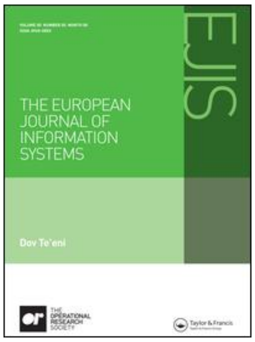

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EMPIRICAL RESEARCH

Internet adoption by the elderly: employing IS technology acceptance theories for understanding the age-related digital divide

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Abstract

Information technology (IT) allows members of the growing elderly population to remain independent longer. However, while technology becomes more and more pervasive, an age-related underutilisation of IT remains observable. For instance, elderly people (65 years of age and older) are significantly less likely to use the Internet than the average population (see, for instance, European Commission, 2011). This age-related digital divide prevents many elderly people from using IT to enhance their quality of life through tools, such as Internet-based service delivery. Despite the significance of this phenomenon, the information systems (IS) literature lacks a comprehensive consideration and explanation of technology acceptance in general and more specifically, Internet adoption by the elderly. This paper thus studies the intentions of the elderly with regard to Internet use and identifies important influencing factors. Four alternative models based on technology acceptance theory are tested in the context of comprehensive survey data. As a result, a model that explains as much as 84% of the variance in technology adoption among the elderly is developed. We discuss the contribution of our analyses to the research on Internet adoption (and IT adoption in general) by the elderly, on the digital divide, and on technology acceptance and identify potentially effective paths for future research and theoretical development.

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Keywords: elderly; digital divide; technology acceptance; Internet adoption

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Introduction

Information technology (IT) has significantly changed the way we live and work. For instance, Internet-based and electronic business has complemented and sometimes even superseded traditional offline channels. Online channels offer distinct value (e.g., constant availability) and, due to their cost structure, are often less expensive than store-bound distributions. As a result, companies often establish online channels as 'privileged channels' to support their objectives of cost-cutting and service optimisation. An example of a privileged channel is the online check-in with airlines that is currently strongly incentivised over the conventional counter check-in. IT is also becoming an important building block in other areas. Smart homes and national digital identity cards (Whitley & Hosein, 2008) are two examples of IT steadily diffusing into more areas of our daily lives.

In our technologised information society (Machlup, 1962; Duff *et al*, 1996) and from a customer perspective, IT competence is having the choice

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between alternative IT- and non-IT-based offerings, which in turn means being able to choose the superior offer. From a political perspective, IT offers the potential to raise economic performance, quality of life, and encourage full participation in society. In Europe, the Council of the European Union's, 2006 Riga Declaration made electronic inclusion (e-Inclusion) a priority on the political agenda. For the representatives, '"e[-]Inclusion" means both inclusive ICT [information and communication technology] and the use of ICT to achieve wider inclusion objectives. It focuses on participation of all individuals and communities in all aspects of the information society. e[-]Inclusion policy, therefore, aims at reducing gaps in ICT usage and promoting the use of ICT to overcome exclusion, and improve economic performance, employment opportunities, quality of life, social participation and cohesion' (European Union, 2006, p. 1). Despite the potential benefits of IT and the quest for e-Inclusion, a fully inclusive information society has not yet been achieved.

Among other groups, the elderly lag behind in using and benefiting from IT in general and the Internet in specific. However, Internet and IT usage offers the elderly significant potential for remaining independent longer (Czaja & Lee, 2007). Some recent examples include research on ambient assisted living (Sun *et al*, 2009) and on electronic health (Cho & Mathiassen, 2007; Klein, 2007; Payton & Kiwanuka-Tondo, 2009). Despite these benefits, a conspicuous age-related digital divide remains (Carter & Bélanger, 2005; Czaja *et al*, 2006; van Dijk, 2006; Agerwal *et al*, 2009). This digital divide means that despite all potential advantages, the elderly are less likely to have access to and to exploit the potential of Internet usage and IT in general (European Commission, 2004; Niehaves & Becker, 2008; Bélanger & Carter, 2009).

As a result of demographic transitions, especially Europe is facing ageing-related challenges in creating an inclusive information society. Currently, nine of the world's 10 'oldest' countries (in terms of percentage of people aged 65 or over) are in Europe (Population Reference Bureau, 2011). While Japan leads this ranking with 23.2%, more than 20% of the population in Germany and Italy is 65 years of age and older. The same age group constitutes more than 18% of the population in Greece and Sweden and more than 17% in all other European countries. Both Japan and Europe currently have so many elderly people and so few newborn babies that the ageing population has established a long-term trend that will continue for generations (Population Reference Bureau, 2011). While varying degrees of Internet adoption among the elderly populations of these countries exist (ranging from 4% in Greece and Bulgaria to as high as 61% in Sweden), we can observe an age-related digital divide in all of them. Notably, lower general Internet adoption is closely related to a stronger age divide. For example, in countries with low population-wide Internet adoption, such as Greece and Bulgaria, people aged 65 and older are more than 11 times less likely to be online than the overall population (see Table 1 for a list of the 10 'oldest' countries with data on Internet adoption among the overall population and the age group 65+). Accordingly, ageing populations and age-related e-Inclusion constitute fundamental European challenges.

With accelerating population ageing, explaining and addressing age-related issues in IT adoption and e-Inclusion is becoming increasingly significant. Given that IT is developing rapidly, theories that are robust to the particular technology specifics and that account for general factors of the elderly's technology adoption are becoming essential. While contemporary research often emphasises physical disabilities, such as low vision, cognitive disabilities, and motor skill limitations (Kraner, 2004; Becker, 2005; Kurniawan & Zaphiris, 2005), and studies their impact in the context of specific technologies, we adopt a broader perspective that draws upon information systems (IS) technology acceptance theories.

In this paper, we examine the influence of a wide range of drivers of Internet usage among the elderly (65 years of age and older). Four alternative models based on two technology acceptance theories (Unified Theory of Acceptance and Use of Technology (UTAUT) and Model of Adoption of Technology in Households (MATH); see Venkatesh *et al*, 2003; and Brown & Venkatesh, 2005) and digital divide literature (e.g., Wagner & Hanna, 1983; van Dijk, 2006; Agerwal *et al*, 2009; Bélanger & Carter, 2009) are created. Taking Internet adoption as an important reflection of broader IT adoption, we test our models using comprehensive survey data ($n = 150$). Our objective is to contribute to understanding Internet adoption by the elderly. Moreover, we investigate the explanatory power and applicability of alternative IS technology acceptance theories. In addition, we discuss the generalisability of our results to IT as a whole.

The paper is structured as follows: In the next section, we present the theoretical background and our research questions. We then develop four alternative research models and present our research methodology. The results

Table 1 Internet adoption in the 10 'oldest' countries in the world

Country	*Share of age group 65+ in population (%)*	*Onliners in population (%)*	*Onliners in age group 65+[a] (%)*
Japan	23.2[b]	79[c]	NA
Germany	20.7	82	43
Italy	20.2	54	12
Greece	18.9	46	4
Sweden	18.1	92	61
Portugal	17.9	53	11
Austria	17.6	75	29
Bulgaria	17.5	46	4
Latvia	17.4	68	12
Belgium	17.2	79	36

Data for 2010; 'Online in the last 12 months'.
[a]Data for age 65–74 years.
[b]*Source*: Population Reference Bureau, 2011.
[c]*Source*: Worldbank, 2011, and other European Commission, 2011.

of our study are presented in the penultimate section and discussed in terms of relevance for theory and practice in the last section. This final section considers the limitations, conclusions and implications for future research.

Theoretical background

Technology acceptance by individuals

Originating in the field of psychology, the phenomenon of technology acceptance has been studied widely by applying a range of alternative theories and models. The concept of individual technology acceptance was introduced into the IS literature by Davis (1986, 1989), with his Technology Acceptance Model (TAM) and has since been subject to subsequent theory development (Venkatesh & Davis, 2000, for instance). Novel theories that are partially based on TAM have been developed to explain individual technology usage behaviour. The UTAUT is derived by Venkatesh and colleagues and unifies constructs from eight competing theoretical models, including TAM (2003). The authors provide evidence that, in the case of IT adoption, their model has the greatest explanatory power compared with other models, including the theory of reasoned action (Fishbein, 1967; Fishbein & Ajzen, 1975), the TAM (Davis, 1989) and the theory of planned behaviour (Ajzen, 1985, 1991; Taylor & Todd, 1995). While UTAUT focuses on technology adoption in both the workplace and private environments, the MATH was created by Venkatesh and Brown to explain the adoption of technology (in early studies: personal computers (PC)) specifically in households and private environments (Venkatesh & Brown, 2001, Brown & Venkatesh, 2005).

