A review of technology acceptance by older adults

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K. Chen, A.H.S. Chan. A review of technology acceptance by older adults. Gerontechnology 2011; 10(1):1-12; doi:10.4017/gt.2011.10.01.006.00 We present a review of empirical research on technology acceptance by older people based on 19 published studies, analyze the results, and evaluate findings and limitations. Research on technology usage and acceptance by older people has not yet given sufficient consideration to age-specific or age-related factors. We conclude that the technology acceptance model (TAM) is a useful model, but to better understand technology acceptance behavior of older people, additional variables are to be included, related to biophysical and psychosocial characteristics, abilities and problems experienced by older people.

Keywords: technology acceptance models, ageing, characteristics

Technology has been shown to be beneficial to older people, but a digital divide remains. Although most older people have a positive attitude towards technology, the usage rates of technologies like mobile phones and computers are low[1,2]. In 2009, only 1.7% of Chinese Internet users were over the age of 60, as compared with 20.7% of those aged between 30 to 39, and 13.9% of those in the 40 to 59-year-old age group[3].

To better predict technology usage behavior, it is important to understand the factors that influence acceptance and usage of technology. The technology acceptance model (TAM) offers a powerful explanation of technology perception and usage and is reviewed here, together with empirical studies concerned with technology acceptance by older people.

TAM

Technology acceptance has been described as "the approval, favorable reception and ongoing use of newly introduced devices and systems"[4]. Level of acceptance contains an attitude towards a certain behavior, that is, the individual's positive or negative feeling or appraisal about the behavior and the degree to which this affects the behavior, and the usage behavior itself. The theory of reasoned action (TRA)[5] offers an explanation of human behavior in general and suggests that a person's behavior is driven by his or her intention to perform the behavior, and that this intention is in turn determined by attitude toward the behavior and subjective norm. Subjective norm is defined as a person's perception that is important to him/her when deciding if s/he should or should not perform a certain behavior. TRA was extended to some extent by the theory of planned behavior (TPB) that added a construct of perceived behavioral control, which is theorized to be an additional determinant of intention and behavior[6].

Based on the TRA, Davis et al.[7] introduced the technology acceptance model (TAM) to predict information technology acceptance and usage behavior of the users (*Figure 1*). According to TAM, the two most important attitudinal factors in explaining acceptance and usage of an information system are perceived usefulness (PU) and perceived ease of use (PEOU). Perceived usefulness was described as "the degree to which a person believes that using the particular technology

would enhance his/her job performance". Perceived ease of use was defined as "the extent to which a person believes that using a technology is free of effort". PU and PEOU jointly determine attitude towards using behavior (AT). PU also mediates the effect of PEOU on AT. PU and AT predict the behavioral intention to use (BI), which directly affects actual usage behavior. TAM also assumes some 'external variables' such as user differences (cognitive style and other personality variables), system characteristics, and task characteristics, the effects of which are fully mediated by PU and PEOU. Numerous empirical studies have confirmed that TAM is a robust and powerful model for explaining acceptance behavior[8-10].

TAM appeared valid in the context of the world-wide-web[11,12], electronic-commerce[13,14], mobile devices[15], and telemedicine[16,17]. TAM has been applied in different countries: USA[18], Europe[15,19], Korea[20], China[9], South Africa[21], Singapore, and Malaysia[22]. The acceptance attitudes and behaviors of students[9,13,23], employees[8,18,24], teachers[10,22] and community groups[19,25] have been thoroughly investigated. Researchers also have extended TAM by combining other theories like innovation diffusion theory[24,26], motivation theory[20] and flow theory[9,12]; or by incorporating other constructs like social norms[9,14,27], trust[13], perceived risk[23,26], cost[26], job relevance[22], playfulness[12], voluntariness of use[28], compatibility[24], and self-efficacy[14].

