial abilities create a need for interfaces that have fewer distractions, provide memory cues, and are simple to learn and understand (Hawthorn, 2000).

The changes experienced by older adults and their implications for computer use have been studied by many different researchers in many different contexts. This article reviews the existing research and provides a holistic view of the field. Since the study of computer use by older adults is a multi-disciplinary topic by

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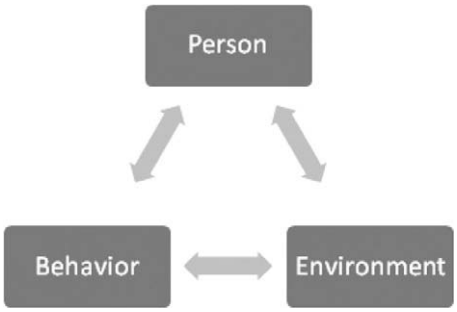

Fig. 1. Triadic reciprocality or reciprocal determinism of SCT.

nature, we provide a synthesis of the findings from across these many disciplines, and attempt to highlight any gaps that exist. This article is organized as follows: In the next section we discuss Social Cognitive Theory and how we have applied it to examine the literature. Next, we discuss the methodology used for finding articles, followed by our literature analysis. The article closes with some discussion and conclusion of our findings.

2. Theoretical background

Social Cognitive Theory (SCT) is a widely accepted model of individual behavior (Chan & Lu, 2004). Developed by Albert Bandura (Bandura, 1986), the roots of SCT lie in the domain of social learning theory. The theory, however, has been applied in various other disciplines including Information Systems. (For example, see Compeau, Higgins, and Huff (1999) and Bolt, Killough, and Koh (2001)).

SCT is "based on the premise that environmental influences such as social pressures or unique situational characteristics, cognitive and other personal factors including personality as well as demographic characteristics, and behavior are reciprocally determined" (Compeau & Higgins, 1995). In other words, individuals choose their environment and also are influenced by it; individual behavior is influenced by personal factors, which in turn are influenced by behaviors; and behavior may be influenced by environmental factors while having their own impact on the environment. This "triadic reciprocality" is illustrated in Fig. 1.

In this paper, we use SCT as a lens to view and organize the literature related to computer use behavior of older adults. In this context, the Person construct refers to the computer using older adult, Behavior refers to computer use, and Environment refers to the computer system. We examine the extant literature concerning older adults and computer use across various disciplines through the SCT framework to understand to which extent the relationships illustrated in Fig. 1 have been investigated. Further, since SCT provides a basis for behavior intervention strategies (Bandura, 1997), we use the concepts of SCT to illustrate potential ways to encourage computer use by older adults.

3. Methodology

The articles for this review were gathered by searching various databases for peer reviewed journal articles on the subject of computer use by older adults. Since this topic is multi-disciplinary in nature, eleven different databases were searched to cover all of the relevant disciplines: business (ABI/Inform, and Business Source Premier); information technology (Inspec); social sciences (Social Sciences Abstracts, Social Sciences Citation Index, and the Applied Social Sciences Index); gerontology (Age Line and Abstracts in Social Gerontology); education (ERIC); psychology (PsychINFO); and SCOPUS (multi-disciplinary, including full coverage of MedLine for healthcare topics). These databases include the core or essential databases in their respective subject areas, as described by electronic library collection development guides (Kovacs & Robinson, 2004).

Search strings included reference to aging (age or aging or old or older or senior) as well as reference to computer use (computer or Internet or web or interface). A cut-off starting point of 1990 was selected for analysis since this approximates the beginning of widespread use of personal computers. In total, 151 articles covering the period 1990–2008 were reviewed to determine the following information: age considered "old", details regarding the sample studied, what methodology and statistical techniques were used, variables or constructs studied, research questions or hypotheses addressed, tasks involved in the experiment, and key findings. The literature analysis in this article is focused on the key research findings of the reviewed papers.

As one would expect, given the multi-disciplinary nature of this topic, articles were found in a diverse range of journals. To enable analysis by discipline, we set out to find a classification scheme for the list of journals. Although a listing was found that contained each of the relevant journals (Ulrich's Periodical Directory), the resulting categories were too broad to be useful for our purposes. As an alternative, a panel of four experts was consulted in order to categorize the journals. The four selected experts are researchers in the field of Information Systems (two Ph.D. students and two established faculty members) with expertise in topics including human–computer interaction, individual differences (including gender and age), user adoption, and social issues related to information technology. In order to categorize the journals, each expert was provided with a list of the journals, the journal's description from its website, and a list of eight possible disciplines to assign it to: business, communication, education, gerontology, human–computer interaction (HCI), healthcare, information systems (IS), and psychology. This list of potential disciplines is similar to the categories found in Ulrich's with the exception of HCI and IS which were added to permit a more granular analysis in the area of computer science. Inter-rater reliability was found to be 0.72, as calculated using a variant of Cohen's kappa (Fleiss' kappa) to accommodate four raters. This reliability is above the recommended minimum of 0.70 (Straub, Boudreau, & Gefen, 2004). A complete list of the journals, along with their corresponding disciplines and the number of related articles found in each, is provided in Appendix A.

4. Literature analysis

4.1. Publication trends

In general, the study of computer use by older adults has received increasing attention over time. As illustrated in Fig. 2, inter-

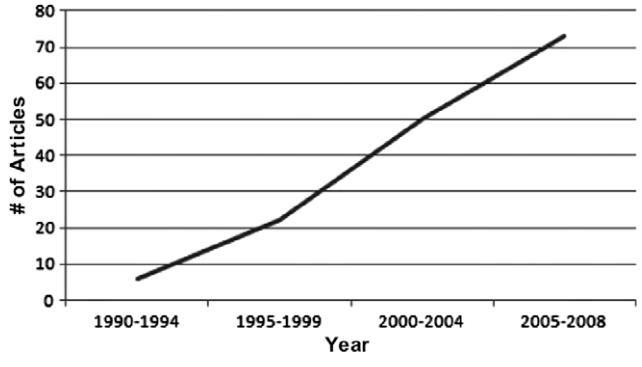

Fig. 2. Articles published by year.