Thus, both UTAUT and MATH are used to explain IT adoption in private, non-mandatory settings. We elected to further explore UTAUT because it unifies several other existing theories and is widely accepted in the IS research. However, the focus of UTAUT is on explaining IT adoption in organisational settings. By contrast, MATH was developed specifically for the adoption of technologies in private and voluntary settings and may thus be suitable to describe technology use among the elderly.

Both theories rely on the psychological construct of Behavioural Intention (BI) as a dependent variable. The construct of BI is well accepted in technology acceptance research (e.g., Davis, 1986; Venkatesh *et al*, 2003; Kim *et al*, 2009; Lin & Bhattacherjee, 2010). A brief definition and several references are shown in Table 2, and corresponding measurement instruments are listed in the Appendix. Both UTAUT and MATH are introduced briefly in the following sections.

UTAUT

UTAUT was developed in an attempt to unify eight distinct, but similar theories that explain technology acceptance. The authors included constructs from the theory of reasoned action (Fishbein, 1967; Fishbein & Ajzen, 1975), the TAM (Davis, 1989), TAM 2 (Venkatesh & Davis, 2000), the motivational model (Vallerand, 1997; Davis *et al*, 1992), the theory of planned behaviour (Ajzen, 1985, 1991), the combined TAM and theory of planned behaviour (Taylor & Todd, 1995), the model of PC utilisation (Thompson *et al*, 1991), innovation diffusion theory (Rogers, 1995) and social cognitive theory (Bandura, 1986). Venkatesh *et al* (2003) provide an introduction to these theories.

Venkatesh *et al* (2003) use all of these constructs to create a unified model based on statistically sound procedures. According to UTAUT, the BI to accept and use a technology depends on both expected performance and effort as well as on social influences. Furthermore, the final use behaviour, in accordance with prior research (e.g., Ajzen, 1985), depends on this BI. The existence of facilitating conditions is an additional predictor of use behaviour (Figure 1).

The definitions and origins of these core constructs can be found in Table 3. The corresponding measurement instruments are listed in the Appendix.

MATH

MATH was created to explain the adoption of technology in households. The key constructs of MATH were developed in a qualitative study (Venkatesh & Brown, 2001). Brown & Venkatesh (2005) subsequently used these variables to provide a comprehensive multi-item measurement model (see Table 4 for construct definitions). They

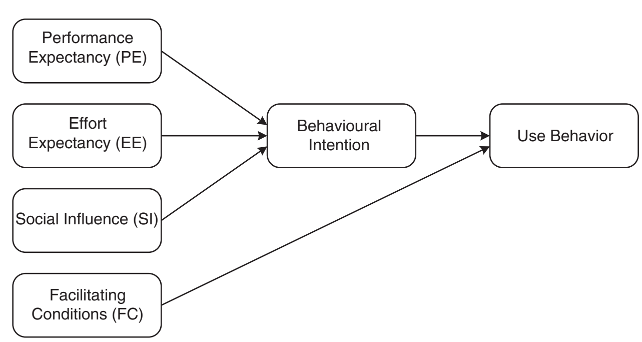

Figure 1 Unified theory of acceptance and use of technology (Venkatesh *et al*, 2003).

Table 2 Dependent variable: behavioural intention

Core construct	*Definition*	*References*
Behavioural Intention (BI)	The degree to which an individual wishes to use a technology (here, the Internet) for personal activities.	Davis (1986), Davis (1989), Taylor & Todd (1995), Venkatesh *et al* (2003), Brown & Venkatesh (2005)

Table 3 UTAUT: constructs and definitions

Core construct	*Definition*	*References*
Performance Expectancy (PE)	The degree to which an individual believes that using the technology will help him or her to improve personal performance.	Davis (1989), Moore & Benbasat (1991), Compeau *et al* (1999), Venkatesh *et al* (2003)
Effort Expectancy (EE)	The degree of ease associated with the use of a technology.	Davis (1989), Moore & Benbasat (1991), Venkatesh *et al* (2003)
Social Influence (SI)	The degree to which an individual believes it to be important that others feel he or she should use a particular technology.	Davis (1989), Aijzen (1991), Thompson *et al* (1991), Venkatesh *et al* (2003)
Facilitating Conditions (FC)	The degree of support available for adopting a specific technology.	Venkatesh *et al* (2003), Thompson *et al* (1991)

Table 4 MATH: constructs and definitions

Core construct	*Definition*	*References*
Applications for Personal Use (AFPU)	The extent to which using a specific technology (here, the Internet) enhances the effectiveness of household activities.	Venkatesh & Brown (2001)
Utility for Children (UFC)	The extent to which using the technology studied enhances children's ability to complete homework and other activities.	Venkatesh & Brown (2001)
Applications for fun (AFF)	The extent to which using a certain technology generates pleasure and is fun.	Webster & Martocchio (1992, 1993), Venkatesh & Brown (2001)
Status Gains (Status)	The increase in prestige associated with the usage of a certain technology.	Venkatesh & Brown (2001)
Friends and Family Influences (FAFI)	The extent to which friends and family members influence the respondent's behaviour.	Venkatesh & Brown (2001)
Secondary Sources' Influences (SSI)	The extent to which information from TV, newspapers and other secondary sources influences behaviour.	Venkatesh & Brown (2001)
Workplace Referents' Influences (WRI)	The extent to which co-workers or colleagues influence behaviour.	Taylor & Todd (1995)
Fear of Technological Advances (FOTA)	The extent to which rapidly changing technology is associated with fear of obsolescence or apprehension regarding Internet usage.	Venkatesh & Brown (2001)
Declining Cost (DC)	The extent to which the cost of technology use is decreasing in such a way that it inhibits adoption.	Venkatesh & Brown (2001)
Cost (COST)	The extent to which the current cost of a technology is considered as too high.	Venkatesh & Brown (2001)
Perceived Ease of Use (PEOU)	The degree of ease associated with using a specific technology.	Davis (1989); Venkatesh & Brown (2001)
Self-Efficacy (SE)	The individual's belief that he/she has the necessary knowledge to use a technology.	Compeau & Higgins (1995a, b), Venkatesh & Brown (2001)

tested this model to predict the adoption of PC in households. The independent variables of MATH are grouped into three categories: attitudinal, normative, and control beliefs. Attitudinal beliefs are those relating to utilitarian outcomes (i.e., applications for personal use, utility for children and utility for work-related use), hedonic outcomes (applications for fun) or social outcomes (status gains). Normative beliefs cover the influences of friends

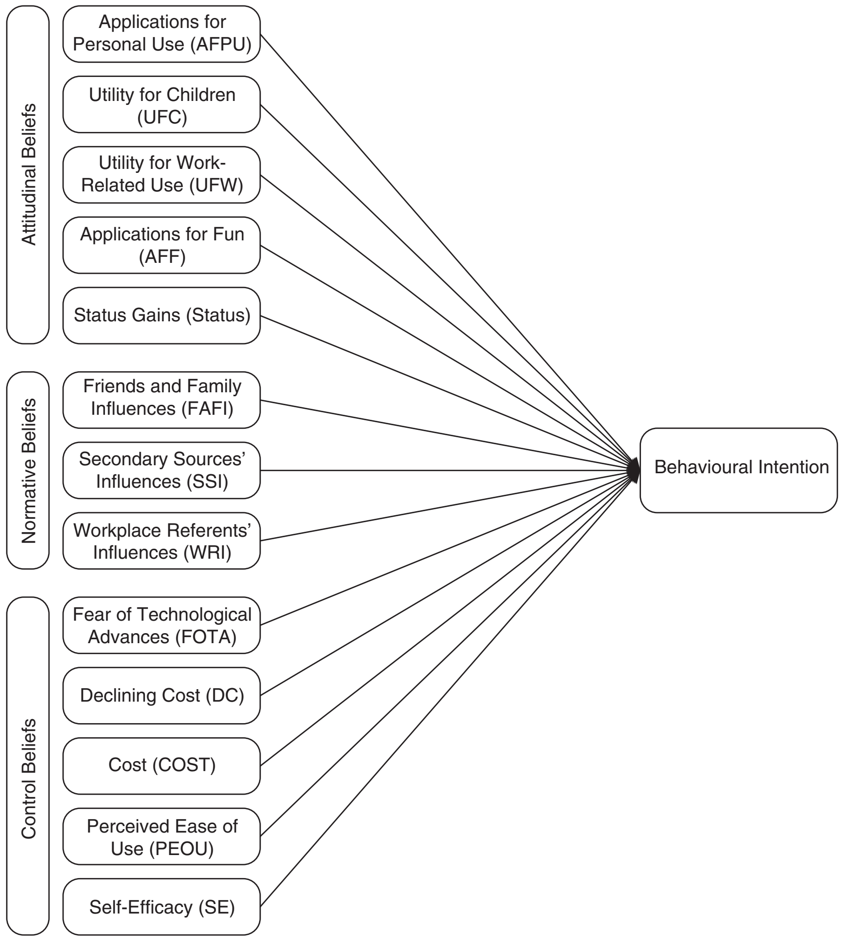

Figure 2 Model of adoption of technology in households (Venkatesh & Brown, 2001; Brown & Venkatesh, 2005).

and family, workplace referents and secondary sources such as television or newspapers. Control beliefs classically refer to the perceived ease of use, requisite knowledge or self-efficacy, fear of technological advances (FOTA), costs and declining costs. All of these factors are assumed to have an impact on BI (Figure 2).

