Older Adults' Preferences towards Using Digital Technologies: Usage Patterns, Facilitators and Barriers for Long-term Use, Potential for Gerontological Research

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List of Abbreviations

- ICT: Information and communication technologies
- IDT: Innovation Diffusion Theory
- IT: Information technology
- mHealth: mobile Health
- PEOU: Perceived ease of use
- PU: Perceived usefulness
- SOC: Selective Optimization with Compensation
- SST: Socioemotional Selectivity Theory
- TAM: Technology Acceptance Model
- TRA: Theory of Reasoned Action

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Abstract

Over the last years, internet-adoption rates have risen in older age groups, with older people starting to use the internet and smartphone technology in more nuanced ways. Still, little is known about how older people interact with new digital technology in their everyday lives. This dissertation contributes to a better understanding of these topics. The overall research question deals with older adults' preferences towards using digital technologies.

The first part of the work presents the theoretical background. The life course perspective provides a conceptual framework. Different theories explaining technology adoption and their empirical evidence for people in old are summarised. This synthesis gives an overview on how the topic is discussed within different scientific disciplines. Two relevant fields of application, digital health and the use of digital technology in gerontological research, are addressed in more detail.

In own studies, three specific research foci were examined: (1) usage patterns, (2) facilitators and barriers for long-term use, and (3) the potential of digital technologies for gerontological research. These aspects have been addressed in five publications that are the basis of this dissertation. A cross-sectional survey in individuals aged 50 and older showed that 29.0% do not use any mobile device in their everyday life and 20.5% use mobile devices for physical activity tracking. Gender, age, and interest in technology were associated with technology use. In a qualitative study, facilitators and barriers of long-term use were identified for a specific digital technology, an activity tracker. Facilitators included awareness of achievements and a reminder function of the device. Lacking customisation, declining interest, and difficult manageability impeded long-term use. In a conceptual evaluation, the advantages and disadvantages of using digital technologies in surveys in the older population were addressed.

These findings are discussed at a general level in the last part of the dissertation. Following the appraisal of the main findings in the general research context and a methodological discussion, the integration of technology and gerontological theory is made a subject of discussion. Recommendations for future research are suggested.

1 General Introduction

Modern digital technologies, such as internet-connected devices and web-based applications have become an integral part of everyday life for many people. In 2015, 43% of the German population described the internet as a daily contact for a wide range of questions and topics (Frees & Koch, 2015). In 2016, 85% stated that they use the internet every day or almost every day (Statistisches Bundesamt, 2016). In line with this development, smartphones are currently the device most used to go online (Koch & Frees, 2016).

For individuals younger than 64 years of age, the internet has become basic technology, since more than 90% use the internet in this group (Statistisches Bundesamt, 2016). Over the last few years, internet-adoption rates have also risen in older age groups, with older people starting to use the internet and smartphone technology in more nuanced ways (Frees & Koch, 2015; Misoch, Doh, & Wahl, 2014). In Germany, 55% of people 65 years and older use the internet and about every third person (37%) in this age group uses mobile internet (Statistisches Bundesamt, 2016). Once they begin using the internet, 67% of adults aged 65 and older report that they go online every day or almost every day (Statistisches Bundesamt, 2016).

Emerging technologies provide new scopes for action and life chances to individuals (Krotz, 2001). Today, the most commonly used digital applications are search engines (such as Google), used to search for various content and information online (Initiative D21, 2016). Digital services for exchanging information with others (such as WhatsApp) are used by more than half of the German population aged 14 years and older (Initiative D21, 2016). Still, a substantial number of people in older age groups do not use the internet and other digital technologies (Seifert & Schelling, 2015; 2016). Considerable differences can be observed within the group of older people: individuals, who are male, younger, better educated, and more affluent use the internet at higher rates compared to older, less educated and poorer people (Seifert & Schelling, 2015; van Deursen & Helsper, 2015). Consequently, some individuals are excluded from the advances of digital transformation and the potential that

modern technologies offer for social participation and self-determined lifestyles in old age (Claßen, Oswald, Doh, Kleinemas, & Wahl, 2014).

These age-related differences in access to modern technologies are also referred to as a first-level divide. A second-level divide implies that young and old individuals differ in the ways they use modern technologies and in their digital skills (van Deursen & van Dijk, 2011). There is some evidence that younger and older people differ in relation to all relevant dimensions of the digitisation level, including access, use, competence, and openness (Initiative D21, 2016). Physical challenges, sceptical attitudes about the benefits, and perceived difficulties in operational learning are further potential barriers older adults face when adopting new technologies (Pew Research Center, 2014). A German study found that age and other socio-demographic variables were determinants for the first-level divide, but not for the second-level divide. This was more dependent on personal interests and attitudes towards new technologies (Coneus & Schleife, 2010).

Older people often use modern technology more functionally and in a less explorative manner when compared to younger people (Misoch et al., 2014). Joyce and Loe (2010) characterise older adults by their creative use of technological innovations and describe them as *Technogenarians*, "individuals who create, use, and adapt technologies to negotiate health and illness in daily life" (Joyce & Loe, 2010, p. 1). According to this understanding, older people are not considered as passive consumers of new technologies, since they adapt them to their personal needs and goals. The authors furthermore argue that technology can be part of a toolkit that older adults compile and use to support their health and social connectedness (Joyce & Loe, 2010). Technology can therefore support the older individual and even compensate for health conditions and bodily changes across the lifespan.

Advances in digital technologies have led to an increase in mobile and wearable digital technologies that users can integrate into their everyday life. Individuals using mobile technology, like smartphones, interact with these devices continuously throughout the day. A recent and relevant development is the use of digital devices and applications to monitor

behaviour, independently and individually, in various contexts (Dobkin, 2013; Dobkin & Dorsch, 2011; Fox & Duggan, 2013; Hayles, 2012; Shull, Jirattigalachote, Hunt, Cutkosky, & Delp, 2014). A growing number of people are using digital technologies to manage chronic health conditions, to track their physical activity or to collect a range of other behavioural, medical or wellness related information (Musselwhite, Freeman, & Marston, 2017; Morgan, 2016). This development has been subsumed under the term *digital health*, which includes "mobile health (mHealth), health information technology (IT), wearable devices, telehealth and telemedicine, and personalized medicine" (U.S. Food & Drug Administration, 2017). One specific aspect of digital health is the use of wearable devices to collect data on one's own everyday activities like the number of steps and distance walked, which is known as *self-tracking* (Swan, 2012; Hingle & Patrick, 2016). Many self-tracking applications run on smartphones, or on external devices coupled with a smartphone (such as activity trackers or smartwatches). While there are always more, new digital applications and devices for digital health available, research in this field is still in its infancy and scientific evaluations are relatively scarce (Musselwhite et al., 2017). Usage patterns of these technologies have not been analysed with representative studies in the older population and the facilitators and barriers of using digital health in the long-term need further investigation.