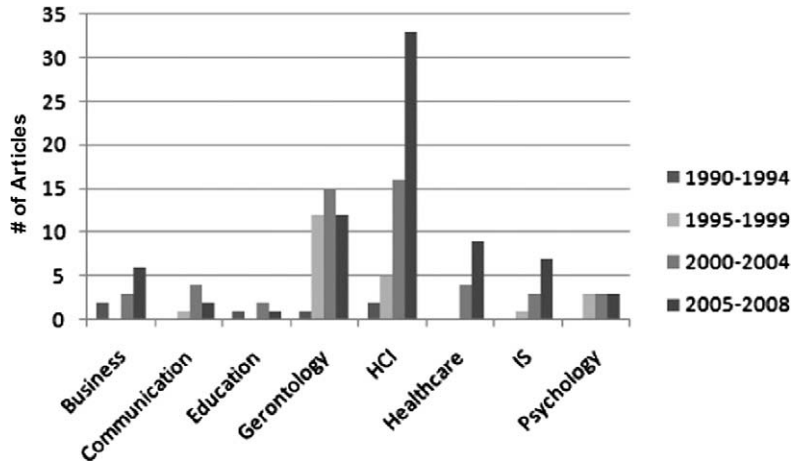

Fig. 3. Publication trends by discipline.

est in this subject has increased steadily over the time period studied (1990–2008). Although the figure is presented in year ranges for clarity, it is interesting to note that prior to 1997, 1994 was the only year with publication of more than one article in this area. In 1997, the first wave of Baby Boomers became 50 years of age (Foot, 1996). It is not likely a coincidence that the number of articles published on this topic per year increased to at least five in that same year. As this large cohort continues to age and remain in the workforce, research on the topic is likely to continue this upward trend.

It is also interesting to observe the publication trends within each discipline, as illustrated in Fig. 3. Over time, the Business discipline has paid increasing attention to the issues of older computer users. Interest began in the Marketing-oriented journals, recognizing older computer users as a potential target audience for marketers. Later Business focus began to include labor-oriented journals, which investigated older computer users in the workforce. Communication journals were later to take older adults into consideration, with the first publications not appearing until 1999. Interest from the communications discipline has been fairly limited, with only seven articles found in total. Gerontology as a discipline has been one of the main contributors to research in this field. With a total of 40 articles, it is second only to HCI with 56 articles. Both of these significant contributors have shown increasing publications in this area over time, particularly HCI in the last few years. IS has begun to pay more attention to older users in the past few years, with seven of the eleven articles found in that discipline published between 2005 and 2008. Psychology has contributed modestly with one publication per year in most recent years. This low level of publication is somewhat surprising since, in general, age differences have been of great interest to psychology researchers for decades (Morris & Venkatesh, 2000). The Healthcare discipline was late to join this area of research with the first article not appearing until 2000, however, interest has been increasing steadily since then. The Education discipline has shown surprisingly little interest in this area, especially considering that continued learning is often listed as a way in which computers and the Internet can be of the most assistance to older adults (Bitterman & Shalev, 2004; Morrell, Mayhorn, & Bennett, 2000).

4.2. Analysis of research findings

As discussed, SCT offers an explanation of individuals' patterns of behavior. In this section we utilize SCT theory as a lens to analyze and organize the literature related to computer use by older adults. We start by examining the literature covering the main elements of SCT theory (i.e. Person, Behavior and Environment). We then discuss the literature covering the reciprocal relationships between those elements. To facilitate readability in the analysis below, references that are included in the tables are not duplicated in the text.

4.2.1. SCT main elements

4.2.1.1. Person. In this context, Person refers to the older adult, including all of the physical, cognitive, and emotional attributes that make up this individual. The literature examined discusses Person attributes primarily related to the emotions/feelings of the older adult toward computers. Table 1 below summarizes the relationships observed among Person attributes in the literature.

As Table 1 illustrates, there are only a few instances where the relationship between the same two variables has been studied more than once. As a result, it is difficult to make any confident assertions about many of these relationships. The most commonly studied Person attribute is attitude toward computers. In general, it seems that as age increases, attitudes toward computers tend to become more negative. Czaja and Sharit (1998), however, found that only particular dimensions of attitude (i.e. comfort, competence, and control) are negatively affected by age. Two studies have examined the impact of gender on attitudes, but results have been inconclusive with one study showing that males have more positive attitudes and the other finding no relationship. And finally, two studies examined the relationship between experience and attitudes, finding that those with more positive attitudes had more experience.

In addition to the quantitative studies summarized in Table 1, a number of qualitative studies have also been conducted in an effort to more thoroughly understand the attitudes of older adults toward computers. These studies have found that: attitudes are forming and not yet strong (Festervand & Meinert, 1994); many older adults believe that they will benefit from computer use while others are sceptical about the benefits (Saunders, 2004); older adults may feel alienated by or too old to learn to use computers (Turner, Turner, & Van de Walle, 2007); and older adults have more negative emotional reactions to making computer errors (Birdi & Zapf, 1997; Saunders, 2004). One recent study included the development of a new measure for attitudes toward computers specifically developed for older adults (Lagana, 2008), indicating that there is ongoing research interest in this topic.

Apart from attitude toward computers, few relationships have been examined in multiple studies. From the literature reviewed, it seems that increasing age may lead to increased computer anxiety. Also, computer anxiety may be more significant for males,

Table 1
Correlations observed between Person attributes.

Variable 1	Correlation*	Variable 2	Reference
Age	–	Experience	Laberge and Scialfa (2005)
	–	Attitudes	Baack and Brown (1991), Kubeck et al. (1999), Morris and Venkatesh, (2000)
	–	Confidence in computer knowledge	Marquié, Jourdan-Boddaert, and Huet (2002)
	+	Anxiety	Laguna and Babcock (1997), Dyck, Gee, and Smither (1998)
	+	Trust	Ho, Wheatley, and Scialfa (2005)
	NR	Trust	McCloskey (2006)
	NR	Attitudes	Czaja and Sharit (1998)
Anxiety	NR	Experience	Hogan (2005)
	–	Life satisfaction	Karavidas et al. (2005)
Attitudes	+	Experience	Dyck and Smither (1996)), Festervand and Meinert (1994))
Computer knowledge	+	Self-efficacy	Karavidas et al. (2005)
	–	Life satisfaction	Karavidas et al. (2005)
	–	Computer anxiety	Karavidas et al. (2005)
Gender (male)	–	Anxiety	Karavidas et al. (2005), Hogan (2005)
	+	Attitudes	Dyck and Smither (1996)
	NR	Anxiety	Laguna and Babcock (1997)
	NR	Attitudes	Czaja and Sharit (1998)
Outcome expectations	+	Intention of Internet use	Lam and Lee (2006)
Satisfaction with computer ability	+	Perception of importance of a computer	Marchant, Tiernan, and Mann (2005)
	+	Perception of performance	Marchant et al. (2005)
Self-efficacy	+	Intention of Internet use	Lam and Lee (2006)
	+	Outcome expectations	Lam and Lee (2006)

* NR, no relationship.

although one study found no relationship. Morris, Venkatesh, and Ackerman (2005) found gender to play a more prominent role with increasing age, in moderating the impact of attitude, subjective norms and perceived behavioral control on behavioral intention to use IS.