Although created in a qualitative study, several constructs of MATH rely on prior research. An overview is presented in Table 4, and the corresponding measurement instruments in the Appendix.

Individual technology acceptance and socio-demographic variables

In technology adoption research, for instance Claisse & Rowe (1987), Gefen & Straub (1997), Morris & Venkatesh (2000), Venkatesh *et al* (2003) and Sykes *et al* (2009) argue that socio-demographic characteristics can play an important role in IT adoption. Socio-demographic variables are defined as those variables that relate to or involve a combination of social and demographic characteristics. They are thus related to the individual person in scope (most prominently age and gender; for instance Venkatesh *et al*, 2003) and not to the setting of the study (such as job characteristics or variables describing the person-technology relationship; see for instance Lam & Lee's (2006) study on self-efficacy).

Arguments for the importance of socio-demographic variables can be found in digital divide research as well. The digital divide is the gap between those who have effective access to and exploit the potential of IT and those who do not. One stream of digital divide research concentrates on the differences between countries and regions (e.g. developed *vs* developing countries, Corrocher & Ordanini, 2002; James, 2004) and is thus only of minor importance for the present research objective. The second stream of digital divide research, however, focuses on the level of the individual. In this respect, there are groups of people (e.g. the elderly) who tend to be excluded from benefiting from IT for a variety of reasons (Kvasny & Keil, 2006; Hill *et al*, 2008; Hsieh *et al*, 2008).

In order to identify the most relevant socio-demographic variables in technology adoption and digital divide research, we conducted a comprehensive literature search

Table 5 Key socio-demographic variables in technology adoption and digital divide studies

Literature search base (including multiple citation indices as well as the major AIS conference publications)		More than 12,000 publication outlets.	
Relevant articles (quantitative technology adoption and digital divide studies that report on socio-demographic variables; before screening 373)		113	100%
Studies addressing the variable *GENDER*	Gilly & Enis (1982), Venkatesh *et al* (2000), Brown & Venkatesh (2005), Agerwal *et al* (2009), Bélanger & Carter (2009)	107	95%
Studies addressing the variable *AGE*	Venkatesh *et al* (2003), Brown & Venkatesh (2005), Czaja *et al* (2006), Yao & Murphy (2007), Sykes *et al* (2009), Brown *et al* (2010)	98	84%
Studies addressing the variable *INCOME*	Wagner & Hanna (1983), Brown & Venkatesh (2005), Agerwal *et al* (2009), Bélanger & Carter (2009)	10	9%
Studies addressing the variable *EDUCATION*	Czaja *et al* (2006), van Dijk (2006), Agerwal *et al* (2009), Bélanger & Carter (2009)	9	8%

in online databases (Thomson Reuters Web of Knowledge covering the Science Citation Index Expanded (SCIE), the Social Sciences Citation Index (SSCI), the Arts & Humanities Citation Index (A&HCI) and other databases in related fields) and screened key Association for Information Systems (AIS) international conferences (accessed via AIS electronic library, AISeL). The database search was complemented by a systematic forward and backward search on the basis of the literature identified. As a result, we were able to identify 373 relevant articles of which 113 studies passed our initial screening (here: actual reporting of socio-demographic variables, quantitative study and technology acceptance and/or digital divide being the focus of the analysis (in contrast to just a referencing of another relevant article)).[1] See Table 5 for an overview over the background and the results of the literature analysis.

Our study yielded the identification of multiple socio-demographic variables. As gender and age were included in the original UTAUT study (Venkatesh *et al*, 2003), they form by far the most used socio-demographic variables we could identify. Gender was used in 107 (95%) and age in 98 (87%) studies. Next, income was used in 10 (9%) and education in 9 (8%) studies. These four variables are the most studied socio-demographic variables in the research our comprehensive literature analysis was able to identify. With these findings, our study, which is oriented towards quantitative analyses, is in line with prior qualitative research, such as Baron *et al* (2006), that discusses the influence of these specific four socio-demographic variables (age, gender, income and education) on technology acceptance.

Thus, current technology acceptance and digital divide literature does not provide an integrated, quantitative study based on IS acceptance theories that includes all of these four key socio-demographic variables. In addition, relevant dependencies between these variables (e.g., high-income groups among the elderly) remain under-researched. Hence, there is a clear gap with respect to the usage of IS acceptance theories including important socio-demographic variables to explain Internet usage among the elderly.

[1]A list of all articles can be requested from the authors.

Technology acceptance by the elderly

A general consensus that elderly people are often more reluctant to accept a specific technology exists in the literature (Morris & Venkatesh, 2000; Venkatesh *et al*, 2003; Czaja *et al*, 2006; Yao & Murphy, 2007; see Table 1). In general, the use of IT has much to offer to senior citizens in terms of increasing their quality of life (Czaja & Lee, 2007; Mitzner *et al*, 2010). Czaja & Lee (2007) provide several examples that can be realised through Internet or IT usage, including reducing social isolation, IT-supported communication with friends and family and active participation in an increasingly computerised healthcare system. Chen & Chan (2011) agree and argue that these potential benefits are not often exploited. In a qualitative study, Renaud and van Biljon discuss the difficulties older adults face in adopting mobile phones (2008). Another study reveals that age has a significant negative influence on both the short-term and long-term acceptance of an organisational information retrieval system (Morris & Venkatesh, 2000). Earlier studies demonstrate a negative relationship between age and the acceptance of automatic teller machines (Rogers *et al*, 1996). Other studies concentrate on the Internet and argue that elderly people are less likely to adopt the Internet (Lam & Lee, 2006; Hill *et al*, 2008). Chung *et al* (2010) argue that a negative relationship between age and Internet self-efficacy exists. In a review of 19 technology acceptance studies, it could be shown that 'TAM is […] effective when applied to older adults' (Chen & Chan, 2011, p. 9). This is underlined by a study using TAM to explain elderly people's e-government webpage usage in Taiwan (Tseng *et al*, 2012). However, research in this area still lacks a comprehensive explanation of why the elderly are more reluctant to accept (information) technologies (Chen & Chan, 2011). In this respect, beliefs or traits (as included in UTAUT and MATH) may have great potential explanatory power (Porter & Donthu, 2006; Mitzner *et al*, 2010). One example would be the self-efficacy that comes with prior technology usage (Burnett *et al*, 2011).

Against this background, we address the following research questions (RQ):

RQ1: *How well does technology acceptance theory explain the intention to adopt the Internet by the elderly?*

RQ2: *Which alternative theory (UTAUT or MATH) is best able to explain the intention to adopt the Internet by the elderly?*

RQ3: *Can an extension of UTAUT and MATH, using a set of socio-demographic variables, provide a better explanation of the intention to adopt the Internet by the elderly?*

Research models

To address these research questions and to allow for a systematic comparison of alternative theoretical approaches to explain Internet adoption by the elderly, we compare four research models. The first of our four research models is based on UTAUT (see section 'UTAUT'). As stated above, UTAUT not only concentrates on the intention to use a certain technology and the corresponding impact of performance expectancy (PE), effort expectancy (EE), and social influence (SI) on this intention but also includes the impact of facilitating conditions and BI on use behaviour. To answer the presented research questions we omitted the constructs of use behaviour and facilitating conditions. The second research model is an enhanced version that includes the four important moderating socio-demographic variables, education, gender, income and age, derived from the literature outlined (Figure 3). While we focus on Internet adoption by all adults over 65 years of age, the additional moderating variable of age is intended to account for more variability within this age group (for instance, if PE is of different importance to younger seniors than to older seniors).