Another relevant field of application of new digital technology might be in survey research. Technological advances allow for new forms of surveys, with the way surveys are administered expected to change in the future (Papastefanou, 2009). Traditional forms of surveys face difficulties on different levels especially when they involve older people. These might include aspects of accessibility, willingness to participate, and communication. Recruitment of older people for empirical studies is generally more difficult and more time consuming when compared to younger people (Davies et al., 2010; McHenry et al., 2015; Ridda, MacIntyre, Lindley, & Tan, 2010). A lower level of willingness to participate in survey studies has been shown for older people (Konradt & Fary, 2006; Saßenroth, 2012). Furthermore, visual and hearing impairments in older age might affect the communication

between the interviewer and participant, which might also have a negative impact on data quality (Knäuper, Schwarz, & Park, 2002). In old age, sequencing of *questions* has less impact on response behaviour while sequencing of *response categories* shows a stronger impact. This has been explained regarding the reduced capability of the working memory in individuals of an advanced age (Schwarz & Knäuper, 2004). Therefore, young and old people might be differently affected by sequencing. Considering this background, researchers face the challenge of managing these age-related effects on response behaviour and must untangle the *real* age-related differences from differences caused by survey methodology. Using digital technology in empirical research allows for the application of innovative study designs, adapted to the individual participant. In this way, physical and cognitive preconditions can be more easily considered. The integration of modern digital technology into gerontological research has not yet been examined systematically. Potentials and barriers to use need to be discussed.

This dissertation will contribute to a better understanding of these topics by examining three specific research foci, all related to older adults' preferences towards using digital technologies. First, the **usage patterns** of mobile digital technologies in general, and for self-tracking purposes, are described. Second, **facilitators and barriers to long-term use** are examined for a specific digital technology, an activity tracker. The third focus is on the **potential** of digital technologies **for gerontological research**.

The first part of the work presents the theoretical background. Theories on technology adoption from different scientific disciplines and their relation to aging and age are summarised. The *life course perspective* provides a conceptual framework for analysing developments across the lifespan and is applied to older adults' technology adoption. The *Technology Acceptance Model, Innovation Diffusion Theory,* and the concept of *technology generations* are presented as different approaches from sociology and social psychology. These theories aim at explaining the adoption and use of new technologies, but reflect on the topic with different emphases. The synthesis of perspectives provides an overview on how

the topic is discussed within different scientific disciplines. Following this, empirical evidence focusing on age will be summarised. The promoting and inhibiting factors of use will be outlined for digital health technologies and the potentials of digital technologies for use in gerontological research will be presented in more detail. At the end of the chapter, the aims and research questions of this dissertation will be summarised.

1.1 Technology Adoption from a Life Course Perspective

Analysing the adoption of new technologies and its relation to age can be embedded in the life course perspective, which examines developments over the lifespan. The life course perspective is not a uniform theory but rather a collection of different perspectives, all concerned with life course developments (Marshall & Bengtson, 2011). The life course framework is concerned with studying "the interaction of historic events, individual decisions and opportunities, and the effect of early life experiences in determining later life outcomes" (Quadagno, 2011, p. 28). It is assumed that an individual's life course is partly shaped by decisions made early in life (decisions on education, marriage, employment) and partly shaped by events that are beyond an individual's control, such as wars or periods of economic growth (Quadagno, 2011).

In studying life courses, one needs to distinguish *period effects*, *age effects*, and *cohort effects*. *Period effects* are defined as specific historical events that have an impact on all people in society independent of their individual age. This might be the intergenerational experience of war or economic growth. *Age effects* are changes within an individual over the lifespan and are caused by psychological and developmental changes. These changes are independent of specific historic events or places (such as bodily and cognitive changes in old age). Finally, a *cohort effect* describes aggregate opinions or attitudes of people that experienced a certain life event at the same point in time. Most often, cohorts are built based on the year of birth, assuming that people born at a specific period share certain opinions and values which differ from the previous and following cohorts. The succession of cohorts is one of the main mechanisms causing social change on the societal level (Yang, 2011).

All three effects can be present when differences between people of different ages are observed. Although the effects can be distinguished conceptually, it is difficult to distinguish them in empirical research. They cannot be quantified simultaneously, as the effects are in a linear combination, shown by the simple equation: *Age* = *Period* – *Cohort* (Huinink & Schröder, 2014). When relying on cross-sectional data, cohort effects are easily and often misunderstood as age effects, because people who belong to different cohorts are mixed and compared at a single point in time. It is the advantage of longitudinal research that specific cohorts are followed over longer periods, which allows for the analysis of whether certain characteristics or attitudes change throughout an individual's life course, or whether they remain stable over the lifespan and differ between the cohorts (Quadagno, 2011). Research on technology adoption has provided (preliminary) arguments for both age effects as well as cohort effects.

1.1.1 Age effects on technology adoption.

Higher chronological age is often associated with changes in bodily and cognitive function, sensory perception, and learning pace (Wahl & Heyl, 2015). Research in the field of *gerontechnology* is concerned with the relevance of these age effects for the use of technology. It is one of the central aims of gerontechnology to study the impacts of technology on older adults' daily life (van Bronswijk, Bouma, & Fozard, 2002) and to understand the relevance of technology throughout an individual's life span (Plaza, Martín, Martin, & Medrano, 2011). Fozard and Wahl (2012) identify four groups of age effects that are of special interest for gerontechnological research: "(i) sensory and motor functioning; (ii) cognitive performance; (iii) personality and self; and (iv) motivation and emotion" (Fozard & Wahl, 2012, p. 14).

An early study on technology use in older adults found that age-related changes in cognition and sensory perception could lead to lower adoption rates of new technological devices in old age (Holzinger, Searle, & Nischelwitzer, 2007). Cognitive functioning was also identified as a factor that has an impact on older adults' attitudes towards new technologies

(Czaja et al., 2006). Wang, Rau, and Salvendy (2011) described physical and cognitive impairments as relevant age effects for technology use. According to their work, older people lose trust and self-confidence due to changes across the lifespan, and have more difficulties in learning new information (Wang et al., 2011). A study on the use of smart mobile devices (such as smartphones, tablets) in older adults with late-life vision impairments showed that reduced visual functioning was one of the major barriers to use of this technology (Piper, Brewer, & Cornejo, 2017). There is also evidence for benefit-driven processes in the adoption of new technologies in old age; benefits were more important than costs for the decision to use communication technologies, like e-mailing (Melenhorst, Rogers, & Bouwhuis, 2006). According to the authors, this finding is opposed to the assumption that barriers determine adoption of new technologies in older people. In many cases, the joint effect of age and an individual's experiences are observed. Problems in handling modern digital technologies are to some extent caused by age effects, like vision impairments and reduced dexterity, but to some extent caused by a lack of trust and limited experience in use (Barnard, Bradley, Hodgson, & Lloyd, 2013).

1.1.2 Cohort effects on technology adoption.

Other research has been more focused on the relevance of cohort effects on technology adoption. Since every cohort is shaped by specific historic and cultural experiences, these approaches assume that this also holds true for their experiences with new technologies. It has been hypothesised that cohort affiliation affects possession, usage of, and attitudes towards new technologies (Prensky, 2009).