Overall, research in this literature examining the older adult covers a variety of topics, with few studies examining the same relationships and thus little validation of results. In some cases where the same relationships were studied multiple times, inconsistent results were found. Future research dedicated to clarifying these inconsistencies and validating previous findings will help to paint a more accurate picture of this group of users. Further, some authors suggest that existing scales may not be appropriate for use by older adults and recommend the creation of new measures specifically for this group (Lagana, 2008; Dyck et al., 1998). This recommendation should be considered by researchers of older adults.

4.2.1.2. Behavior. In this context, the Behavior of interest is computer use by older adults. In general, older users have joined the computer and Internet community to a lesser extent than younger adults, yet their segment is growing most quickly (Hart et al., 2008). Studies often found older adults to be keen users (Juznic, Blazic, Mercun, & Plestenjak, (2006); Tak & Hong, 2005; Vuori & Holmlund-Rytkönen, 2005) with evolving motivational reasons for their use (Ng, 2008). Amount of use was not found to vary by gender among older adults (Karavidas, Lim, & Katsikas, 2005). One of the key indicators of ongoing use is short-term use (Bickmore, Caruso, Clough-Gorr, & Heeren, 2005; Morris et al., 2005), indicating that encouraging initial use is crucial to subsequent computer use by older adults.

Older adults often use computers and the Internet for the same activities that younger users are known to, but do different activities to different extents (Vuori & Holmlund-Rytkönen, 2005). The main activities this group engages in are summarized in Table 2. Although their activities are similar, older users tend not to take advantage of many of the more advanced tools available online as much as their younger counterparts (Bucur, Renold, & Henke, 1999).

Table 2
Most common computer uses for older adults.

Activity	Reference
Communication and social support	McMellon and Schiffman (2000), Morrell et al. (2000), Opalinski (2001), Mann, Belchior, Tomita, and Kemp (2005), Thayer and Ray (2006), Alexy (2000)
Leisure and entertainment	McMellon and Schiffman (2000), Opalinski (2001), Campbell (2008)
Information seeking-health	Morrell et al. (2000), Tak and Hong (2005), Flynn, Smith, and Freese (2006), Campbell (2008), Macias and McMillan (2008)
Information seeking-education	McMellon and Schiffman (2000), Opalinski (2001), Dorin (2007)
Productivity	White and Weatherall (2000), Campbell (2008)

The most common use of computers and the Internet for older adults appears to be for communication and social support. Benefits include increased contact with family and friends (Thayer & Ray, 2006), especially grandchildren (White & Weatherall, 2000), coping with grief (Opalinski, 2001), and dealing with geographic boundaries or limited mobility (Alexy, 2000). Different types of online communication are used including email, instant messaging, and online forums, each being used to support different social interactions (Xie, 2008). Computer-mediated social support for older adults is another topic for which a new measure has recently been developed, indicating the ongoing popularity of this research topic (Nahm, Resnick, & Gaines, 2004).

Other common uses of computers and the Internet by older adults include: leisure and entertainment, which tends to be related to offline interests and hobbies such as genealogy (White & Weatherall, 2000); information seeking (Blake, 1998; Opalinski, 2001), particularly in the area of health related information, education, and productivity, including mental stimulation (Rosenthal, 2008; White & Weatherall, 2000).

The surveyed literature also discusses reasons for non-use, or barriers to computer use by older adults, as summarized below in Table 3. Melenhorst, Rogers, and Bouwhuis (2006) assert that

Table 3
Barriers to computer use by older adults.

Barrier to use	Reference
Perceived lack of benefit	Mann et al. (2005), Melenhorst et al. (2006)
Lack of interest or motivation	Selwyn, Gorard, Furlong, and Madden (2003), Carpenter and Buday (2007), Morris, Goodman, and Brading (2007), Peacock and Kunemund (2007)
Lack of knowledge	Opalinski (2001), Peacock and Kunemund (2007), Ng (2008)
Lack of access	Peacock and Kunemund (2007)
Cost	Festervand and Meinert (1994), White and Weatherall (2000), Opalinski (2001), Saunders (2004), Mann et al. (2005), Carpenter and Buday (2007)
Fear of hardware being outdated quickly	Saunders (2004)
Perceived barriers due to physical limitations	Carpenter and Buday (2007), Saunders (2004)

Table 4
Performance impacts of system characteristics.

Observation	Reference
Different web interface personalization instruments impact user satisfaction	Kurniawan, King, Evans, and Blenkhorn (2006)
Lack of boundaries and ability to use external reminders impact usability	Curzon, Wilson, and Whitney (2005)
Advanced functionality causes usability issues	Mead, Sit, Rogers, Jamieson, and Rousseau (2000)
Information presentation mode: animation lead to best information retention	Lin (2004)
Feedback condition: haptic improved performance most	Jacko et al. (2004)
Website layout: performance was best in the hierarchical typology	Lin (2003b) (2004)
More supportive interfaces result in better performance	Charness et al. (2001)

while it is commonly believed that costs deter older adults from using new technologies, it is actually the lack of perceived benefit that is to blame. Either the technology does not meet the needs of the user, or they do not understand the technology sufficiently to appreciate the benefits. In any case, there are a variety of issues to address in order to encourage older adults to use computers.

4.2.1.3. Environment. In this context, the Environment of interest is the computer system used by the older adult. We use the term system in its broad context, including the hardware, software, people interactions, and context of use involved. As a result, the coverage of Environment in this literature includes topics such as interface usability, training, and support, as well as measures of system success such as performance and satisfaction.