MATH (see section 'MATH') forms the basis of the third research model. One of its constructs is utility for work-related use, defined as the extent to which using a PC enhances the effectiveness of work-related activities (Aijzen, 1991; Venkatesh & Brown, 2001; Venkatesh *et al*, 2003). Another construct looks at the influence of work-related peers (workplace referents' influence) and can be understood as the extent to which co-workers or colleagues influence behaviour (Taylor & Todd, 1995). As our study focuses on Internet acceptance by individuals who are already past usual retirement age, these two variables cannot be interpreted effectively and are therefore

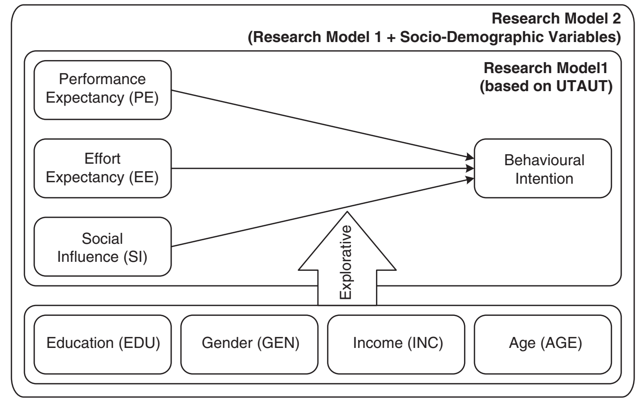

Figure 3 Research models 1 and 2: original and extended UTAUT.

excluded from our study. This slight alteration of MATH forms the third research model. This research model is again extended by socio-demographic variables, which constitute the fourth research model (Figure 4).

All MATH and UTAUT constructs are measured using well-established items, as introduced and tested in the original literature (see above and the Appendix). The items for the socio-demographic variables are listed in Table 6.

Our study focuses on Internet adoption as an important case of IT adoption (DiMaggio & Hargittai, 2001; European Union, 2006; van Dijk, 2006; Agerwal *et al*, 2009; Bélanger & Carter, 2009). Firstly, the Internet is one of the most important technological innovations in recent years. From a user perspective, the elderly can gain various advantages from Internet use (Czaja *et al*, 2013). The Internet offers significant potential for remaining independent longer (Czaja & Lee, 2007; see, for instance, research on ambient assisted living (Sun *et al*, 2009) and electronic health records management (Cho & Mathiassen, 2007; Klein, 2007; Payton & Kiwanuka-Tondo, 2009; Czaja *et al*, 2013). Users can participate in social processes via social networks, improve their consumer behaviour in terms of raising utility through e-commerce or participate in political processes through e-government and e-democracy. The Internet is the basic technology that must be mastered to gain all of these benefits. From a provider perspective, 'encouraging older consumers to use the Internet makes good business sense' (Porter & Donthu, 2006; see also Kohlbacher & Herstatt, 2008), as they tend to be more loyal to their provider and have greater spending power than younger consumers (Moschis *et al*, 2004). Secondly, the Internet is viable for study purposes, as most people have already encountered an Internet user and have thus been confronted with the technology. Thirdly, choosing the Internet as the focal technology enabled us to secure the support of the local authorities for our research. They were interested in the results to improve their e-inclusion policies. Focusing on Internet adoption as an example of IT adoption, our study has specific implications for e-inclusion practice as applied to Europe's changing population.

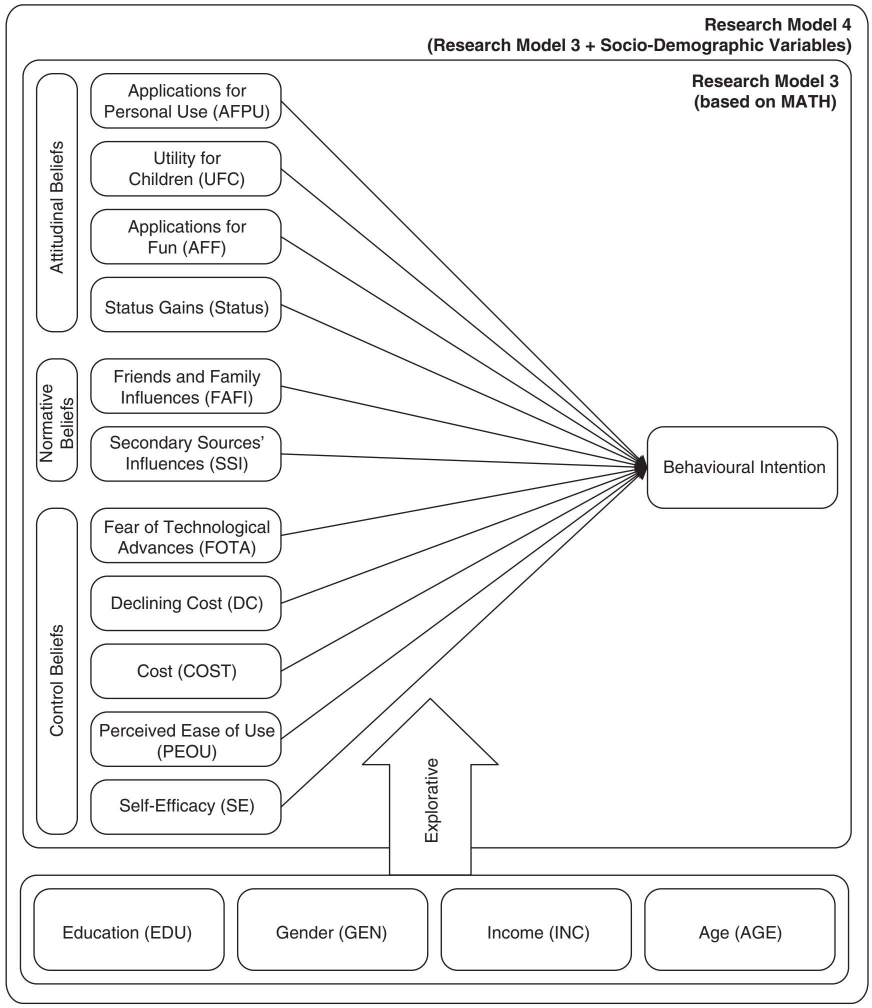

Figure 4 Research models 3 and 4: MATH.

Research methodology

Data collection phase

Prior to the data collection phase, we developed a questionnaire that included items related to the four research models presented above. Our measures included established constructs and items (see the Appendix for an overview of the items used). We validated the questionnaire in a pilot study with seven respondents. This validity check did not result in any changes to the set of questions, items or constructs.

We distributed the questionnaire in Germany, the 'oldest' European country, in which older adults (age 65+) constitute 20.7% of the population. Germany has a high rate of Internet adoption (82% of the overall population) and exhibits strong Internet usage among the elderly as well (43%, Table 1). Against this background, we can expect sufficient variance in our dependent variable.

In Germany, we selected two medium-sized neighbouring cities and collected the data at the end of 2009 and the beginning of 2010. We employed a multi-channel strategy to reach randomly selected respondents: 6500 surveys were distributed via regular mail to randomly selected citizens, 100 telephone interviews were performed with randomly selected individuals and 3500 questionnaires were placed in public places such as the town-hall and local libraries. Different channels did not lead to significantly different patterns of answers. Potential respondents were assured of the confidentiality of their responses. The survey was conducted across the entire population, independent of age and we received 150 complete surveys from respondents aged 65 or over. This data set constitutes the basis of the analysis. A non-response analysis based on a chi-square test of the socio-demographic variables of our study did not reveal any significant differences between early and late respondents. This indicates the absence of non-response bias (Lindner *et al*, 2001; Recker & Rosemann, 2010).

Data analyses phase

The structured data were first analysed with regards to sample demographics, missing values, and non-responses

Table 6 Socio-demographic variables

Core construct	*Items*
Education (EDU) (Czaja *et al*, 2006; van Dijk, 2006; Agerwal *et al*, 2009; Bélanger & Carter, 2009)	EDU: I spent <x> number of years in school, college, university or comparable educational institution.
Gender (GEN) (Gilly & Enis, 1982; Venkatesh *et al*, 2000; Brown & Venkatesh, 2005; Agerwal *et al*, 2009; Bélanger & Carter, 2009)	GEN: I am a <woman [0] | man [1]>.
Income (INC) (Wagner & Hanna, 1983; Brown & Venkatesh, 2005; Carter & Bélanger, 2005; Agerwal *et al*, 2009; Bélanger & Carter, 2009)	INC: The average monthly net income of the household I'm living in is <less than 1000€ [0] | between 1000€ and 2000€ [1] | between 2000€ and 3000€ [2] | more than 3000€ [3]>
Biological Age (AGE) (Venkatesh *et al*, 2003; Brown & Venkatesh, 2005; Czaja *et al*, 2006; Yao & Murphy, 2007; Sykes *et al*, 2009; Brown *et al*, 2010)	AGE: I am <x> years old.