LeRouge, van Slyke, Seale, and Wright (2014) examine the adoption of consumer health technologies in Baby Boomers (born 1946-1964; aged 46-64 years) compared to younger and older individuals. They examined what consumer health technologies Baby Boomers are ready to use, their knowledge- and motivation-based barriers to use, and whether readiness and barriers differ from younger and older consumers. Readiness to use ranged from 82.7% for using a standard telephone, to 22.3% for wikis. The oldest group

indicated the lowest readiness scores. Significant differences between the groups were found for 31 of 154 barriers, whereby 21 were significantly different between the Baby Boomers and the older group. Baby Boomers were not always more favourable toward the technologies than the older individuals. All things considered, motivation-based barriers were more important than knowledge-based barriers. The top motivation-based barrier was enjoyment and the top knowledge-based barrier was "don't know how to use" (LeRouge et al., 2014). The results indicate a cohort effect, but should be interpreted with caution. Analyses were based on cross-sectional data, which does not allow for a distinction between cohort effects and age effects.

It is reasonable to assume that both age effects and cohort effects are relevant for technology adoption. However, current research in this field does not always distinguish between age effects and cohort effects, nor allow for their interplay (Fozard & Wahl, 2012). In addition to the methodological issues in distinguishing age effects from cohort effects, one of the most relevant problems is related to the fact that questions on technology use are sparse within current longitudinal panel-data like the German Aging Survey (DEAS) or the Survey of Health, Ageing and Retirement in Europe (SHARE). This limits the possibilities for analysis of age-related technology adoption and for untangling age effects from cohort effects (Sackmann & Winkler, 2013). Therefore, no such data is analysed in this dissertation and the analyses are based on data that have been collected for this research.

1.2 Theories Explaining the Adoption of New Technologies in Old Age

1.2.1 Technology Acceptance Model.

Studying adoption processes of new technologies has a long tradition in information systems research (Venkatesh, Davis, & Morris, 2007). Originally developed to explain technology acceptance in professional work contexts, one of the most important models in this field is the *Technology Acceptance Model* (TAM) introduced by Davis, Bagozzi, and Warshaw in 1989. The model is based on the *Theory of Reasoned Action* (TRA) (Fishbein &

Ajzen, 1975), which aims to explain human behaviour in general. It is the central assumption in TRA that a specific behaviour is driven by the behavioural intention to perform this behaviour. Intentions, in turn, are affected by attitudes and subjective norms, defined as a "[...] person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein & Ajzen, 1975, p. 302). This explanation of behaviour is applied to the context of information technology use in TAM. Like in TRA, TAM poses that behavioural intention is the best predictor for actual behaviour. According to the model, the two most important factors to explain technology acceptance are the perceived ease of use (PEOU) and the perceived usefulness (PU) of a specific technology. PEOU is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320) and PU is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). Both, PEOU and PU, are expected to determine attitudes towards using a technology which then, following the reasoning of TRA, lead to the behavioural intention to use. Furthermore, PU is expected to affect behavioural intention (Davis, Bagozzi, & Warshaw, 1989). The conceptual structure of TAM is illustrated in Figure 1.

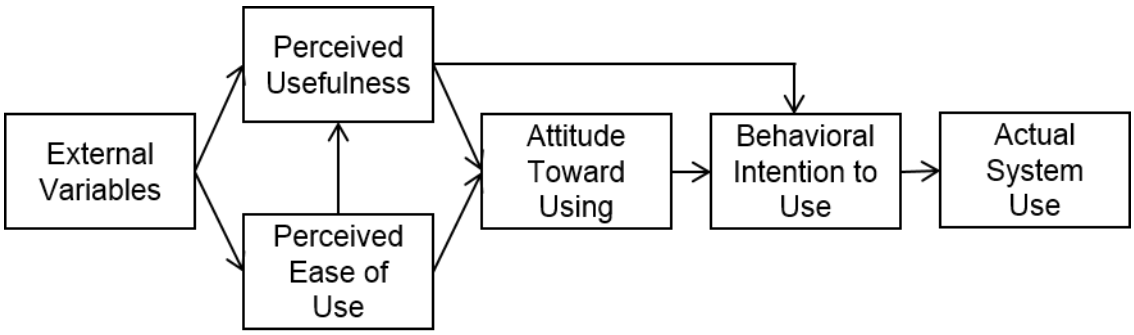

Figure 1. Technology Acceptance Model (TAM).

Adapted from "User acceptance of computer technology: A comparison of two theoretical models," by F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, 1989, *Management Science, 35*(8), p. 985.

TAM has become the most widespread and widely used model to examine technology adoption (King & He, 2006) and the model has been refined in different ways.

Several empirical studies added further influencing factors to the basic TAM constructs, like enjoyment, cost, image (Revels, Tojib, & Tsarenko, 2010), or affect (Karaiskos, Drossos, Tsiaousis, Giaglis, & Fouskas, 2012). Conceptual revisions of TAM resulted in TAM 2 (Venkatesh & Davis, 2000) and TAM 3 (Venkatesh & Bala, 2008). The *Unified Theory of Acceptance and Use of Technology* (Venkatesh, Morris, Davis, & Davis, 2003) was developed based on a review of TAM and seven other technology acceptance models and aims to explain technology use intentions. Several acceptance models focusing on older adults, including two forms of a *Senior Technology Acceptance Model* (Chen & Chan, 2014; Renaud & van Biljon, 2008), have also been proposed. Despite the many changes and adaptations, the basic structure and central assumptions of technology adoption, including attitudinal factors and use intention, remain the same in all these models.

The TAM framework allows for the examination of the possible determinants of adoption in more detail. Many empirical studies and reviews examine TAM in different contexts, like mobile services (Karaiskos et al., 2012; Revels et al., 2010), e-commerce (Bruner & Kumar, 2005), Web 2.0 (Corrocher, 2011), or in healthcare (Ward, 2013). In the healthcare sector, TAM is also applied for the study of technology acceptance of specific groups, including physicians (Dünnebeil, Sunyaev, Blohm, Leimeister, & Krcmar, 2012), care professionals (Asua, Orruño, Reviriego, & Gagnon, 2012; Saborowski & Kollak, 2015), and groups of patients (Seto et al., 2010).

The model has also been applied to study older adults' technology acceptance. A review by Chen and Chan (2011) on the use of TAM in older adults showed that age-related variables are important preconditions for TAM-constructs. These include chronological and psychological age, individual resources, previous experiences with technology, and computer anxiety. The authors also describe differences between younger and older adults in evaluating PU and PEOU. When younger people judge PEOU, their focus is on efficiency (defined as the time to solve a task). For older people the judgement of PEOU mainly relates to effectiveness (defined as success in solving a task). These differences in judgement also

lead to different interrelations between PU and PEOU in younger and older people. For younger individuals, PEOU is less important when judging PU while for older individuals PEOU is very important when evaluating the PU of a specific technology (Chen & Chan, 2011).

More recent studies also examine older adults' acceptance of digital technologies. PEOU, PU and enjoyment have been shown to affect intentions to use smartphone apps in people 50 years and older, with higher enjoyment leading to higher PU (Gurtner, Reinhardt, & Soyez, 2014). Zhou, Rau, and Salvendy (2014) described factors that are relevant for older adults' use of new functions in smartphones. These include awareness and attractiveness of the functions, connectivity, and concern of learning. In another study, trust in technology was a determinant of adoption, while a lack of trust was an important barrier to use (Fischer, David, Crotty, Dierks, & Safran, 2014). Older adults established higher levels of trust by greater experience in using. When they had minimal experiences with new technologies, or saw no additional benefit in using, the adoption of new technologies was less likely (Fischer et al., 2014). Social norms are also highly relevant for older adults' adoption of new technologies. Their children, care professionals, other family members and friends can influence the decision to adopt new technologies (Peek et al., 2014).