The discussion of Environment is unique in this context because of the physical and cognitive changes that older adults experience as a result of the natural aging process. These changes result in a unique set of needs for this user group. A number of papers discuss these changes and the implications that they have for communicating with (Charness & Holley, 2004; Lippincott, 2004; O'Hara, 2004) and developing interfaces for older adults (Czaja & Hiltz, 2005; Furlong, 1997; Hawthorn, 2000; Morris, 1994; Zajicek, 2004), while others go a step further and provide guidelines for the development of interfaces (Bitterman & Shalev, 2004; Hutchison, Eastman, & Tirrito, 1997; Naditz, 2005; Zaphiris, Kurniqwan, & Ghiawadawala, 2007). A few studies (Becker 2004b; Becker 2005; Hart et al., 2008) have examined how well existing websites conform to published usability guidelines for older adults.

A number of papers describe the development of specific systems for older adults in order to provide insights for developers of future systems. Topics include healthcare management (Alemagno, Niles, & Treiber, 2004; Deatrick, 1997), email applications (Dickinson, Newell, Smith, & Hill, 2005), websites (DeGraves & Denesiuk, 2000; Ellis & Kurnlawan, 2000; Given, Ruecker, Simpson, Sadler, & Ruskin, 2007; Morrell 2005; Nahm, Resnick, & Covington, 2006), accessibility tools (Becker, 2004a), personalization tools (Hanson & Crayne, 2005), cognitive exercises (Merzenich, 2007), authentication (Renaud & Ramsay, 2007), and learning applications (Hawthorn, 2007). Mead, Batsakes, Fisk, and Mykityshyn (1999) make recommendations for conducting research for computer use by older adults, taking into consideration the unique characteristics of this participant group.

Training older adults to use computers is another popular research topic. Given the changing cognition of older adults, researchers suggest that training should be specifically tailored to this group (Aula, 2005). A number of papers suggest models or frameworks for consideration when designing training materials (Baldi, 1997; Chaffin & Harlow, 2005; Jones & Bayen, 1998; Mayhorn, 2004) and others provide specific recommendations as to how best to provide training through traditional means (Dickinson, Eisma, Gregor, Syme, & Milne, 2005; Hollis-Sawyer & Sterns, 1999; Kelley & Charness, 1995; Lustbader, 1997; Mayhorn, 2004) or through e-learning (Stoltz-Loike, Morrell, & Loike, 2005; Trentin, 2004). Several studies mention that providing adequate support is very important when training this unique group (Ng, 2008; Rosenthal, 2008; Vuori & Holmlund-Rytkönen, 2005).

Studies examining older adults' performance when using computers describe how performance is impacted by different system characteristics, as summarized in Table 4. These relationships between the interface and system success measures highlight the importance of good design for this group.

4.2.2. SCT reciprocal relationships

Having examined the extant literature on computer use by older adults covering the main elements of SCT, we now examine the literature covering the reciprocal relationships between those elements. An overview of the research covering these relationships in the literature is provided in Fig. 4.

The most commonly studied relationships are those where Person attributes influence Behavior and Environment attributes. In other words, researchers in this field have primarily been interested in determining what Person attributes lead to computer use by older adults as well as what Person attributes influence the success of the system Environment, particularly as measured by user performance. Relatively little research has examined how Behavior and Environment may influence the Person, or how Environment and Behavior interact with one another. While the importance of these less often studied relationships may not be as intuitive, given the triadic reciprocality of SCT they may offer alternative routes for influencing the computer use behaviors of older adults. Each type of relationship is discussed in detail below.

4.2.2.1. The influence of person.

4.2.2.1.1. Person → Behavior. The influence of Person attributes on Behavior, or computer use by older adults, has been widely studied. As summarized below in Table 5, a broad range of influences on computer use have been studied to varying degrees. Most commonly studied is the influence of age on computer use. In most cases, increasing age indicated decreasing computer use, yet a few

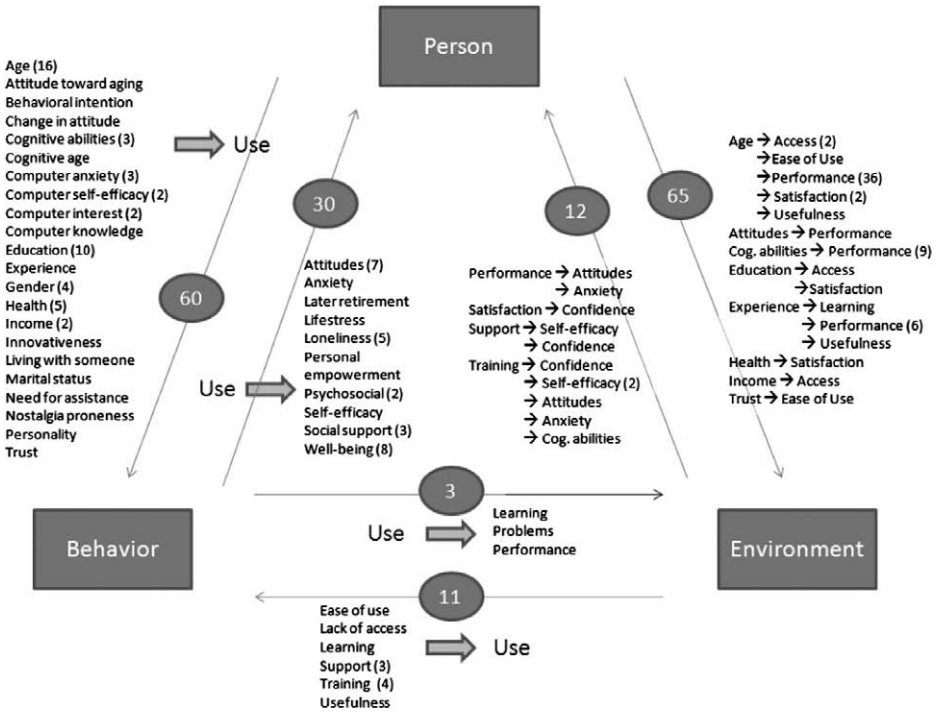

Fig. 4. SCT as observed in the studied literature.

Table 5
Articles studying the impact of Person on Behavior.