Table 7 Demographics of the analysed sample

Question	*N*	*Min*	*Max*	*Mean*	*SD*
AGE: I am <x> years old.	150	65	88	69.5667	4.210
EDU: I spent <x> number of years in school, college, university or comparable institution.	142	6	23	12.4648	3.820
GEN: I am a	150	0	1	0.6467	0.480
<woman [0] |	53				
man [1]>.	87				
INC: The average monthly net income of the household I'm living in is	116	0	3	1.8448	0.840
<less than 1000€ [0] |	5				
between 1000€ and 2000€ [1] |	36				
between 2000€ and 3000€ [2] |	47				
more than 3000€ [3]>	28				

using SPSS 17.0.0. To address our research questions, we limited our data to only those questionnaires from respondents aged 65 or over, which yielded 150 cases. To further analyse our data set, we employed the partial least squares (PLS) path-modelling algorithm (Henseler & Fassott, 2010; Marcoulides *et al*, 2009). We employed the centroid-weighting scheme as there is less risk of overestimated effects than when using the factor weighting scheme (Wilson & Henseler, 2007). The software package to support this was SmartPLS (Ringle *et al*, 2005). The constructs were all modelled using reflective indicators (Venkatesh *et al*, 2003; for a detailed discussion on formative *vs* reflective indicators, see Diamantopoulos & Siguaw, 2006). The data incorporate some missing values. On average, there are 2.2 missing answers per case, with a standard deviation of 3.34. These missing values were treated using the mean replacement algorithm (Afifi & Elashoff, 1966). In the analysis phase, we compared the four different models presented above, UTAUT and MATH, both with and without the moderating effects of our four socio-demographic variables.

Sample demographics

Our sample consists of data obtained from 150 senior citizens. The mean age of the respondents was 69.6 years. The respondents had spent on average 12.5 years in school or at university. Our sample is almost equally distributed by gender, with a marginal surplus of men. The income variable yields the most missing values (34). Observed household income in our sample is at a medium level (Table 7).

Additional analyses of the ethnic background of our participants show that the number of people who are immigrants is relatively low. Furthermore, 99.3% of respondents have German citizenship and 98.0% are

Table 8 Measurement model estimation (research models 1 and 2)

		ICR	*Mean*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	BI	0.89	5.69	1.65	0.91							
2	PE	0.75	4.58	1.26	0.79	0.77						
3	EE	0.83	4.73	1.36	0.77	0.75	0.81					
4	SI	0.67	4.75	1.05	0.56	0.51	0.44	0.71				
5	EDU	1.00	12.46	3.72	0.23	0.09	0.20	0.03	1.00			
6	GEN	1.00	0.65	0.48	0.21	0.23	0.23	0.04	0.24	1.00		
7	INC	1.00	2.84	0.74	0.22	0.23	0.28	0.14	0.39	0.22	1.00	
8	AGE	1.00	69.57	4.21	–0.21	–0.16	–0.14	–0.14	–0.03	–0.05	–0.12	1.00

(a) ICR: Internal consistency reliability (Cronbach's alpha).
(b) Diagonal elements are the square root of the shared variance between the constructs and their measures.
(c) Off-diagonal elements are correlations between constructs.

Table 9 Measurement model estimation (research models 3 and 4)

		ICR	*Mean*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1	BI	0.89	5.69	1.65	0.91															
2	APFU	0.83	4.60	1.37	0.64	0.86														
3	UFC	0.84	5.12	1.08	0.22	0.16	0.87													
4	AFF	0.82	4.53	1.29	0.73	0.66	0.33	0.81												
5	Status	0.78	4.21	1.17	0.20	0.23	0.14	0.34	0.82											
6	FAFI	0.88	4.69	1.33	0.49	0.51	0.23	0.43	0.40	0.86										
7	SSI	0.84	4.59	1.26	0.30	0.24	0.28	0.39	0.37	0.36	0.87									
8	FOTA	0.68	4.08	1.84	–0.25	–0.23	0.02	–0.20	0.02	–0.01	0.13	0.64								
9	DC	0.79	4.64	1.11	0.40	0.33	0.35	0.40	0.25	0.30	0.29	–0.14	0.84							
10	COST	0.83	3.59	1.33	–0.12	–0.04	–0.03	–0.03	0.14	0.07	0.09	0.11	–0.17	0.86						
11	PEOU	0.87	4.76	1.46	0.74	0.62	0.29	0.70	0.22	0.31	0.28	–0.32	0.39	–0.14	0.85					
12	SE	0.81	5.12	1.46	0.82	0.63	0.28	0.69	0.20	0.47	0.31	–0.15	0.35	–0.02	0.78	0.85				
13	EDU	1.00	12.46	3.72	0.23	0.03	–0.13	0.03	–0.08	0.04	0.04	–0.03	0.21	–0.14	0.14	0.12	1.00			
14	GEN	1.00	0.65	0.48	0.21	0.22	–0.01	0.10	0.09	0.04	–0.11	–0.23	0.13	–0.06	0.25	0.13	0.24	1.00		
15	INC	1.00	1.84	0.74	0.23	0.17	0.03	0.11	0.04	0.20	0.12	–0.05	00.21	–0.19	0.29	0.25	0.39	0.22	1.00	
16	AGE	1.00	69.57	4.21	–0.21	–0.01	–0.11	–0.10	–0.04	–0.12	–0.04	0.04	0.00	–0.05	–0.12	–0.18	–0.03	–0.05	–0.12	1.00

(a) ICR: Internal consistency reliability (Cronbach's alpha)
(b) Diagonal elements are the square root of the shared variance between the constructs and their measures
(c) Off-diagonal elements are correlations between constructs

native speakers of German. This low rate of migrants is typical for the areas studied, especially within the age group concerned.

Results

The results of our study are presented below in three steps. Firstly, we examine the validity of our constructs (outer model) using standardised measures that are consistent with Venkatesh *et al* (2008), Brown & Venkatesh (2005) or Venkatesh *et al* (2003). Secondly, we present the inner model: the paths and their coefficients in all four models (UTAUT and MATH with and without moderating socio-demographic variables). Thirdly, we present and compare the coefficient of determination for each of the four models.

Outer model

The results derived from using the above-mentioned methodology are listed in Table 8. We measured the internal consistency reliability (ICR) of all latent variables using Cronbach's alpha. Generally speaking, an ICR above 0.9 is considered excellent, between 0.7 and 0.9 is considered high, between 0.5 and 0.7 is considered moderately high, and all other values are considered low (Hinton *et al*, 2004). The reliabilities for the UTAUT model are comparably high, with only SI in the moderately high area (Table 8).

In the later models based on MATH (Table 9), reliabilities can also be considered high, with FOTA being moderately high. High ICRs indicate that the items validly measure the corresponding construct. In addition, in all but one case (Models 1 and 2, PE), correlations between the constructs are lower than the square roots of the shared variance between the constructs and their measures in every case. According to Fornell & Larker (1981), this supports convergent and discriminant validity (Table 9). Hence, special care has to be taken with regard to the relationship between PE and BI. However, as no past study on UTAUT revealed difficulties in distinguishing PE from

Table 10 Item loadings (moderator effect – significance of items is stable)

Research model 1+2				*Research model 3+4*							
LV	*Item*	*Loading*	*p*	*LV*	*Item*	*Loading*	*p*	*LV*	*Item*	*Loading*	*p*
BI	BI1	0.9083	<0.001	BI	BI1	0.9078	<0.001	SSI	SSI1	0.8903	<0.001
	BI2	0.8824	<0.001		BI2	0.8805	<0.001		SSI2	0.8574	<0.001
	BI3	0.9323	<0.001		BI3	0.9345	<0.001		SSI3	0.8497	<0.001
PE	PE1	0.8951	<0.001	AFPU	AFPU1	0.8887	<0.001	FOTA	FOTA1	0.8222	<0.001
	PE2	0.8798	<0.001		AFPU2	0.7921	<0.001		FOTA2	−0.1471	0.6220
	PE3	0.8023	<0.001		AFPU3	0.9013	<0.001		FOTA3	0.7370	<0.001
	PE4	0.3576	<0.001	UFC	UFC1	0.8011	<0.001	DC	DC1	0.8440	<0.001
EE	EE1	0.8603	<0.001		UFC2	0.9087	<0.001		DC2	0.8603	<0.001
	EE2	0.8262	<0.001		UFC3	0.8890	<0.001		DC3	0.8193	<0.001
	EE3	0.8458	<0.001	AFF	AFF1	0.8530	<0.001	COST	COST1	0.8912	<0.001
	EE4	0.7159	<0.001		AFF2	0.5611	<0.001		COST2	0.8568	<0.001
SI	SI1	0.6708	<0.001		AFF3	0.8819	<0.001		COST3	0.8202	<0.001
	SI2	0.7579	<0.001		AFF4	0.8971	<0.001	PEOU	PEOU1	0.9044	<0.001
	SI3	0.6053	<0.001	Status	Status1	0.8434	<0.001		PEOU2	0.8657	<0.001
	SI4	0.7739	<0.001		Status2	0.8991	<0.001		PEOU3	0.7172	<0.001
					Status3	0.6945	<0.001		PEOU4	0.8951	<0.001
				FAFI	FAFI1	0.8835	<0.001	SE	SE1	0.8334	<0.001
					FAFI2	0.8531	<0.001		SE2	0.8008	<0.001
					FAFI3	0.8836	<0.001		SE3	0.9084	<0.001
					FAFI4	0.8136	<0.001				

Education, Income, and Gender were measured using one variable.