1.2.2 Innovation Diffusion Theory.

A different branch of research that also aims to explain adoption decisions is more concerned with the process of diffusion of new technologies on an aggregate level. Rogers' (1995) *Innovation Diffusion Theory* (IDT) has made an important contribution to this research field. According to Rogers, the decision to adopt a (technological) innovation is a process that occurs over time. Every individual undergoes five different stages when deciding on the adoption of an innovation. At the first stage, *knowledge*, an individual is first exposed to, and initially made aware of, an innovation. During the second stage, *persuasion*, a positive or negative opinion about the innovation is developed. Afterwards, the individual decides to adopt or reject the innovation (*decision*). During the fourth stage, *implementation*, the

innovation is used, given a positive in the decision stage. At the last stage, *confirmation*, there is further reinforcement of the decision (Rogers, 1995).

IDT poses that every individual works through these decision stages, leading to the adoption or rejection of the innovation. Beyond this individual decision process, every individual can be characterised by their *innovativeness* (Rogers, 1995, p. 261), defined as the degree to which a person is relatively early in adopting the innovation, compared to other individuals. Rogers (1995) distinguishes five adopter categories that differ in terms of their innovativeness. *Innovators* are the first ones to adopt an innovation, they are highly willing to take risks and accept uncertainties. They have a high social status and substantial financial resources. *Innovators* can understand complex technical contexts. *Early Adopters* are the second group to adopt and are described as opinion leaders and role models. Other potential adopters rely on the opinions and advice expressed by *Early Adopters*. They are typically highly educated, with a high social status, but are not different in age compared to the later adopter categories. The *Early Majority* tends to be slower than the *Early Adopters* and starts to use an innovation only just before half of the individuals in society. They are less often opinion leaders and link the relatively early and the relatively late adopter categories. The decision process to adopt an innovation takes longer in the *Early Majority* than in the two previous groups. The next adopter category. the *Late Majority*, is more sceptical about innovations. The *Late Majority* adopts an innovation only if the majority in society has already done so. They may be pressured by peers to adopt an innovation. The last group to adopt are the *Laggards* who are typically averse to changes. *Laggards* hold more traditional views and adjust their current behaviour based on their decisions in the past. The decision process to adopt is relatively long in *Laggards* and they are far behind the other groups regarding awareness and knowledge of innovations. *Laggards* have a low social status and limited financial resources (Rogers, 1995).

Rogers' (1995) hypothesised that the adoption rate of new technologies on the aggregate level follows an s-shaped curve over the course of time. It starts with a small

number of adopters and increases slightly, followed by a rapid increase in the middle, and levels-off when most people have adopted the innovation. Accordingly, the percentage of adopters in the different adopter categories is expected to follow a normal distribution (see Figure 2). This pattern was also demonstrated by Rogers' own empirical work (Rogers, 1995) and has been identified for various technology innovations, like the diffusion of mobile phones (Rice & Pearce, 2015), or broadband connections (Pew Research Center, 2015).

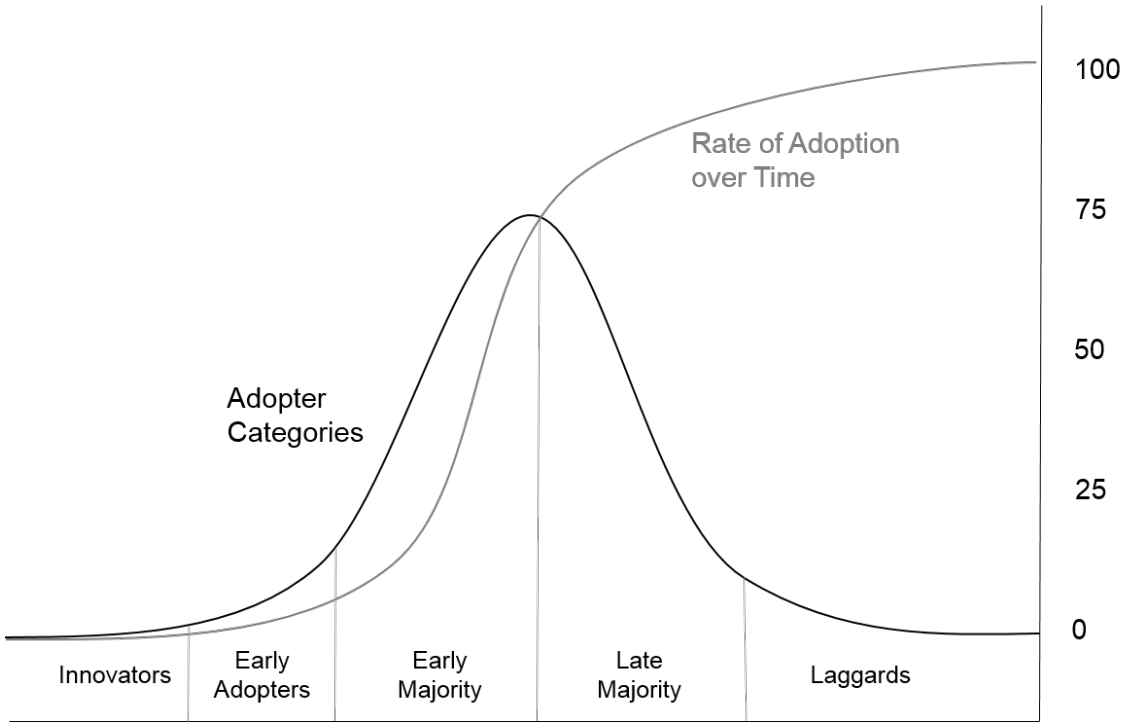

Figure 2. Rate of Adoption and Adopter Categories in IDT.

Adapted from *Diffusion of innovation (*pp. 258 & 262), by E. M. Rogers, 1995, New York: The Free Press.

Older adults are mostly described as late adopters (*Laggards*) of new technologies, since they continue to be behind the adoptions rates in younger age groups (Pew Research Center, 2014). This is in line with the lower usage rates of digital technologies in older age groups reported at the beginning of this chapter, and indicates an age-related first-level divide in technology adoption. The *innovativeness-needs-paradox* might be relevant for the

adoption of innovations in old age. This paradox describes the situation when the individuals who objectively need an innovation the most are among the last ones to adopt. A possible reason for this situation is that producers follow the line of least resistance, and their products first address individuals with a high degree of innovativeness (Claßen et al., 2014). In addition, differences in relation to further socio-demographic variables have also been described within the group of older people (Seifert & Schelling, 2015; van Deursen & Helsper, 2015). These findings suggest that, on the one hand, older adults potentially differ from younger individuals, and on the other hand, that older people form a heterogeneous group in terms of innovativeness. Consequently, a variety of adopter categories might be present within older people, and interpreting them as a homogenous group in the context of technology adoption would be misleading.