Independent variable	Impact*	Dependent variable	References
Age	–	Use	Chen and Persson (2002), Selwyn et al. (2003), Cutler, Hendricks, and Guyer (2003), Friedberg (2003), Schleife (2006), Morrell et al. (2000) Thayer and Ray (2006), Morris and Venkatesh (2000), Czaja et al. (2006), Carpenter and Buday (2007), Peacock and Kunemund (2007), Juznic et al. (2006), Morris et al. (2007), McCloskey (2006)
	NR	Use	Knight and Pearson (2005), Tian and Robinson (2008)
	NR	Continuance	White et al. (2002)
Attitude toward aging	+	Use	Cody, Dunn, Hoppin, and Wendt (1999)
Behavioral intention	+	Use	Morris et al. (2005)
Change in attitudes	NR	Continuance	Kelley, Morrell, Park, and Mayhorn (1999)
Cognitive abilities	+	Use	Czaja et al. (2006), Freese, Rivas, and Hargittai (2006), Kelley et al. (1999)
Cognitive age	–	Use	Eastman and Iyer (2005)
Computer anxiety	–	Use	Cody et al. (1999), Knight and Pearson (2005), Czaja et al. (2006)
Computer self-efficacy	+	Use	Cody et al. (1999), Czaja et al. (2006)
Computer interest	+	Use	Kelley et al. (1999)
	+	Continuance	Kelley et al. (1999)
Computer knowledge	+	Use	Morrell et al. (2000)
Education	+	Use	Chen and Persson (2002), Selwyn et al. (2003), Cutler et al. (2003), Schleife (2006), Morrell et al. (2000), Czaja et al. (2006), Carpenter and Buday (2007), Tak and Hong (2005), Juznic et al. (2006)
	NR	Continuance	White et al. (2002)
Experience	+	Continuance	White et al. (2002)
Gender (male)	+	Use	Selwyn et al. (2003), Morris et al. (2005)
	NR	Use	Knight and Pearson (2005), Hogan (2005)
Health	+	Use	Chen and Persson (2002), Carpenter and Buday (2007), McMellon and Schiffman (2000)
	NR	Use	Selwyn et al. (2003)
	NR	Continuance	White et al. (2002)
Income	+	Use	Chen and Persson (2002), Schleife (2006)
Innovativeness	+	Use	Reisenwitz, Iyer, Kuhlmeier, and Eastman (2007)
Living with someone	+	Continuance	White et al. (2002)
Marital status (married)	+	Use	Selwyn et al. (2003)
Need for assistance	NR	Continuance	White et al. (2002)
Nostalgia proneness	–	Use	Reisenwitz et al. (2007)
Personality	NR	Use	Chen and Persson (2002)
Trust	+	Use	McCloskey (2006)

* NR, no relationship.

studies found no relationship. Apart from age, a few other Person attributes have been examined in multiple studies. Cognitive abilities, computer self-efficacy, computer interest, education, health, and income seem to be positively related to computer use. In other words, older adults who use computers tend to have higher levels of cognitive abilities, computer self-efficacy, and computer inter-

Table 6
Articles studying the impact of Person on performance measures.

Independent variable	Impact*	Performance measure	References
Age	–	Correct answers	Echt, Morrell, and Park (1998), Laguna and Babcock (1997), Reed, Doty, and May (2005), Charness et al. (2001), Sharit et al. (2008)
	–	Browsing efficiency	Graff (2005), Lin (2003a), Fukuda and Bubb (2003)
	–	Efficiency	Sjolinder, Höök, Nilsson, and Andersson (2005), Charness et al. (2001)
	–	Quality	Kubeck et al. (1999)
	–	Work output	Czaja et al. (2001)
	+	Errors	Echt et al. (1998), Ho et al. (2005), Czaja and Sharit (1993), Charness et al. (2001)
	+	Support sought	Kressig and Echt (2002), Birdi and Zapf (1997)
	+	Time	Echt et al. (1998), Freudenthal (2001), Laguna and Babcock (1997), Sayers (2004), Sjolinder et al. (2005), Grahame, Laberge, and Scialfa (2004), Stronge, Rogers, and Fisk (2006), Czaja and Sharit (1993), Charness et al. (2001), Fukuda and Bubb (2003), Sjolinder, Höök, and Nilsson (2003), Lindberg et al. (2006), Laberge and Scialfa (2005)
	NR	Correct answers	Stronge et al. (2006), Webster and Martocchio (1993)
	NR	Browsing efficiency	Laberge and Scialfa (2005)
	NR	Errors	Birdi, Pennington, and Zapf (1997)
	NR	Time	Kressig and Echt (2002)
Attitudes	+	Correct answers	Shoemaker (2003)
Cognitive abilities	+	Browsing efficiency	Freudenthal (2001)
	+	Correct answers	Dyck and Smither (1996)
	+	Efficiency	Jimison, Pavel, McKanna, and Pavel (2004)
	+	Work output	Czaja et al. (2001)
	–	Errors	Echt et al. (1998)
	–	Time	Sjolinder et al. (2003), Laberge and Scialfa (2005)
	NR	Errors	Kressig and Echt (2002)
	NR	Quality	Czaja et al. (2001)
	NR	Time	(Kressig and Echt (2002), Priest, Nayak, and Stuart-Hamilton (2007)
Experience	–	Time	Kressig and Echt (2002), Priest et al. (2007), Sjolinder et al. (2003), Jacko et al. (2004), Czaja and Sharit (1993)
	–	Need for support	Kressig and Echt (2002)

* NR, no relationship.

est; tend to be more educated, in better health, and have higher incomes. Conversely, users tend to have lower levels of computer anxiety. The influence of gender on computer use is particularly uncertain with two studies finding that male older adults are more likely to use computers compared to their female counterparts, while two studies found no influence of gender. Each of the remaining independent variables listed in the table were examined in a single study, thus the findings may carry less weight. These attributes present opportunity for further research in order to validate the findings of these existing studies.

While Table 5 describes the univariate relationships observed in the litrature, studies often took several indicators of computer use into account simultaneously. For example, Czaja et al. (2006) found that both attitudinal and cognitive variables were necessary to predict computer use since cognitive ability was necessary but not sufficient to predict. The same study concluded further that there was a strong age effect, independent of the effect of attitudes and cognitive ability, thus suggesting an answer to a question often posed in the literature: Is there an independent effect of age, or can age effects be explained by other variables?