BI, we still assume that convergent and discriminant validity is given.

We employed a bootstrapping method (minimum of 1000 iterations) using randomly selected sub-samples to test the significance of our PLS model.[2] Analysing the item loadings, we generally observed that latent variables were adequately measured by the corresponding items in both models. All of the items except PE4 and FOTA2 have high loadings (Table 10). In this respect, analysing the average variance extracted demonstrates that PE and facilitating conditions can still be considered valid (Hinton *et al*, 2004).

Inner model

In the first research model (UTAUT without moderator effects), the bootstrapping method shows that all paths are significant. We observed a high influence of PE on BI. The other path coefficients are lower. In the second model (UTAUT with moderating socio-demographic variables), these relationships are moderated by education, gender, income, and age. Accordingly, 12 interaction terms related to demographic variables were added to the analysis. Bootstrapping suggests that only a minority of all paths used is significant (Table 11) because a high number of moderating variables often goes in hand with lower statistical power (Aguinis, 1995). This phenomenon is observable in prior IS research as well (e.g. Brown & Venkatesh, 2005 or Venkatesh *et al*, 2003, where most of the interaction terms were non-significant). However, we can observe that age has a negative direct effect on BI. Moreover, age positively influences the relationship between PE and BI. Several paths in the third model can be considered significant (UFC, AFF, FAFI, COST, PEOU, and SE). Moreover, FOTA is only marginally above our *P*-value threshold of 0.1. Again, in the fourth model, four moderator variables were added, leading to the inclusion of 44 interaction terms.

[2]We list the specific *P*-values as the probabilities of obtaining results at least as extreme as the calculated ones, given that the true path influence would have been 0. We consider each path with a *P*-value below 0.1 to be significant.

Coefficient of determination

The coefficient of determination (R^2) is defined as the proportion of variance in the data explained by the statistical model and not by random error terms or non-included constructs. In addition, we provide information on the adjusted R^2, which accounts for the number of independent variables (Theil, 1961). The original UTAUT achieved an R^2 for BI between 0.51 and 0.77 (Venkatesh *et al*, 2003). Our analyses already yield an adjusted determination coefficient of 0.7221 for BI in the first model without moderating effects, which is in line with Venkatesh *et al*'s results. In the second case, with moderating effects, we observe even higher (adjusted) R^2-values for BI (0.7660). When MATH was used to explicate private PC adoption (Brown & Venkatesh, 2005), the adjusted R^2 was 0.50. Including such interaction terms as age, marital status, or income led to an adjusted coefficient of determination of 0.74. In our study, applying the non-moderated

Table 11 Path coefficients

	Research model 1		*Research model 2*	
	Path	*P*	*Path*	*P*
R^2	0.7277		0.7770	
R^2 adjusted	0.7221		0.7660	
PE	0.4172	*<0.001*	0.1821	0.3173
EE	0.3818	*<0.001*	0.3311	*0.0697*
SI	0.1804	*0.0008*	0.1935	*0.0878*
EDU			0.1479	*0.0776*
GEN			0.4637	0.1037
INC			−0.0542	0.2334
AGE			−0.1398	*0.0515*
PE×EDU			−0.2890	0.1717
PE×GEN			−0.1841	0.3958
PE×INC			0.1044	0.4241
PE×AGE			0.5320	*0.0081*
EE×EDU			0.0551	0.2557
EE×GEN			0.1060	0.5829
EE×INC			−0.1965	0.2276
EE×AGE			−0.0431	0.7558
SI×EDU			0.2242	0.2532
SI×GEN			−0.4058	0.1328
SI×INC			0.0466	0.6251
SI×AGE			−0.0126	0.8924

	Research model 3		*Research model 4*	
	Path	*P*	*Path*	*P*
R^2	0.7632		0.8592	
R^2 adjusted	0.7443		0.8434	
AFPU	0.0219	0.6114	−0.0771	0.7248
UFC	−0.0765	*0.0760*	0.1098	0.5105
AFF	0.2370	*0.0010*	0.3646	0.3464
Status	−0.0582	0.1630	−0.2678	0.2818
FAFI	0.1409	*0.0219*	0.1326	0.3993
SSI	0.0169	0.6252	0.0919	0.6593
FOTA	−0.0688	0.1245	0.0003	0.9985
DC	0.0555	0.1920	0.0717	0.6451
COST	−0.0693	*0.0848*	−0.0231	0.8941
PEOU	0.1192	*0.0687*	−0.2913	0.4025
SE	0.4807	*<0.001*	0.5998	*0.0729*
EDU			0.0829	0.5993
GEN			−0.2019	0.5549
INC			−0.0259	0.6543
AGE			−0.0701	0.5437
AFPU×EDU			−0.1709	0.5990
AFPU×GEN			0.2125	0.5581
AFPU×INC			−0.1674	0.5258
AFPU×AGE			0.2833	0.3142
UFC×EDU			0.2764	0.3783
UFC×GEN			0.3300	0.2782
UFC×INC			0.0728	0.7372
UFC×AGE			−0.4730	0.1242
AFF×EDU			−0.0597	0.8818
AFF×GEN			−0.3846	0.2731
AFF×INC			−0.1324	0.5963
AFF×AGE			0.0403	0.9114
Status×EDU			−0.0991	0.7129
Status×GEN			0.1366	0.5576
Status×INC			0.1301	0.4867
Status×AGE			0.2694	0.3436

	Research model 3		*Research model 4*	
	Path	*P*	*Path*	*P*
FAFI×EDU			0.2727	0.4253
FAFI×GEN			0.1198	0.7124
FAFI×INC			−0.1238	0.6470
FAFI×AGE			−0.2585	0.3429
SSI×EDU			−0.0154	0.9616
SSI×GEN			−0.2044	0.5077
SSI×INC			0.0603	0.8272
SSI×AGE			0.0679	0.7926
FOTA×EDU			−0.0816	0.6982
FOTA×GEN			0.1207	0.5355
FOTA×INC			0.0060	0.9723
FOTA×AGE			−0.0886	0.6982
DC×EDU			−0.3168	0.4087
DC×GEN			0.1707	0.5853
DC×INC			0.0472	0.8493
DC×AGE			0.1087	0.7156
COST×EDU			−0.0342	0.8327
COST×GEN			0.0317	0.8309
COST×INC			−0.0890	0.4267
COST×AGE			0.0122	0.9445
PEOU×EDU			0.2501	0.4996
PEOU×GEN			0.2838	0.3666
PEOU×INC			0.3008	0.4012
PEOU×AGE			−0.0355	0.9196
SE×EDU			−0.0180	0.9616
SE×GEN			−0.5211	0.2609
SE×INC			−0.1576	0.6470
SE×AGE			0.0729	0.8424

Italic paths are significant on a $P<0.1$ level.

MATH model yields an adjusted R^2 of 0.7443. The inclusion of our socio-demographic moderating variables results in an explanation of almost 85% of the variance in the data (adjusted $R^2=0.8434$; see Table 11). To analyse whether the increase of R^2 was significant, we conducted a further model comparison. Hence, we computed an F-statistic and compared it with the corresponding critical values following the work of Chin (2010). Both increases of R^2 (UTAUT models: 0.7277 to 0.7770, MATH models: from 0.7632 to 0.8592) were significant. Hence, we conclude that the inclusion of the socio-demographic moderating variables is valuable.

Discussion

Discussion of the findings

In light of our findings, we can address our three research questions:

Which alternative theory most effectively explains Internet adoption by the elderly? (RQ2) Both UTAUT and MATH account for >70% of the variance of BI even without the inclusion of moderating effects (UTAUT, Model 1: adjusted $R^2=0.7221$, MATH, Model 3: adjusted $R^2=0.7443$). On the one hand, MATH (Model 3) leads to a slightly better coefficient of determination, consisting of as many as 11 independent variables (33 items required for independent variable measurement). However, UTAUT, on the other hand, requires only three independent variables (measured by 12 items). Against this background, we can conclude that the two theories are both able to explain Internet adoption by the elderly. However, MATH has slightly superior explanatory power (adjusted R^2) and UTAUT has greater feasibility (lower number of items). Future research will be needed to evaluate and test this finding, with respect to the extent to which other areas of IT adoption among the elderly confirm this marginal difference in determination.

Can an extension of these two technology acceptance theories by a set of socio-demographic variables provide a better explanation of Internet adoption by the elderly?