1.2.3 The concept of technology generations.

The concept of *technology generations* is a sociological approach that aims to explain age-related differences in technology adoption, focusing on birth cohorts. The concept was first conceived by Sackmann and Weymann (1994) and was further developed by van de Goor and Becker (2000). A technology generation is defined as "a group of birth cohorts whose behaviour and attitudes towards technology show the effects of one or more major technological changes that occurred in their formative period" (van de Goor & Becker, 2000, p. 16). The formative period is between the age of ten and 25. The authors argue that knowledge gained during this phase of life has a higher chance of being remembered in later life. New technology present during this stage of life is more easily learned, and experiences made with technology during this phase of life affect the acquisition and handling of this and similar technologies in the future (van de Goor & Becker, 2000).

Sackmann and Weymann (1994) distinguished four technology generations in their original taxonomy: a *mechanical generation* (born before 1939), a *generation of household revolution* (born 1939-1948), a *generation of technology spread* (born 1949-1963), and a

computer generation (born 1964-1978). In later work (Sackmann & Winkler, 2013) this categorisation was expanded by an *internet generation* (born after 1980).

Individuals born after 1980 have been described as *digital natives* (Palfrey & Gasser, 2008), a generation who have grown up with internet-technologies and who are accustomed to modern digital technologies, like smartphones. Schwarze (2012) proposes that only the birth cohorts after 1990 should be considered as *digital natives* or the *internet generation*. Despite these differences in detail and some variation in the identification of the cohorts, all concepts emphasise the importance of cohort for the adoption and use of new technologies.

In an experimental setting, Docampo Rama, Ridder, and Bouma (2001) explicitly studied whether older adults' difficulties with technology use are caused more by age-related or cohort-related factors. They argue that age effects would produce a continuous decrease with birth cohort while cohort effects would occur more suddenly and discontinuously, because they are caused by equally sudden technological innovations on a societal level. The researchers showed that the number of errors made when handling modern technologies demonstrated a discontinuous course across different age groups, indicating a cohort effect. For task duration, the authors identified continuous differences between the groups; these were interpreted as age effects (Docampo Rama et al., 2001).

These theoretical assumptions and empirical results, based on TAM, IDT, and the concept of technology generations, provide further evidence for age-related determinants of technology adoption. This implies that findings on preferences, derived from studies in younger age groups, cannot be directly transferred to older people. Additionally, the findings stress the importance of a research focus on the individual, since age alone does not seem sufficient to explain the differences in adoption.

1.3 Promoting and Inhibiting Factors for Use: The Example of Digital Health

Using digital health devices and applications can support a healthier style of living because users can constantly access their health-related data and are therefore more aware of it (Morgan, 2016). A common reason to engage in self-tracking is the personal interest of

users (Swan, 2013) who would like to inform themselves about their behaviour and health (Appelboom et al., 2014). This can help individuals detect possible correlations between their behaviour and health outcomes. The activities of voluntary self-tracking are like the objectives of health promotion, including enough physical activity (World Health Organization, 2008; 2010). The use of digital health devices and applications is expected to lead to positive behavioural changes, because individuals can actively participate in decision-making and self-care (Bhavnani, Narula, & Sengupta, 2016). However, a review examining the theoretical basis of digital health interventions concludes that behaviour change models are insufficiently discussed in this context. Although several studies reported a theoretical basis, only a few of them examined the specific theoretical components (Riley et al., 2011) and the interventions might therefore be ineffective. A recent study by Ernsting et al. (2017) provides evidence for the last point by showing that the health apps people have installed on their smartphone do not represent their actual behaviour, but more likely the behaviour they want to change. Using health apps was not necessarily related to healthier behaviours. When evaluating the sustainability of use, other work concluded that 80% of smart devices users abandoned the use of these apps after two months (Lazar, Koehler, Tanenbaum, & Nguyen, 2015). A study on the use of activity trackers showed that about half the users quit using devices after six months (Ledger & McCaffrey, 2014). Usage rates for mobile fitness applications have also been shown to decrease after five months (Herrmann & Kim, 2017).

A scoping review on the use of digital devices for self-management concludes that "the advances in smartphones, wearables, and other smart devices align well with the developing interests of older adults to integrate technology into their healthcare" (Kim & Lee, 2017). The authors of the study identified relevant facilitators and barriers to successful adoption of smart device-based mHealth interventions by older adults (Kim & Lee, 2017). One important facilitator is the recognition of the benefits of using smart devices. Digital health can increase awareness, motivation, and engagement in chronic disease management. The motivation to comply with mHealth interventions is enhanced by the aim of

achieving predetermined goals. By using mHealth, older people experience the relationship between their behaviour and its impact on their health. Another facilitator is the sense of connectedness and reassurance due to mHealth. On the other hand, there are relevant barriers to use. These include a diminished motivation to use, due to usability and technical issues, a lack of value of the intervention, and insufficient training to use the devices (Kim & Lee, 2017). It has also been demonstrated that older people place more trust in digital fitness technologies that they rate higher in usability (Rupp, Michaelis, McConnell, & Smither, 2016).

Another study (Preusse, Mitzner, Fausset, & Rogers, 2014) examined the process of older adults' adoption or non-adoption of two specific wellness management technologies (an activity tracker and a health app) over time. Participants (n = 16) were asked to use the technologies over 28 consecutive days, after which they had to decide whether they would adopt the technology. At the beginning, all participants had a neutral opinion towards using the technology, while at the end, 12 indicated a willingness to adopt and four indicated no willingness to adopt. Adopters made more positive comments relative to negative comments, compared to non-adopters. They also had higher intention to use and scored the technologies higher on usability. This result highlights the importance of studying adoption processes over time (Preusse et al., 2014). Another study examining health-related technologies concluded that older adults are not ready to adopt this technology easily, and use new technologies selectively. The most common reasons for non-use were lacking a need and lacking an interest (Heart & Kalderon, 2013).

These studies are among the first focusing on older adults. Most other studies focus on younger age groups, especially people in middle age (Direito, Jiang, Whittaker, & Maddison, 2015; Ernsting et al., 2017; Safran Naimark, Madar, & Shahar, 2015; Walsh, Corbett, Hogan, Duggan, & McNamara, 2016). Furthermore, only a few studies have investigated the long-term effects, potentials and risks of self-tracking (Vandelanotte et al., 2016). However, "to fully comprehend individuals' use of new technologies, it is necessary to

investigate not only the initial adoption of a technology but also their continuance intention to use the technology" (Cho, 2016, p. 77).

1.4 Digital Technologies in Gerontological Research

Traditional forms of surveys are relatively static and not easy to customise. Using digital technologies when surveying data allows for innovative designs that can be adjusted to the individual participant in content, form, and scope (Intille, 2007). This development includes online surveys and the application of *ambulatory assessments*. Ambulatory assessment is defined as "the use of (mainly) electronic devices and computer-assisted methods of data collection suitable for use in the field to collect self-report data, behavior observation data, psychometric behavior measures, and physiological data in unrestrained daily life settings" (Fahrenberg, Myrtek, Pawlik, & Perrez, 2007, p. 207). One important advantage of ambulatory assessments compared to other forms of surveys is its ecological validity. Behaviour is surveyed *in situ* and there is no bias due to memory problems or social desirability present (Fahrenberg et al., 2007). Considering cognitive changes in old age, this may be a good method to gain more reliable data. Furthermore, ambulatory assessments can also be applied to measure objective parameters (such as blood pressure, heart rate, skin conductance), which can be used in supplement to traditional survey methods. Newly developed and more reliable sensors can be used to assess physiologically and socially relevant information (Kang et al., 2010). Ambulatory assessments are already currently used in research on aging (Brose & Ebner-Priemer, 2015). Important applications include the documentation of health-related processes, self-reports of symptoms, and monitoring of activities in daily life. Further potential is possible for the identification of within-subject processes, multivariate assessments, and the combination of monitoring and interventions in real time (Brose & Ebner-Priemer, 2015).