One context of particular interest is computer use in the workplace. Friedberg (2003) found that rates of computer use in the workplace were similar for all but the oldest workers, who exhibited lower levels of use. This study found that upcoming retirement, not simply age, may influence an older worker's computer use patterns. Alternatively, Morris et al. (2005) examined gender differences in computer use among older workers. They found that gender differences became more pronounced among older workers, where older male workers were more likely to be computer users than older female workers. This pattern did not, however, exist among younger workers.

4.2.2.1.2. Person → Environment. The influence of Person attributes on Environment has also been widely studied. In this case, one particular relationship has dominated the research: the impact of age on performance. As illustrated in Fig. 4, over half of the empirical results in this category (36 of 65) examine this particular relationship. The literature strongly indicates that there is a negative relationship between age and performance (see Table 6 below). In particular, as age increases, correct answers, browsing efficiency, overall efficiency, quality, and work output tend to decrease. Similarly, number of errors, amount of support sought, and time to complete exercises all increase with age. While a few studies found no relationship when studying these constructs, findings have otherwise been quite consistent in this area.

Computer performance among older adults has been found to vary widely (Czaja, Sharit, Ownby, Roth, & Nair, 2001; Lindberg, Nasanen, & Muller, 2006), suggesting that predictions should not be based solely on chronological age. Some suggest that age effects are largely mediated by contextual factors such as experience and cognitive abilities (Czaja et al., 2001). Charness, Kelley, Bosman, and Mottram (2001) found that age and experience trade off with roughly equal weight, while Czaja and Sharit (1993) found that experience accounted for the largest portion of variance. The most recent study, by Sharit, Hernandez, Czaja, and Pirolli (2008) found that after accounting for knowledge and cognitive ability factors, the influence of age was negligible. While the relative importance of each is uncertain, age and experience certainly have strong implications on computer performance by older adults.

Table 6 also summarizes the empirical findings in relationships between other Person attributes and performance using computers. As is often the case in this body of literature, there are few cases where results have been validated. Time (to complete exercises) is the only performance outcome studied multiple times along with Person attributes other than age. Findings indicate that as experience increases, time decreases. The relationship between cognitive abilities and time is less clear with two studies finding a negative relationship and two others finding no relationship. Although there is little validation and some results are inconsistent, in general it seems that higher levels of cognitive abilities and experience both have a positive impact on performance measures.

Table 7
Articles studying the impact of Person on Environment.

Independent variable	Impact*	Dependent variable	References
Age	–	Access	Loges and Jung (2001), Cutler et al. (2003)
	–	Ease of use	McCloskey (2006)
	NR	Satisfaction	Fukuda and Bubb (2003), Gagliardi, Mazzarini, Papa, Giuli, and Marcellini (2008)
	NR	Usefulness	McCloskey (2006)
Education	+	Satisfaction	Gagliardi et al. (2008)
	+	Access	Cutler et al. (2003)
Experience	+	Learning	Shoemaker (2003)
	+	Usefulness	McCloskey (2006)
Health	+	Satisfaction	Gagliardi et al. (2008)
Income	+	Access	Cutler et al. (2003)
Trust	+	Ease of use	McCloskey (2006)

* NR, no relationship.

Table 9
Articles studying the impact of Environment on Person.

Independent variable	Impact	Dependent variable	References
Performance	+	Attitudes	Czaja and Sharit (1998)
	–	Anxiety	Laguna and Babcock (1997)
Satisfaction	+	Confidence	Leung, Ko, Chan, Chi, and Chow (2007)
Support	+	Self-efficacy	Lam and Lee (2006)
	+	Confidence	Osman et al. (2005)
Training	+	Confidence	Osman et al. (2005)
	+	Self-efficacy	Hollis-Sawyer and Sterns (1999), Segrist (2004)
	+	Attitudes	Hollis-Sawyer and Sterns (1999)
	+	Cognitive abilities	Gunther, Schafer, Holzner, and Kemmler (2003)
	–	Anxiety	Hollis-Sawyer and Sterns (1999)

Apart from studies examining the impact of Person attributes on performance, relatively little research has been conducted concerning the relationship between Person and Environment. The remaining studies are summarized in Table 7. Again, most relationships are studied only once. There is some support to suggest that as age increases access to computers decreases, and that age is not related to satisfaction.

4.2.2.2. Influence on Person. Although the influence of the Person element has been studied most in this literature, researchers have also been interested in discovering what factors have an influence on Person. As illustrated in Fig. 4, a variety of Behavior and Environment factors potentially impacting Person have been examined.

4.2.2.2.1. Behavior → Person. This category of study is concerned with how the use of computers by older adults has impacted their personal attributes. Compared to areas of the literature discussed thus far, this particular area has placed more emphasis on validation of results, as summarized below in Table 8. While there has been considerable effort toward validation many of the results have been inconsistent, creating some controversy, particularly concerning the impact of computer use on psychosocial indicators. Several studies have found that computer use has a positive impact on psychosocial outcomes; improving general well being, reducing life stress, and loneliness. In some of the cases where positive impacts were not found, researchers indicated that was likely a result of "ceiling effects" of the measures (Chen & Persson, 2002; White et al., 1999, 2002), meaning that participants had relatively high scores on the measures prior to the intervention and as a result the intervention did not produce statistically significant results. That being said, a review study by Dickinson and Gregor (2006) examined articles which claim that computer use has a positive effect on the well being of older adults. They concluded that the results of these studies were flawed for a variety of reasons and that computer use in fact did not have a positive impact. It should be noted that many of the papers that support the notion that computer use improves well being are qualitative in nature rather than controlled experiments and thus were not considered by Dickinson & Gregor. While the empirical results may be inconclusive, qualitative descriptions about the impact of computer use on the lives of older adults are generally positive.

Another effect of computer use often studied is attitudes toward computers. The findings for this attribute have been much more consistent, almost unanimously indicating that use of computers improves attitudes toward computers among older adults. Studies also suggest that use of computers leads to increased social support. One particularly interesting article discussed the use of computers and the Internet for meeting romantic partners, finding that older adults develop meaningful and long-lasting relationships online (Malta, 2007).