Venkatesh and Davis[28] introduced TAM2 that includes social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, and result demonstrability) as additions to the original TAM. Venkatesh et al.[27] reviewed eight user acceptance models and formulated a unified theory of acceptance and use of technology (UTAUT), which explained 70% of variance in usage intention. UTAUT identifies three direct determinants of intention of usage (performance expectancy, effort expectancy, and social influence), two direct determinants of usage behavior (behavioral intention and facilitating conditions), and incorporates four moderators (gender, age, experience, and voluntariness of use).

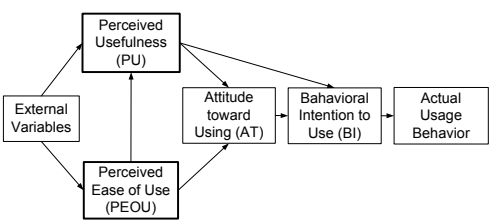

Figure 1. Technology Acceptance Model (TAM) for the prediction of information technology acceptance and usage behavior

Older persons

Most discussion of technology and technological devices and their use is directed to young adults; older people are neglected. Some studies suggested that demographic characteristics are less important than characteristics of the technology in determining the acceptance and usage of specific technologies[7,29]. More recent studies provided preliminary evidence that different age groups may think differently and make different decisions when it comes to the adoption and use of technology[4,18,30].

Method

This study reviewed empirical studies on technology acceptance by older people published from 2000 to June, 2010. The selection criteria were: TAM or related models or constructs were used in the empirical study; the research subjects included older people; research methodology and subject were clearly described; the research results were completely presented; and language was English. Two electronic databases, Social Science Citation Index and Scopus, were used as search tools. In total 19 papers were identified and used for analysis. Many of the papers examined acceptance of specific technologies as follows: the Internet[20,31,32], mobile phone[21,33], and assistive or health technology[17,34]. Major TAM related constructs, such as PU, PEOU, BI, usage were used in the selected studies. In terms of research method, eleven studies used

cross-sectional questionnaire surveys, five studies used focus group interviews, two studies conducted an experiment, and one study combined a questionnaire survey with interviews (*Table 1*).

Results and discussion

Technology use and influential factors

Most older adults have positive attitudes towards technology; however, they do not show great interest in adopting new technology and are less likely to use technology than younger adults[20,25,35]. The technology that older people reported using was primarily in the home and related to domestic matters, especially use of the Internet and mobile phone[35,36].

TAM-related constructs, such as perceived usefulness, perceived ease of use, attitude, behavior intention, and usage behavior were used in those studies. TAM or related models, such as TAM2 and UTAUT, appeared valid among older people. Nevertheless, the influence of some factors may be different. In the study of Arning & Ziefle[4], age-specific processes were involved in the assessment of the PEOU and the judgment of PU. In the evaluation of the PEOU, younger adults referred to time on task (task efficiency) whereas older adults referred to success in solving tasks (task effectiveness). When assessing the PU of a technical device, for the older adults, PEOU played the main role, whereas the PEOU was less important for the younger adults.

Perceived usefulness

PU and PEOU are the most critical factors for older people. McCreadie and Tinker[34] suggested that the 'felt need', i.e., the individual feels that they need help, is central to technology adoption. Technology non-users often held the attitude that new technology is irrelevant to their daily life and considered it unnecessary[31,37]. As many older people are retired, 'enhancing job performance' may not be suitable for defining PU. Consensus among researchers exists that older people would accept and use new technologies if they believed and realized that those technologies might be used to improve their lives and satisfy their needs. With respect to usefulness, older people placed a high value on independence and perceived impact on quality of life[25,38]. Older people did not show interest in high-technology products, but rather value the technology that can make their daily life easier and provide added safety and security[15]. Older adults' positive attitudes were most frequently associated to how the technology supported activities, enhanced convenience, and contained useful features[35].