However, the disadvantages of using digital technologies in gerontological research also need to be discussed. People who do not use digital technologies are automatically excluded from this form of survey, which makes representative studies within the whole

population impossible. This problem is directly linked to the described age effects and cohort effects on adoption and use of modern digital technologies (see chapter 1.1).

1.5 Aims and Research Questions of this Dissertation

This dissertation analyses older adults' preferences towards using digital technologies, with a focus on usage patterns, facilitators and barriers for long-term use, and the potential of digital technologies for gerontological research. Theories explaining technology adoption from different scientific disciplines and their empirical evidence for people in old age have been presented. The Technology Acceptance Model (TAM), developed in information systems research, is one of the models most used to explain technology adoption today. The model underlines the importance of age-related determinants of technology adoption and can easily be extended by the addition of new determinants. At the same time, TAM is a rather static model of technology adoption. Once people form an intention to use a specific technology, adoption and use are considered as a given fact. Rogers' Innovation Diffusion Theory puts more emphasis on the procedural character of adoption decisions, which seems more reasonable in explaining the different adoption patterns across individuals with different prerequisites and interests. Still, it is assumed that all individuals will eventually start the adoption process. The sociological concept of technology generations focuses on the differences between birth cohorts in technology adoption. Age-related differences are explained regarding different experiences during the formative phases of life.

All these models aim to explain technology adoption from different perspectives. Common to all these approaches is the primary focus on a first-level divide in using new technologies. The theories are mainly concerned with *whether* and *when* a certain technology is used, but do not examine the *why* and *how* of use, once a technology is adopted. However, older adults' adoption decisions seem to be more complex and diverse than described in the models. Given these arguments, the presented theories are used as background knowledge for this dissertation, but their hypotheses are not directly tested.

It should be acknowledged, that beyond age effects and cohort effects, as described by the life course perspective, individual differences and individual reasons for use are also relevant for the adoption of new technologies in old age. Current research shows that these might include enjoyment, attractiveness of functions, perceived benefits from using, or simply knowing about it. Age norms[1] for using digital technology might also be of relevance. On the one hand, older adults might feel *too old* to use modern digital technologies, like smartphones. On the other hand, they might also feel *too young* to use digital technologies for health issues (that is too young to use assistive digital health technologies). All these factors need to be considered rendering an individualised approach in researching preferences towards using digital technology in old age important. Therefore, an explorative mixed methods approach is followed in this dissertation, which accounts for the diversity of decisions to adopt digital technologies in old age and the novelty of the research field.

The overall research question of this dissertation asks:

What preferences do older adults have towards using digital technologies?

This overarching question can be divided into several sub-questions that relate to the three research foci of the dissertation. These have been addressed in five publications that are the basis of this dissertation.

The first two publications (Seifert, Schlomann, Rietz, & Schelling, 2017; Schlomann, Seifert, & Rietz, under review) report the results of a cross-sectional study in the general population of people aged 50 years and older and analyse **usage patterns**. These publications focus on the general use of mobile devices and use for self-tracking purposes, answering four research questions:

[1] Age norms are defined as "informal rules that specify age-appropriate roles and behaviour" (Quadagno, 2011, p. 27).

1) How many individuals over 50 years of age are using mobile devices in general and for tracking physical activity?
2) How do individuals who track their physical activity with mobile devices differ from those who do not track their activity?
3) What are the most common reasons for using mobile devices to track physical activity?
4) Does using mobile devices for physical activity affect the association between physical activity and a specific area of life satisfaction, i.e., satisfaction with physical fitness?

To analyse the **facilitators and barriers of long-term use**, the following two publications (Schlomann, von Storch, Rasche, & Rietz, 2016; Schlomann, 2017) examine older adults' usage experiences over a longer period and address the research questions:

1) How do older adults' use of a specific activity tracking technology (i.e., an activity tracker) in the long-term?
2) What are the reasons for continued or abandoned use?
3) What effects can be observed on the physical activity level?

The last publication (Schlomann & Rietz, in press) discusses the **potential of digital technologies for gerontological research** and compares traditional survey methods to the implementation of ambulatory assessments in surveys for older populations. The following questions are addressed:

1) Which new survey methods for gerontological research emerge with the advent of digital technology?
2) What are the positive and negative aspects of using digital technologies in surveys in older populations?

Chapter 2 outlines the publications that address the different research questions. In chapter 3, the research questions are discussed based on the findings in the publications and in relation to the general research context.

2 Outline of Publications

2.1 Mobile Devices for Physical Activity Tracking in Older Adults' Everyday Life

Seifert, A., Schlomann, A., Rietz, C., & Schelling, H. R. (2017). The use of mobile devices for physical activity tracking in older adults' everyday life. *Digital Health, 3*, 1-12, doi: 10.1177/2055207617740088.

Schlomann, A., Seifert, A., & Rietz, C. (under review). Moderating effect of mobile activity tracking on the relationship between physical activity level and satisfaction with physical fitness in older adults.

2.2 Older Adults' Long-term Use of an Activity Tracker

Schlomann, A., von Storch, K., Rasche, P., & Rietz, C. (2016). Means of Motivation or of Stress? The Use of Fitness Trackers for Self-Monitoring by Older Adults. *HeilberufeScience*, *7*(3), 111-116, doi: 10.1007/s16024-016-0275-6.

Schlomann, A. (2017). A case study on older adults' long-term use of an activity tracker. *Gerontechnology, 16*(2), 115-124, doi:10.4017/gt.2017.16.2.007.00.

2.3 Surveys in Older Populations

Schlomann, A. & Rietz, C. (in press): *Erhebung von Daten in der älteren Bevölkerung*. In: K. Hank, F. Schulz-Nieswandt, M. Wagner, S. & Zank (Hrsg.): Alternsforschung. Handbuch für Wissenschaft und Studium. Kapitel 26. Baden-Baden: Nomos-Verlag.

3 General Discussion

This dissertation examined usage patterns, as well as the facilitators and barriers to using digital technologies in older adults. Furthermore, the potential of digital technologies for gerontological research has been discussed. The results of this dissertation are based on a cross-sectional survey of the general population of older individuals, a qualitative long-term study, and a conceptual paper.

The next chapter is a general discussion of the results. It starts with an overview of the main findings of the publications this dissertation is based on. The results will then be related to the general research context that was reported in the general introduction (see chapter 1). A methodological discussion follows, with a focus on study design, theoretical background, and measurement instruments. The integration of technology and gerontological theory is subsequently discussed. In the following sections, recommendations for future research are suggested. These include researching aspects of digital literacy, participatory user-centred approaches, and an evaluation of two current technology trends, gamification and augmented reality. The chapter closes with a general conclusion.