(RQ3) On the one hand, an extension in terms of the four socio-demographic variables of gender, income, education, and age is clearly able to increase the adjusted coefficient of determination for both UTAUT (adjusted R^2, 0.7221 without moderating effects to 0.7660 with moderating effects) and MATH (adjusted R^2, 0.7443 to 0.8434). Accounting for the fact that the four socio-demographic constructs are measured with one item each, we argue that the socio-demographic perspective is both valuable (significantly increased explanatory power) and feasible (only few more additional items to measure) as an extension of both UTAUT and MATH for explaining Internet adoption by the elderly. On the other hand, a significant extension of the theoretical model and the model paths (hypotheses) results habitually in a decrease of the number of significant individual paths (Venkatesh *et al*, 2003; Brown & Venkatesh, 2005). Still, research model 2 (extended UTAUT) reveals interesting insights. EDU exerts not only a moderating, but also a direct positive effect on Internet adoption (0.1479, $P<0.1$ significance level). Apparently, people with higher education are more likely to have the intention to use the Internet. In addition, AGE has a negative direct effect on Internet adoption. Bearing in mind that we already studied the population 65+, we can observe that older seniors adopt the Internet significantly less often than younger seniors. In turn, that means that 'the elderly' cannot be considered a fully homogeneous group with regard to Internet adoption. This becomes even clearer when looking at the significant AGE-moderated effect of PE (PE×AGE, 0.5320, $P<0.1$ significance level). Especially for the more senior elderly (higher in AGE), it is most crucial that these individuals realise how using this technology will help him or her improve personal performance (PE).

With regard to Research Question 1 (How well does technology acceptance theory explain Internet adoption by the elderly?), we can conclude that technology acceptance theories, here UTAUT and MATH, are able to very effectively explain Internet adoption by the elderly. The additional inclusion of (four) socio-demographic variables can further increase the models' power to determine whether elderly people (65 and older) ultimately adopt the Internet and to what extent.

Contribution to theory

Our findings can inform and stimulate digital divide research, especially research concerned with age-related aspects. By closing the research gap as identified by Porter & Donthu (2006), we contribute constructs to digital divide research that represent traits and beliefs and that exert a significant influence on IT adoption. We complement, for instance, Agerwal *et al*'s IS-oriented digital divide study (2009) that refers mainly to socio-demographic variables (e.g. gender, income, household situation, and housing data). In addition, by examining UTAUT and MATH, two well-tested and established sets of constructs can now be applied to the digital divide via their corresponding quantitative instruments. Accordingly, our research enriches the existing studies of the digital divide (see, for instance, DiMaggio & Hargittai, 2001; van Dijk, 2006) that refer to different types of access, such as material, skill, and motivational access without providing solid empirical measurement instruments.

With regard to the age-related digital divide specifically, we examined the influence of four socio-demographic variables within the group of the elderly (65+). Thus, our study not only views age as one of many socio-demographic variables (along with gender, income, and education; see also van Dijk, 2006), it focuses on elderly people to address the broader challenges of a technologised information society on the one hand and an increasingly ageing population on the other hand. Interestingly, we still find an effect of age within the group of the elderly. In the extended UTAUT model (research model 2), age has a direct impact (negative effect on BI) as well as a significant moderating impact on the relationship between PE and BI. Apparently, the expected performance of the Internet (and IT in general) has a greater influence on the intention to use this technology for older elderly than for younger elderly individuals.

While our study focuses on the Internet, the results can, at least to a certain extent, be generalised to apply to IT as a whole. The Internet is an important case of IT and can be seen as a basic technology that has to be mastered prior to using other IT-based service offerings. Many of these services, for example, from the e-commerce or e-government perspective, are offered over the Internet. Hence, our results will form a baseline for their adoption. Moreover, other technology innovations (e.g., smartphones) have similar properties to the Internet. They foster communication and service consumption while having a user interface that is only to a certain extent similar to prior technologies. Thus, we argue that researchers can build on this study when examining adoption of other technologies by the elderly.

Based on our study's theoretical development and testing efforts, we can now argue that technology acceptance theories, together with socio-demographic aspects already familiar within digital divide research, can form a more powerful (high degree of determination), technology-independent (UTAUT and MATH constructs applied in numerous IT adoption areas) and well-tested (see literature review, section 'Theoretical background') instrument for understanding and explaining the age-related digital divide. We argue further that our technology acceptance approach also has the potential to contribute to other specific digital divide studies such as studies of low-income groups, the unemployed, and those in rural areas. Future research will be able to contrast these digital divide issues with our elderly specific study findings.

Our findings also advance technology acceptance research in IS. With respect to UTAUT specifically, we have added socio-demographic variables that moderate the direct effects of PE, EE, and SI on BI to use technology (here: the Internet). We not only studied gender and age but also investigated income and education. Against this background, our research complements and enhances prior UTAUT studies that focus on the moderating effects of gender and age only (for instance, Venkatesh *et al*, 2003; Yao & Murphy, 2007; Brown *et al*, 2010). We encourage future UTAUT research to revisit and study the significance of broader sets of socio-demographic variables.

With regard to research involving MATH specifically, we seek to complement recent studies on the influence of the household situation. Brown & Venkatesh (2005) enrich their original MATH approach (Venkatesh & Brown, 2001) by incorporating the household life cycle model. In addition to age, their new model examines the moderating effects of marital status, children's age and income and was able to significantly increase explanatory power ($R^2=0.50$ without moderating effects, to $R^2=0.74$ when accounting for the household life cycle). In our study, we were able to raise the coefficient of determination from 0.7443 to as much as 0.8434 (both adjusted R^2s) by including the four socio-demographic variables of income, gender, education, and age. Future research may compare the two (alternative and potentially complementary) sets of moderating variables and theoretical perspectives (household life cycle *vs* digital divide).

For the study of both UTAUT and MATH, we have contributed another specific field of application, that of Internet adoption by the elderly. Our study demonstrates an additional and important area in which these two theories can make a valuable contribution. In addition, we can enrich technology acceptance research in IS through an integrated and comparative study of the explanatory power of the two alternative theories. We found the adjusted R^2s to be slightly greater when applying MATH (both the core and extended models; research models 3 and 4), which does, however, come at the cost of a larger set of items to be measured (core MATH requires 19 items more than core UTAUT). While this comparative perspective on UTAUT and MATH is still under-represented in IS technology acceptance research, we believe that there is additional potential for future research to develop an integrated theory of the digital divide. Such work might follow a similar path to that of Venkatesh *et al* (2003), in building UTAUT based on other competing acceptance theories.

Finally, we challenge technology acceptance research, especially MATH, by reporting that the explanatory power of our MATH application in the area of IT adoption by the elderly is greater than in the original study and field of application (BI to buy a PC, full age spectrum). We interpret this as elderly people possibly acting more consistently than younger people in their IT adoption decision and/or that the variables of MATH are better able to capture the beliefs and perceptions (relevant to IT adoption) of elderly people than those of younger people. Future research wishing to consider this argument will need to comparatively examine the validity and explanatory power of MATH among different age groups.

Implications for practitioners

Our study has practical implications. Taking Europe as an example, the declaration of Riga by the Council of Ministers of the EU has made e-Inclusion a priority on the political agenda. E-Inclusion is regarded as being able to improve economic performance, employment opportunities, quality of life, social participation, and cohesion (European Union, 2006, p. 1). In this context, national and local governments (e.g., the two neighbouring cities in which we conducted our data analysis) are undertaking massive efforts to accelerate Internet adoption among the population (see Niehaves *et al*, 2010 and examples below). In this respect, studies like ours have the potential to contribute to e-Inclusion strategy-making in practice.

MATH has the advantage of being relatively differentiated (11 independent belief variables). In our study setting it was important for elderly people that the Internet offers applications for fun (AFF, path coefficient of 0.2370), that it bears utility for children (UFC, 0.0760) and that friends and family support them in their adoption decision (FAFI, 0.1409). We can observe a strong impact of the extent to which elderly people have faith in their own skills and capabilities (SE, 0.4807) and of how easily the Internet is perceived to be used (PEOU, 0.1192). In addition, Internet costs impact adoption (COST, 0.0848) negatively. However, when looking at the significant relationships (six in research model 3), the effects appear to be scattered across all different aspects of the problem, making it difficult to develop a feasible and targeted e-Inclusion strategy. All the same, the three independent variables of UTAUT (PE, EE, SI) are more condensed and all have been established as being significant in our study. In this regard, PE exerts the greatest influence on the Internet adoption decision (path coefficient of 0.4172), even more so than EE (0.3818) and SI (0.1804).