Perceived ease of use

In addition to PU, PEOU is of great importance for older people[36]. Ease of use has been reported to strongly influence technology acceptance and adoption. Besides the direct impact, PEOU is also a salient indicator of PU for older users[31,39]. Most older people do not fully accept modern technology and they show ambivalent feelings of acceptance of and detachment from technology. On the one hand, older adults have realized that modern technology brings progress and many benefits; on the other hand, they are not sure that they are able to get benefits from it, because they consider themselves not skilled enough to use these kinds of high-technology applications[19,35]. Older people have a lower self-efficacy and higher technology anxiety[37,40]. Although older adults are increasingly using technology, they have more difficulty than younger people in learning to use and operate widely used current technologies like mobile phones and the Internet[21,39]. Barriers to use technology are largely associated with design and usability of these devices and services[15,35]. Older people are more likely to accept technologies that are easy to understand and have a simple interface design[33,41].

Personal characteristics

Cost, which has been neglected in many previous studies, is the most critical factor in determining an older person's acceptance of technology[15,25]. Enjoyment of some kinds of technology, such as robots and internet-

Table 1. Empirical studies of technology acceptance by older persons; AT=Attitude towards using; AU=Actual use; BI=Behavioral intention to use; IDT=Innovation diffusion theory; IU=Intention to use; PEOU=Perceived ease of use, PS=Perceived safety; PU=Perceived usefulness; STA=Subjective technical competence; STAM=Senior Technology Acceptance & adoption model for Mobile technology; TAM=Technology Acceptance Model; TAM2=TAM version 2; TRA=Theory of Reasoned Action; UB=Actual usage behavior; UP=User performance; UTAUT= Unified Theory of Acceptance and Use of Technology

Technology studied	Main constructs	Method	Subjects	Model used	Reference
Assistive technology	Disability, living arrangement, carer needs, user preference, housing type & design, perceived need & availability, attributes, AU	In-depth interview with semi-structured questionnaire	67 community-dwelling adults, ≥70 yrs, England & Scotland	None	34
Conversational robot	Perceived enjoyment, IU, UB	Test session (3 min.); questionnaire survey; long term user observation	30 adults, 65-94 yrs, The Netherlands	TAM	43
Domestic robots	Technology & robot experience, robot characteristics & tasks, PU, PEOU, AT, BI	Cross-sectional questionnaire survey	117 adults, 65-86 yrs; 60 adults, 18-25 yrs, Atlanta Metropolitan area, USA	TAM	41
Health IT applications	Subjective norm, image, age, job level, work experience, computer skill, voluntariness, PEOU, PU, BI	Cross-sectional questionnaire survey	134 staff in 15 long-term care facilities, 30-59 yrs, Australia	TAM2	17
Internet	Gender, age, subjective norm, facilitating conditions, BI, PU, PEOU, UB	Cross-sectional questionnaire survey	374 adults, 50-81 yrs, Beijing, China	UTAUT	31
Internet usage	Gender, age, education, health, relevance, PU, PEOU, AT, UB	Cross-sectional questionnaire survey	592 community-dwelling adults, 60-88 yrs, UK	TAM	32
Mobile medical technologies, smart environments & clothing	Gender, age, educational level, health status, inconspicuousness, aesthetics, design, control, communication comfort, PU, PEOU, UB	Cross-sectional questionnaire survey	82 users, 40-92 yrs, Germany	None	36
Mobile devices & services	Expected benefit, perceived security; usability, anxiety, training, guidance, price barriers, social influence	Qualitative pilot study; semi-structured interviews	16 stakeholders interested in older adults, Finland	UTAUT	15
Mobile phone	Interlinked acceptance factors, adoption phase	Semi-structured interview	34 adults, 60-92 yrs, South-Africa	STAM	21
	Social influence, intrinsic motivation,	Cross-sectional questionnaire	740 adults >65 yrs,	None	33