4.2.2.2.2. Environment → Person. Studies in this area are concerned with how the system Environment impacts the older adult, as summarized below in Table 9. While again there is little validation of results, it seems that high quality systems have a positive

Table 8
Articles studying the impact of Behavior (Use) on Person.

Independent variable	Impact*	Dependent variable	References
Use	+	Attitudes	Kubeck et al. (1999), Kelley et al. (1999), Czaja and Sharit (1998), Osman, Poulson, and Nicolle (2005), Smith (2005), Lagana (2008)
	+	Later retirement	Friedberg (2003), Schleife (2006)
	+	Personal empowerment	McMellon and Schiffman (2002)
	+	Self-efficacy	Lagana (2008)
	+	Social support	Cody et al. (1999), Wright (2000), Blit-Cohen and Litwin (2004)
	+	Well being	Osman et al. (2005), Xie (2007)), Shapira, Barak, and Gal (2007)
	–	Anxiety	Cody et al. (1999)
	–	Life stress	Wright (2000)
	–	Loneliness	White et al. (1999), Bickmore et al. (2005), Sum, Mathews, Hughes, and Campbell (2008), Shapira et al. (2007)), Blit-Cohen and Litwin (2004)
	NR	Attitudes	Dyck and Smither (1996)
	NR	Psychosocial	Kelley et al. (1999), White et al. (2002)
	NR	Well being	Chen and Persson (2002), Bickmore et al. (2005), Dickinson and Gregor (2006), Dorin (2007), Smith (2005)

* NR, no relationship.

Table 10
Articles studying the impact of Behavior (Use) on Environment.

Independent variable	Impact	Dependent variable	References
Use	+	Learning	Oermann, Hamilton, and Shook (2003)
	+	Performance	Czaja et al. (2001), Mead et al. (2000)
	–	Technical problems	White et al. (1999)

Table 11
Articles studying the impact of Environment on Behavior (Use).

Independent variable	Impact*	Dependent variable	References
Ease of use	NR	Use	McCloskey (2006)
Lack of access	–	Use	Morrell et al. (2000)
Learning	+	Use	Kelley et al. (1999)
Support	+	Use	Freese et al. (2006), Rosenthal (2008),
	+	Use	Aula (2005)
Training	+	Use	White et al. (2002), White et al. (1999), Leung et al. (2007), Trentin (2004)
Usefulness	+	Use	McCloskey (2006)

* NR, no relationship.

impact on the older adult. For example, higher levels of performance and satisfaction have a positive impact on older adults by improving their attitudes and confidence, and reducing their anxiety towards computer use. The support and training provided for the system also seem to be very important, with good support and training leading to higher levels of self-efficacy, confidence, attitudes, and reduced anxiety.

4.2.2.3. Interaction between Environment and Behavior. The relationship between the system Environment and use of computers by older adults has received relatively little research attention thus far.

4.2.2.3.1. Behavior → Environment. Research in this area examines how the use of computers impacts the system Environment. The few studies conducted indicate that increased use of computers improves learning outcomes and improves performance, as summarized in Table 10.

4.2.2.3.2. Environment → Behavior. The articles in this area generally discuss elements of the system Environment that encourage computer use by older adults, as summarized in Table 11. Of particular importance are support and training. As suggested by Aula (2005), access to computers is not sufficient for older adults; they need support and need to be motivated to undertake their first experience.

5. Discussion and conclusions

In this article we examined the literature related to computer use by older adults across multiple disciplines through the lens of SCT. Through this approach we showed that the older adult, their computer use, and their computer systems exist in a triadic reciprocality. Observing the literature through this lens demonstrates that there is great potential for future research in this subject area. As illustrated in Fig. 4, the influence of Person on Behavior and Environment are the two SCT relationships that have received considerable research attention in the context of older adults' computer use. There remains plenty of opportunity in the other SCT relationships, particularly in those between Behavior and Environment. Potential research topics can fairly easily be extracted from Fig. 4 in three different ways, as detailed below.

First, many of the relationships between constructs belonging to the main SCT elements that are studied in one direction could also be studied in the other direction where appropriate. For example, the impact of computer use (the Behavior construct) on the loneliness of the older adult (a Person construct) has been studied, but could feelings of loneliness also impact computer use?

Second, researches could identify constructs that have been studied in relationships between two of the main SCT elements for potential relationships with constructs in the third SCT element. For example, the impacts of different Person constructs on Satisfaction (an Environment construct) were considered in a few papers. Researchers could then consider studying the impact of Use (the Behavior construct) on Satisfaction or the impact of Satisfaction on Use.

Finally, there are potential constructs belonging to the various SCT elements that are not included in Fig. 4 because they have not been observed in the reviewed literature. Researchers could identify such constructs as belonging to one of the main SCT elements and study their relations with constructs in the other two main SCT elements. For example, the level of social presence of the online interface (an Environment construct) has been shown to positively impact antecedents to attitudes towards shopping websites using student samples (e.g. Hassanein & Head, 2007). This construct may then be studied to identify its potential impacts on constructs belonging to the other two main elements of SCT (i.e. Person and Behavior) for an older adult population.

Our conceptualization of the Environment construct as the hardware, software, people interactions, and context of use involved highlights another opportunity for future research. In the literature examined, the context of use was primarily personal (hedonic) computer use. Very few studies considered older workers or workplace concerns. As the workforce continues to age, this will become an increasingly important area of study.

Viewing the literature through the lens of SCT also has practical implications. System developers may control only one portion of the model: the system Environment. However, SCT suggests that the system Environment may influence the use Behavior of the older adult through two separate mechanisms. First, use Behavior may be encouraged directly by the Environment. For example, providing good support for the system has been shown to encourage use of the system. Thus, in practice, support personnel should be equipped with strategies specifically designed to assist older adults, thereby encouraging their future use of the system. Secondly, Behavior may be encouraged indirectly via Person attributes. For example, training has been shown to increase older adults' computer self-efficacy. At the same time, higher levels of computer self-efficacy have been shown to increase computer use. Thus, an important goal of designing training for older adult users should be to increase their computer self-efficacy, which may subsequently encourage increased use Behavior. Thus, when developing systems for older adults, it would be wise to consider not only use Behavior, but also Person attributes during system planning and implementation. Further, developers should bear in mind the barriers that older adults' perceive to their computer use, in particular perceived lack of benefit and lack of motivation. Training designed for systems should emphasize the benefits of the system and create motivation for use. Support personnel should be trained to highlight these points, since older users tend to rely heavily on this service. Finally, systems should be designed with the physical limitations of older users in mind, so that training and support may also encourage older adults to make use of functionality implemented for their own benefit (e.g. font size control on websites). By considering the older adult and their use Behaviors throughout the systems design process, the resulting

systems are more likely to encourage effective and ongoing use by older adults.