3.1 Main Findings

3.1.1 Description of usage patterns.

(based on Seifert et al., 2017; Schlomann et al., under review)

This study examined older adults' usage patterns for mobile technologies in general and for self-tracking purposes, using a population-based telephone survey in Switzerland (n = 1,013). Distinguishing features between users and non-users of mobile technologies have been identified and the reasons for using or not using were examined. Furthermore, interrelations with physical activity and one specific aspect of life satisfaction were analysed.

The first research focus was on how many individuals aged 50 or older were using mobile devices in general and for tracking physical activity. Smartphones were used by 62.3% and tablets by 45.0% of the sample. Furthermore, 6.6% of participants reported to use

a smartwatch in their everyday life. The study showed that about 1 in 5 (20.5%) people over the age of 50 and living in Switzerland used any mobile device for tracking their physical activity. Within the whole sample, 15.1% used an application on their smartphone or tablet to track physical activity. The most common wearable device for physical activity tracking were activity trackers, used by 10.8%, while smartwatches were used by 1.7%. When they began to use mobile devices for self-tracking, many participants in the survey reported to use them every day. Usage rates were generally higher in the youngest age group (50-64 years) and lowest in the oldest group (80+). Within the whole sample, 29.0% of participants did not use any mobile device in their everyday life.

Second, an analysis was conducted on the distinguishing characteristics between individuals who tracked their physical activity with mobile devices and those who did not. The differences between users and non-users were identified in a multivariate approach (multivariate logistic regression analyses). Physical activity tracking was more common in younger, male individuals. Those with a strong interest in technology and those who frequently exercised were also more likely to use mobile devices for self-tracking. A multivariate analysis of the general use of mobile devices showed different effects. Younger age and a higher interest in technology had a positive effect on use but there was no difference between men and women. Furthermore, people with a higher level of education, and individuals who were more satisfied with their health status, used mobile devices more likely than less educated people, and those who were less satisfied with their health status.

The third research question concerned the reasons for using mobile devices to track physical activity. The most common reasons for use were a general interest in tracking daily activity and the motivation to remain healthy. These reasons were more often agreed with than were social aspects, such as exchanging data with friends, or documenting data for physicians.

Finally, the relationship between physical activity tracking and satisfaction with physical fitness, which can be used as a specific metric of life satisfaction, was evaluated in

more detail. Data showed that individuals who were more often physically active were also more satisfied with their physical fitness. The use of mobile devices for physical activity tracking could add to this positive relationship, that is, the positive effect of physical activity level on satisfaction was stronger for older adults who used mobile devices for physical activity tracking. On the other hand, physical activity tracking had a negative effect on satisfaction with physical fitness for individuals with low physical activity levels.

3.1.2 Facilitators and barriers for long-term use.

(based on Schlomann et al., 2016; Schlomann, 2017)

The long-term use of a specific self-tracking technology, an activity tracker, was analysed in a small sample of adults aged 65 years and older. Semi-structured personal and telephone interviews were used in a qualitative, long-term study, spread over one year. The study was composed of three steps (see Figure 3), an in-depth study of usability (*n* = 15), a group interview one month after the usability study (*n* = 6), and telephone interviews one year after the start of the study (*n* = 6). Experiences while using an activity tracker were examined and possible reasons for continued use or abandonment were discussed. The study also reported on the effects of using an activity tracker on physical activity levels and feelings of well-being.

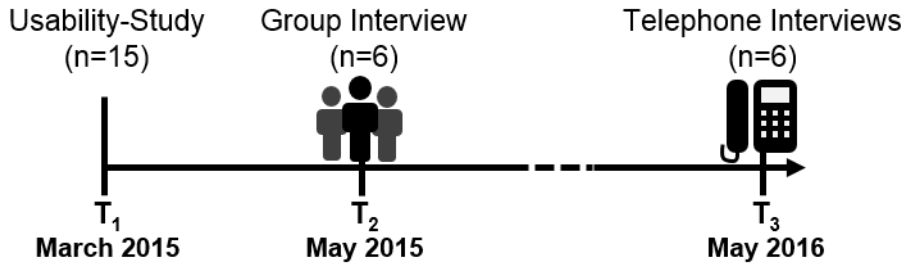

Figure 3. Study Design of Qualitative Long-term Study.

Reprinted from "A case study on older adults' long-term use of an activity tracker," by A. Schlomann, 2017, *Gerontechnology, 16*(2), p. 117.

The first research focus was on how older adults generally used a specific activity tracking technology (such as an activity tracker) in the long-term. Participants in the study did not make use of the range of functions of their devices, but limited their use to the main features (i.e., counting steps). At the same time, the devices were still used after one year by several individuals, with routines of use having been developed. Some participants reported daily habits in use, while others used the devices infrequently, for very specific occasions.

Aspects relevant for continued use in the long-term included an increased awareness of personal achievements due to the device. The participants were more sensitized for the relevance of physical activity. The reminder function of the activity tracker was another factor relevant for continued use. Participants perceived the activity tracker as a device related to health behaviour, and stressed the positive effects of physical activity on health. However, the permanent reminder of health issues also led to reduced use in one participant. Lacking customisation of the activity trackers also led to reduced or abandoned use. The devices were not suited to activities in everyday life because they were not waterproof and lacked functions such as measuring blood pressure or pulse. Another reason for abandonment was a declining interest in the gathered information (i.e., number of steps). In some cases, this was caused by a lack of perceived need. Technical aspects, like difficult manageability and incompatibility with other technology also impeded long-term use.

When focusing on the effects of using the activity tracker on physical activity level, some participants reported to adjust their behaviour according to the feedback of the device. Others reported that their general lifestyle and physical activity levels were not affected by using the activity tracker. The number of steps, as objectively measured by the devices, did not change.

3.1.3 Potential for gerontological research.

(based on Schlomann & Rietz, in press)

This publication is a conceptual evaluation of the use of digital technologies in surveys in the older population. The chapter starts with a summary of relevant German and

international surveys in older populations and discusses issues of accessibility and willingness to participate. The cognitive and communicative fundamentals in surveys with older people are reported.

After evaluating these topics in the context of traditional forms of surveys, the use of digital technologies in surveys with older populations is discussed. With the advent of modern technology, new forms of surveys become feasible. This includes online surveys and ambulatory assessments. The chapter discusses the advantages and disadvantages of surveys making use of modern digital technologies, and ambulatory assessments in the context of gerontological research. Advantages include avoiding biases due to memory errors and social desirability that become more common in old age. Assessments of objective parameters, like blood pressure or skin conductance, seem beneficial in groups of people who cannot report their opinions or conditions due to cognitive impairments or physical constraints. In this way, objective parameters measured by ambulatory assessments might be a good addition to self-report surveys or to proxy interviews[2]. The development of new and better sensors, often implemented into modern digital technologies like smartphones, can eventually promote the integration of these technologies into future gerontological research.

The publication also addresses potential problems in using modern technology in aging research. These are related to the different usage rates and usage routines of modern technology in different cohorts and age groups. When surveys are administered in professional care contexts, care professionals need to agree to the use of digital technologies. Training might therefore be necessary for different groups, before digital technologies can be applied in these contexts. In general, the use of digital technologies in surveys within the older population can be judged as a promising approach and might compensate for age-related differences.

[2] Proxy interviews are used when a target person is not willing or able to participate in a survey. A short form of the questionnaire is answered by a third person and basic information, like country of birth, years in education, or marital status are assessed (Engstler & Hameister, 2016).