	mobile phone support, self-actualization, PEOU, PS, PU, BI, UB	survey	Northern Italy		
Online communities	Age, Internet self-efficacy, perceived quality, perceived technology affordance, perceived privacy protection, PEOU, PU, BI	Cross-sectional online questionnaire survey	248 non-users of online communities, 20-82 yrs, USA	TAM	37
Online shopping	Trust, e-commerce participation, age, PEOU, PU	Cross-sectional questionnaire survey	110 Internet users, 52-87 yrs, Pennsylvania, USA	TAM	39
Online video user-created content (UCC) services	Perceived user resource & physical condition, prior experience, computer anxiety, life course events, perceived benefit & enjoyment, compatibility, BI, PEOU	Online questionnaire survey	290 online users >50 yrs, Korea	TAM+ motivation theory+IDT +age-specific constructs	20
PDA	STA, PEOU, PU, age, UP	Questionnaire survey for STA, PEOU, PU; experimental tasks measuring performance	16 adults, 18-27 yrs; 16 adults 50-69 yrs, USA	TAM	4
Social network website	Social heritage and identity, need to control, mirroring offline & online, social bonding & bridging, skill & anxiety, integration of tools, PEOU	Questionnaire survey and interview	500 Internet users, Norway; 34 participants, neighborhood community, Belgium	TAM+ UTAUT	19
Social robot	General use, communication & relationship with robot, personal interest in technology	10-day interaction with robot, semi-structured interview	3 older adults, The Netherlands	TAM	42
Technology in general	Age, education, health, computer efficacy & anxiety; crystallized & fluid intelligence, AT, UB	Cross-sectional questionnaire survey	1,204 community-dwelling adults, 18-91 yrs, USA	None	40
Technology in home, work & health domain	(In)convenience, feedback, features, complexity, reliability, serviceability, system characteristics, activity support, miscellaneous reasons, AU	Focus group interview	113 community-dwelling adults, 65-85 yrs, USA	None	35
Wireless sensor network (WSN)	Independence, perceived impact on quality of life, concerns with WSNs, personal preference, design preference, external factors	Focus groups interviews	13 participants, >65 yrs, community groups, golf clubs & churches, Sydney, Australia	TRA+TAM +UTRAUT	25

based services, like games, is also of great importance for an older person's intention to use[20,42,43].

Ryu et al.[20] examined adoption by older people (aged above 50) of user-created content video services in Korea. They introduced age-specific constructs such as perceived physical condition (physical age), life course events (psycho-social age), perceived user resources, prior similar experience, and computer anxiety; each reflecting the complex ageing process. The effects of age-specific variables were mediated by internal beliefs (PU and PEOU). This implies that the age-specific variables can be seen as antecedents for conventional TAM constructs. Czaja et al.[40] investigated 1,204 community-dwelling adults ranging in age from 18 to 91 years, and found that cognitive abilities are important to technology adoption. The relationship between age and adoption of technology was mediated by cognitive abilities, computer self-efficacy, and computer anxiety.

Ageing brings with it changes in perception, cognition, movement, and psychosocial functioning[44,45]. These changes need to be addressed in terms of the ways in which they may influence an older person's needs and his or her capabilities to use a technology or technical devices. Self-rated physical condition and cognitive ability play a major role in the use of different technologies[36,46]. Older adults with physical difficulties in vision, hearing and motion used fewer technologies than people with good health. Cognitive ability is also an important predictor of the use of technology. People with higher levels of crystallized and fluid intelligence used a greater variety of different types of technology[40]. Physical condition and life course events (such as retirement, becoming a grandparent, loss of spouse, etc.) have impacts on older people's usage behavior[20]. These findings show that biological, social, and psychological life changes influence perception of usefulness and ease of use, and affect the ways in which people interact with environments. No single study has incorporated both the biophysical and psychosocial characteristics of older adults (*Table 1*).

Biophysical characteristics

With increasing age reserve capacities decrease. Biophysical change in ageing is associated with functional loss in visual and auditory perception, touch and movement, working memory, cognition, etc.[47-49]. "Individuals over age 65 experience declines in sensory, perceptual, motor, and cognitive abilities that may interfere with their ability to interact with systems ranging from doorknobs to microwave ovens to computers"[50].