We derive several practical implications from this scenario. Firstly, while being actually under-represented in practice, governments and other bodies engaged in e-Inclusion should launch initiatives aimed at increasing a general understanding among the elderly of the nature of the Internet and the potential benefits it offers for their lives in practice. While governments have made efforts to market the take-up of public e-services (see for instance Mellor (2006) on U.K. national marketing campaigns for local authority e-channels), marketing of and spreading information regarding the Internet in general can be a potentially very effective measure for increasing the adoption by the elderly. Here, the project named 'Say IT on the radio' by Dundalk.fm, Ireland, which features elderly people sharing their positive experiences on the Internet with other senior listeners, could pose as an example. Secondly, we note that initiatives aiming at building Internet skill (see for instance DiMaggio & Hargittai, 2001 or Niehaves *et al*, 2010), addressing the issue of EE, can also exert impact. Thirdly, the project 'Keep IT in the family' by Digital Birmingham, U.K., demonstrates how e-Inclusion initiatives may target and utilise the consistently important element of SI: In this project, comics are handed out to children of school-age that are intended to help and motivate them to tell their parents and grandparents how to use the Internet. Overall, we argue that e-Inclusion strategies should embody a wider spectrum and a portfolio of initiatives with distinct goals (PE, EE, SI). In many cases, this means going beyond measures that aim merely at educating seniors technically about the Internet (e.g., classroom instruction and focusing on EE) and instead informing them about Internet potentialities (PE), possibly by involving friends, family and other peers (SI). Future research and consulting could usefully test these findings in other settings or at a later point in time, and there is great potential for a longitudinal study on this topic. If researchers are mainly interested in practical applications, we recommend using the UTAUT models (research models 1 and 2) for reasons of intelligibility and feasibility, as indicated above. We expect our findings to be replicable, especially in other Western societies and look forward to contrasting insights from other settings.

Summary and outlook

Demographic ageing is an important trend, especially in Western societies. It has implications for public and private organisations as the growing group of elderly has different attitudes, beliefs, and intentions when it comes to technology usage. In general, we can observe that the elderly are more reluctant to use information technologies. Exemplarily, the Internet is significantly less adopted by the elderly than by other age groups. In this paper we set out to understand Internet adoption by the elderly. We investigate alternative theories (MATH and UTAUT) and study in how far socio-demographic variables improve the explanatory power of the theories. Our results show that UTAUT and MATH are able to explain more than 70% of the variance in Internet adoption intention. An extension with the socio-demographic variables education, gender, income, and age leads to a significant increase of the coefficients of determination. Our findings have several contributions to theory. We close the research gap identified by Porter & Donthu (2006) and contribute constructs to digital divide research that represent traits and beliefs. We also argue that 'the elderly' are no homogenous group as age still has a significant moderating effect in this group. Moreover, our study also underlines the importance of socio-demographic variables for technology acceptance research. Furthermore, our study enriches the knowledge in the area of technology acceptance research through comparing two different baseline theories with MATH explaining slightly more variance than UTAUT. To further inform future research, we propose the following directions and approaches.

Comparative research Future research should be conducted in other geographical settings, possibly beyond Western society. We would consider comparative research on whether and how these theoretical models play out differently in distinct cultural settings a very important perspective (see also Chen & Chan, 2011). Here, it would be worthwhile investigating in how far countries with high overall rates of Internet adoption, such as the studied case of Germany, are different from settings with a low degree of Internet adoption (for instance, Bulgaria or Greece; see again Table 1).

Constructs All constructs are valid, confirming the theoretical foundation. However, the original UTAUT construct of SI and the MATH construct of FOTA have only moderately high ICR. Further theory development could attempt to discover items that fit better.

Sample size Owing to the high number of moderating variables, models 2 and 4 have several insignificant paths. Aguinis (1995) names two strategies to overcome this limitation. Firstly, the sample size could be increased, and secondly, statistical corrections could be implemented. While the first strategy was not possible due to practical considerations in the data collection phase, the second comes with several potential errors (Aguinis, 1995) and was not suitable for our analyses. Against this background, we would expect that future replications of this study with greater sample sizes will be able to address this issue and to identify a greater number of significant paths even in very large models.

E-Inclusion IS technology acceptance research has extensively studied variables that impact BI. However, we found very few studies that demonstrate how to effectively increase PE, EE, or SI. This applies especially to the specific area of Internet adoption, where we were unable to find any systematic study of how to stimulate these important independent variables. Systematic and empirical studies of the effects of e-Inclusion measures of certain qualities on PE, EE, and SI constitute a potentially fruitful path for future interdisciplinary research.

Socio-demographic variables and social context With our study we are able to contribute a first integrated quantitative study of the impact of AGE, GENDER, INCOME, and ECUCATION on technology acceptance and Internet adoption specifically. However, including additional socio-demographic variables, such as ETHNICITY (see for instance Agerwal *et al*, 2009, other terminology includes 'migration background', 'race' or 'nationality') that provide additional explanatory power would be interesting. As for our study, we in fact collected relevant data, but were not able to include this factor due to the low ethnic diversity in the region studied. More generally, Agerwal *et al* (2009) as well as Sarker & Valacich (2010) show that groups play a major role in Internet technology adoption. It is about relevant peers and this will hold true for Internet adoption of elderly as well. While we have addressed this issue by several constructs (including SI (UTAUT) or friends and family influence (MATH)) we consider it an important path to explore and theorise on the social context to individual technology adoption.

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Appendix

Table A1 Constructs and items used in the study

Core construct	*Items*
Behavioural Intention (BI)	BI1: I intend to use the system in the next 3 months. BI2: I predict I would use the system in the next 3 months. BI3: I plan to use the system in the next 3 months.
Performance Expectancy (PE)	PE1: I find the Internet useful. PE2: Using the Internet enables me to accomplish tasks more quickly. PE3: Using the Internet increases my productivity. PE4: If I use the Internet, I will increase my chances of getting a raise.
Effort Expectancy (EE)	EE1: My interaction with the Internet would be clear and understandable. EE2: It would be easy for me to become skilful at using the Internet. EE3: I would find the Internet easy to use. EE4: Learning to operate the Internet is easy for me.
Social Influence (SI)	SI1: People who influence my behaviour think that I should use the Internet. SI2: People who are important to me think that I should use the Internet. SI3:[a] I use the Internet because of the proportion of peers who use the Internet. SI4: In general, my peers have supported the use of the Internet.
Applications for Personal Use (AFPU)	AFPU1: I find that the Internet has tools for personal productivity. AFPU2: I find that the Internet has tools to support household activities. AFPU3: The Internet has software that helps with activities in the house.
Utility for Children (UFC)	UFC1: The Internet provides applications that my kid(s) can use. UFC2: The Internet has useful software for my child (or children). UFC3: I find the Internet to be a useful tool for my child (or children).
Applications for Fun (AFF)	AFF1: The Internet provides many applications that are enjoyable. AFF2: I enjoy the Internet. AFF3: My Internet has applications that are fun. AFF4: I am able to have fun in the Internet.
Status Gains (Status)	Status1: People who use the Internet at home have more prestige than those who do not. Status2: People who use the Internet at home have a high profile. Status3: Using the Internet is a status symbol.

Table A1: (*Continued*)

Core construct	*Items*
Friends and Family Influences (FAFI)	FAFI1: My friends think I should use the Internet at home. FAFI2: Those in my social circle think I should use the Internet at home. FAFI3: My family members think I should use the Internet at home. FAFI4: My relatives think I should use the Internet at home.
Secondary Sources' Influences (SSI)	SSI1: Information from newspapers suggests that I should use the Internet at home. SSI2: Information that I gather by watching TV encourages me to use the Internet at home. SSI3: Based on what I have heard on the radio, I am encouraged to use the Internet at home.
Fear of Technological Advances (FOTA)	FOTA1: The trends in technological advancement are worrisome to me. FOTA2: I fear that today's fastest Internet connection will be obsolete fairly soon. FOTA3: I am worried about the rapid advances in information technology.
Declining Cost (DC)	DC1: The costs of Internet usage are constantly declining. DC2: I believe the cost of Internet usage will continue to decline in the future. DC3: I think the Internet will offer more for lower prices in the near future.
Cost (COST)	COST1: Nowadays, the Internet is too expensive. COST2: I think using the Internet is expensive. COST3: It is not cheap to use the Internet.
Perceived Ease of Use (PEOU)	PEOU1: My interaction with the Internet would be clear and understandable. PEOU2: I would find the Internet easy to use. PEOU3: Using the Internet does not require a lot of mental effort. PEOU4: I find it easy to do what I want in the Internet.
Self-Efficacy (SE)	SE1: I feel comfortable using the Internet on my own. SE2: If I wanted to, I could easily operate the Internet on my own. SE3: I can use the Internet even if no one is around to help me.

[a]Item SI3 from original UTAUT (=influence of senior management) did not fit the purpose of our study. Hence, we included an item with an evenly high loading (see Thompson *et al*, 1991; Venkatesh *et al*, 2003, p 459).