Our examination of the literature concerning computer use by older adults demonstrates the uniqueness of this context. This uniqueness creates a number of important considerations for researchers. Throughout the literature studied, a number of researchers suggested that existing scales for constructs may not be appropriate for older adults since they are often developed and validated using student samples. Researchers should consider this when conducting their studies by including a step to validate such scales for this particular user group. It may be necessary to develop several new scales to more accurately study this particular population.

It is also important to note that existing research concerning computer use by older adults defines age based on chronological age. A number of other conceptualizations of age have been suggested such as functional or performance-based age, psychosocial or subjective age, and the life span concept of age (Kooij et al., 2008). Researchers should consider which conceptualization of age is most appropriate for their topic of study. For example, a participant's psychosocial age, which is based on their personal perception of age, may impact their attitudes toward computers.

Further, age differences may arise as a result of period effects or cohort effects (Rhodes, 1983). Period effects refer to time-of-measurement anomalies, such as a change in the workplace. For example, a change in reward structure may impact older workers differently than younger workers. Cohort effects are based on a person's date of birth. For example, a fifty year old "baby boomer" may have different attitudes toward computers than a fifty year old of a different age cohort. Rhodes (1983) suggests that cross-sectional study, which is primarily what was observed in this body of literature examined here, is limited because it does not allow the researcher to determine whether age differences are a result of age, period, or cohort. She suggests that both longitudinal and cross-sectional study is needed in order to determine the impact of each.

As demonstrated through this review article, computer use by older adults is a multi-disciplinary topic by nature. The discovery of different methodologies, operationalizations, constructs, or relationships from other disciplines may inspire further research and ultimately broaden and enrich the understanding of the topic as a whole. Researchers in this subject area should be sure to consider research that has been conducted in a variety of disciplines when designing and conducting their studies.

As discussed in several sections of the literature analysis of this article, there is an abundance of opportunities for the validation of previous results. Very few relationships have been examined in multiple studies, prohibiting the application of quantitative meta-analysis techniques. These techniques can be used to approximate the true effect size of the relationship between two variables by combining the results from multiple studies. The validation of results, and resulting meta-analyses, are essential for the maturation of any field of study and enable the development of more sound theories.

Overall, although there has been significant research dedicated to the use of computers by older adults, there is certainly still a plethora of opportunities for further study in this increasingly relevant field. It is hoped that this article will draw attention to this important area of study and provide researchers with a foundation upon which future knowledge can be built.

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Appendix A

Journal	Discipline	Articles
ACM Transactions on Computer–Human Interaction	HCI	2
Advances in Consumer Research	Business	1
Ageing & Society	Gerontology	1
Aging & Mental Health	Gerontology	3
American Behavioral Scientist	Psychology	1
Australian Journal of Emerging Technologies and Society	IS	1
Behaviour & Information Technology	HCI	13
Care Management Journals	Healthcare	1
CIN: Comupters, Informatics, Nursing	Healthcare	2
Communication Education	Communication	1
Communication Research	Communication	1
Communications of the ACM	IS	2
Computers in Human Behavior	HCI	8
Contemporary Long Term Care	Healthcare	1
Cyberpsychology & Behavior	Psychology	3
Displays	HCI	1
Educational Gerontology	Gerontology	21
Ergonomics	HCI	1
Ergonomics in Design	HCI	1
European Journal of Ageing	Gerontology	1
Generations	Gerontology	3
Geriatric Nursing	Healthcare	1
Gerontologist	Gerontology	1
Health Communications	Communication	1
Holistic Nursing Practice	Healthcare	1
Home Health Care Management & Practice	Healthcare	1
Human Factors	HCI	4
IEEE Transactions on Engineering Management	IS	1
IEEE Transactions on Information Technology in Biomedicine	IS	1
IEEE Transactions on Professional Communication	Communication	1
Industrial & Labor Relations Review	Business	1
Interacting with Computers	HCI	10
Interactions	HCI	1
International Journal of Behavioral Development	Psychology	1
International Journal of Consumer Studies	Business	1
International Journal of Human–Computer Interaction	HCI	3
International Journal of Human–Computer Studies	HCI	1
Irish Journal of Management	Business	1
Journal of Aging Studies	Gerontology	1
Journal of Applied Business Research	Business	1
Journal of Applied Gerontology	Gerontology	2
Journal of Communication	Communication	1
Journal of Computer Assisted Learning	Education	1
Journal of Computer-Mediated Communication	Communication	1

(*continued on next page*)

Appendix A (*continued*)

Journal	Discipline	Articles
Journal of Consumer Marketing	Business	2
Journal of General Internal Medicine	Healthcare	1
Journal of Management	Business	1
Journal of Management Information Systems	IS	1
Journal of Managerial Issues	Business	1
Journal of Nursing Care Quality	Healthcare	1
Journal of Occupational & Organizational Psychology	Psychology	1
Journal of Organizational and End User Computing	HCI	2
Journal of Research on Computing in Education	Education	1
Journal of Technology in Human Services	IS	1
Journal of the American Society for Information Science and Technology	IS	1
Labour	Business	1
Marketing Intelligence & Planning	Business	1
New Library World	Education	1
New Review of Information Networking	IS	1
Orthopaedic Nursing	Healthcare	1
OTJR Occupation, Participation and Health	Healthcare	1
Patient Education and Counseling	Healthcare	1
Personnel Psychology	Psychology	1
Poetics	Psychology	1
PsychNology Journal	HCI	1
Psychology and Aging	Gerontology	5
Public Health Nursing	Healthcare	1
Research Strategies	Education	1
Social Science Computer Review	IS	1
Spatial Cognition and Computation	Psychology	1
Technical Communication Quarterly	Communication	1
Technology and Disability	IS	1
The Journals of Gerontology	Gerontology	2
Universal Access in the Information Society	HCI	8

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