Sensation and perception

Visual and hearing problems are often reported by older adults. Problems of visual perception are mainly in spatial vision (acuity and contrast sensitivity), seeing in poor light or near distance, processing color information, adapting to glare, slowing of vision processing, diminished field of view and visual search[47,51]. Age related hearing problems involve slowing of auditory processing, reduced hearing in noisy environments, reduced hearing for higher frequencies, and reduced comprehension of both normal and distorted speech[52,53]. Vision and hearing are also important 'social senses'. Much interpersonal information transfer is achieved using speech, facial expressions and gestures. Thus, changes in vision and hearing can affect activities such as reading, driving, communication and social functioning[54]. Most devices (for instance, mobile phone, PDA and auto GPS navigation) rely primarily on traditional graphical or text-based user interfaces or sound (for instance, telephones and alarms) to present information[53,54]. Age related visual and hearing impairments may influence the ease with which these technologies are used.

Perception of the physical environment, such as textures, roughness, pressure and spatial acuity also decreases with age[50,53]. Due to the decline in touch sensitivity, old people may have difficulty in performing accurate, discrete movements like tapping

very small targets, pressing small buttons, or writing with a stylus, as required by many technological devices[55].

Mobility

With ageing, control of gait and balance decline, thereby increasing the risk of falling. Older people take more time to make movements than younger adults, and their movements are less precise[50]. The speed of muscle contraction diminishes with ageing, resulting in difficulty in controlling movements[56]. The decreases in strength, movement coordination, and increases of reaction time, can influence task performance required by manipulating technology devices, such as using a mouse to point or double click and driving a car[51].

Cognition

Selective attention (orientation to and processing information from only one part of the environment to the exclusion of other parts) and dynamic attention (reorientation and focusing of attention) both decrease with ageing[49]. Older adults are more susceptible to distracting extraneous information and events[44,57]. Older adults' ability to inhibit irrelevant information is reduced, thus they tend to use more selective attention as a compensation for the reduced inhibition[57]. During driving tasks, older adults may have difficulty in recognizing and reacting to traffic signs; processing information from dials, warning lights, and auditory warnings more or less simultaneously; as well as coordinating these activities with other tasks such as steering, gear shifting and identifying hazards[50].

The age-related decline in working memory has been well documented[45]. Working memory is necessary for most daily activities such as understanding written or spoken language, and dialing a telephone number which you have just been told. Older people using automated telephone menu systems to pay bills or check bank balances are required to listen to each option, keep in mind the instructions, and make a choice[48]. Working memory capacity, information processing speed and ability to disregard unwanted information, all show age-related deficits, thereby making it difficult or even impossible for older people to complete such tasks[58].

Long-term memory is a more permanent store of knowledge[56]. Semantic memory, which refers to acquired factual information (for instance, historical facts or the meanings of words), remains largely intact with age[49]. But prospective memory (i.e., remembering to do something in the future) declines. Moreover, age related declines in prospective memory are greater for time-based tasks (do something at a later time) than for event-based tasks (act after some event)[52]. Another aspect of long-term memory is procedural memory which is about how to do something[48]. Older people show minimal declines when automatically performing procedural tasks (steering a car), but have difficulty in tasks that involve acquiring new procedures (using a new device)[59]. A big challenge for older people is that, for successful completion of many types of technology-based tasks, they have to remember how to execute a sequence of command activities.

Age-related memory declines have widespread effects on the acquisition and storage of new knowledge and skills[54]. Use of new technologies, such as Instant Messaging and Web 2.0, requires learning new skills on how to locate, access, manipulate, and use information sources. Given the age-related declines in cognitive abilities such as working memory, older people are slower to acquire computer skills than younger adults and require more help and hands-on practice when searching for information in electronic environments[56,60].

Psychosocial characteristics

The psychosocial changes in older people involve status loss, loneliness, fear of illness and death, social isolation, and deterioration of the quality of life. Those changes may have effects on people's instinct motivation to use technology.

Weinstein[54] proposed that "late life is a period of transition and adjustment to losses". Transition includes retirement and relocation. When older adults retire, they leave work and social roles that provided economic rewards as well as social status[44,61]. Apart from the loss of status and poorer economic conditions, older people may also experience loss of good health, and the illness and death of a spouse and of friends.

Older people are likely to be more at risk for feeling a loss of control[44,62]. The sense that personal control decreases with age might be the reason that older people are likely to have experienced events beyond their control, such as loss of loved ones and loss of health. Self-efficacy, which is the sense of personal ability to successfully perform a given task, also declines in the later years of life. Older adults possess lower computer self-efficacy and a higher degree of anxiety about computers than younger adults[63]. Self-efficacy and personal control for use of technology are the intrinsic factors underlying perceived ease of use which greatly influences attitudes towards adoption of a technology[7, 22].

Social relationship

When people grow old, they become more selective in their social relationships. Older adults have more emotional investment in ties with family members and established friends but less interest in forming ties with new acquaintances[64]. Grandchildren and children tend to be more influential than strangers or sales people to the decisions that older adults make about adopting and using a technological device[15]. Older adults have less frequent contact with other people and therefore have reduced social networks[44]. Social isolation is more pronounced among older people accompanied by a decline in health or increased impairment[62]. The key defense against social isolation is to improve communication and to develop a network of social support. Negative feelings and attitudes of older people towards post-retirement life can be improved by using the Internet[61].

Limitations of TAM Studies

Three limitations are noted with regard to the empirical studies on TAM in connection with ageing in the last decade. Firstly, all studies intended to investigate factors that influence the older person's acceptance of technology, but only a few studies considered age-related factors. The factor of 'age' in the majority of studies was measured by 'chronological age' which is the number of years or months that have passed since the person's birth. Ageing occurs on many levels and can be categorized on five dimensions: chronological, biological, functional, psychological, and social[44,56]. Chronological age cannot differentiate people who are different in physical functions, or psychological performance[52]. To better predict acceptance of technology and usage behavior by older people, more age-related characteristics or limitations need to be considered.

Secondly, among the empirical studies identified, eleven of them used questionnaire-based quantitative research methods, and the majority was based on cross-sectional data. Cross-sectional studies are less clear about causal inference[65]. Experience and learning impact on the acceptance of technology[27]. The effects of social influence processes on perceived usefulness (PU) and behavioral intention to use (BI) weaken with increasing experience, but the effects of cognitive instrumental processes remain significant over time. Longitudinal studies are needed since user attitudes, intentions and needs may change when they become more familiar with a technology[22].

Another problem concerns the measurement of usage behavior. In the 19 studies used for analysis here, only two examined actual usage. Studies mainly rely on self-reported frequency of use, amount of time using, and number of usages. Self-reported usage is subject to method bias, which "distorts and exaggerates the causal relationship between independent and dependent variables"[65].

Thirdly, most studies examined here were carried out in Europe and America. Personality,

type of technology and culture have moderating effects on relationships in TAM[66]. In Western cultures the effect of PU is more important, while PEOU is more relevant in non-Western cultures. Asian countries, with a large percentage of the older population of the world, have not been widely explored. It is not known to what extent the findings for populations in developed countries can be generalized to the older population in developing countries.

Communication and assistive technology in the home domain have been the major research targets in TAM studies, neglecting other categories, such as personal mobility and transportation, and education and recreation[67,68]. More systematic research is needed to generate a better understanding of the determinants of technology acceptance for the older people in general. Further exploration should take into account more context-specific factors and target a variety of types of technologies.

Conclusion

Technology offers a challenge and an opportunity in providing support and in enhancing the daily lives of older people. TAM is a useful theoretical model to explain and predict technology usage behavior. We found that TAM is also effective when applied to older adults. The basic constructs in TAM and related models, such as PU and PEOU, are critical for older people as well as for the young. To understand how older people interact successfully with software and hardware of technological devices and systems, it is essential to take into account biophysical and psychosocial characteristics, abilities and problems experienced by older people. There is a pressing need for research here. Communication and health technology are currently the major research targets for TAM studies. Extending the research to other life domains is another future direction of study. The majority of controlled studies in the field of TAM concern European and USA-based populations. Asian countries, accounting for the majority of older people on earth, are underrepresented. Understanding and creating the conditions under which technology can be incorporated into the lives of older people remains a high-priority research issue.

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