3.2 Appraisal of Main Findings in the General Research Context

This chapter will evaluate the main findings of this dissertation in the general research context and will relate the results to the introduction of this dissertation. The population-based study (see Seifert et al., 2017; Schlomann et al., under review) was one of the first representative analyses of self-tracking in older adults. User rates for the general use of smartphones and tablets are comparable to the figures reported in recent public reports (Koch & Frees, 2017; Statistisches Bundesamt, 2016). In own analyses, sociodemographic differences (beyond age) between users and non-users were identified. The interrelations between sociodemographic variables and use were different for the general use of mobile devices and for the use of mobile devices for self-tracking purposes. A higher level of education was only important for general use of mobile devices, while gender was only important for the use of self-tracking. These findings indicate that self-tracking represents a specific application of technology use, which should be studied separately and requires further systematic investigation. These detailed data on the usage rates of specific devices and applications, and their interrelation with individual characteristics, contribute to a better understanding of usage patterns and adoption decisions in the older population. Population-based longitudinal aging surveys have not yet integrated these questions into their sets of questions.

Existing research has analysed the reasons for self-tracking mainly in younger age groups (e.g., Appelboom et al., 2014; Swan, 2013). As shown by own research (see Schlomann et al., 2016; Schlomann, 2017), the most important reasons for use were quite similar in older adults; daily tracking of physical activity and a motivation to remain healthy were the predominant reasons for use. In the qualitative interviews, participants reported a high interest in health information and the activity tracker could provide this information. At the same time, exchanging the gathered data with others was not a widespread behaviour. This lack of exchange with others could be seen in the population-based study, as well as in the qualitative study, and indicates that this component of self-tracking is currently not used

by older adults. There is a general interest in exchanging with others via digital technologies, as shown by the high usage rates of digital services and applications for this purpose (Initiative D21, 2016). Furthermore, exchanging with others might be an important promoter of use in old age. Reinforcement by family and peers seems to be especially important at the beginning of use (Peek et al., 2014). A documentation of data for physicians might furthermore contribute to better healthcare.

Participants in the qualitative study reported that they limited their use to the main functionalities of the devices. This finding agrees with older adults' knowledge-related barriers to use new technologies (LeRouge et al., 2014) and their general selectivity in using (Heart & Kalderon, 2013), reported in other work. The individualised and very specific use of modern technologies is also expressed by the characterisation of older adults as *Technogenarians* (Joyce & Loe, 2010). Research has shown that the attractiveness of function is relevant for adoption by individuals in old age (Zhou et al., 2014). This could be confirmed by own research. Participants in the qualitative study criticised unnecessary functions, as well as the lack of important functions. This criticism led to limited or abandoned use in some individuals. After one year of using, participants of the study still complained about difficult manageability of the devices. This is a strong indicator that easy-to-use devices (as expressed by PEOU in TAM) are especially important for older people. As shown by other research, ease-of-using might also influence the perceived usefulness of a specific technology (Chen & Chan, 2011).

In the qualitative long-term study, intentions for use and routines changed over time, and were individualised after the study period of one year. These findings once again indicate the heterogeneity within the group of older people and the importance of a long-term perspective. Preusse et al. (2014) identified changes in adoption over the duration of one month. The qualitative study in this dissertation extended the time-horizon to one year. In this way, the processes of adoption, use, and potential abandonment could be examined over a longer period. A diminished motivation to use in the long-term was mainly caused by a lack

of individual fit of the devices, diminishing interest in the gathered information, and no perceived benefits from use. These findings are similar to the reasons reported for younger age groups in existing research (Fischer et al., 2014; Heart & Kalderon, 2013) and indicate that younger and older individuals are not too different in this domain.

Previous research reported the positive effects of self-tracking on physical activity levels (Poirier et al., 2016). This effect could not be identified in the qualitative study, although some participants reported a higher degree of sensitivity for the importance of physical activity as a consequence of using the activity tracker. In the population-based study, self-tracking was associated with higher self-reported levels of physical activity. Due to these conflicting results and inherent methodological issues of causality or selectivity (see chapter 3.3.1) this issue cannot be resolved based on the results in this dissertation. Nevertheless, the findings provide some preliminary evidence that self-tracking has the potential to positively affect well-being and specific aspects of life satisfaction in older adults. Other researchers (Melenhorst et al., 2006) have also described a benefit-driven approach in technology use in old age. Older participants might profit from self-tracking, although there is a lack of exchange with others and a limitation to some basic functionalities.

In the context of ambulatory assessments and the application of digital technologies in gerontological research, no own research was conducted (see Schlomann & Rietz, in press). The discussion of this work therefore must be limited to a methodological discussion (see chapter 3.3).

3.3 Methodological Discussion

The methodological approach of the dissertation was an exploratory mixed methods approach. It combined a population-based study with a qualitative long-term study. Mixed methods approaches, combining qualitative and quantitative methods in the field of technology acceptance, have also been proposed by other researchers, since this provides potential for theory building (Wu, 2012). In this dissertation, a conceptual chapter adds to a

holistic view on the topic. Some methodological aspects relating to study design, theoretical background, and measurement instruments will be discussed in the next sections.

3.3.1 Study design.

For the research in this dissertation, own data was collected because no sufficient data on technology adoption was currently available in population-based longitudinal studies. Existing surveys are limited to very basic questions on technology use (Sackmann & Winkler, 2013). By collecting own data, it was possible to survey a wider range of questions and topics and information on possible correlates, like socio-demographic variables, interest in technology, and physical activity levels. However, due to time, as well as personnel and financial restraints, the surveys were also limited in scope and extent. Data on important background factors (objective health status), everyday life factors (coping with activities of daily life, social contact), and psychological factors (personality) are not available in the data, limiting the possibilities for analysis.

Furthermore, the population-based study was only a cross-sectional study, and in this way, did not allow for an evaluation of developments over time. It is not possible to distinguish between age effects and cohort effects in the reported differences in adoption. There might also be bidirectional causality; devices for self-tracking might motivate individuals to be more physically active, which causes higher rates of physical activity in this group. On the other hand, it is equally reasonable to assume that physically active people use self-tracking devices more often to monitor their activity. In this way, there might be a selection effect and no causal effect of technology use on behaviour. Objective data on physical activity, which might contribute to a better understanding of the relevant processes, were not available in the population-based study. Analyses had to rely on self-report data only. Further longitudinal analyses are needed to better understand the causal mechanisms and intra-individual change processes.

Another limitation relates to the survey method, which was a telephone survey. Telephone surveys suffer from several problems, including brief questionnaires, acoustic

problems, non-availability, or a lack of trust in telephone surveys. For this study, it can be assumed that the advantages outweigh the disadvantages. Telephone interviews are an efficient and effective method to gather a wide range of information (Diekmann, 2007; Groves, 2004). They are relatively inexpensive in comparison to other forms, like face-to-face interviews. Since the conducted study had an exploratory character, the results can serve as basis for further studies.

The qualitative study followed a small sample of older individuals over the duration of one year. The sample was relatively small from the beginning limiting the explanatory power of the results. A common problem in longitudinal studies is the withdrawal of willingness to participate throughout the study period, which is problematic when non-participation is related to variables of interest (Groves, 2004). A reduction in sample size was also evident in the present study. It was possible to test for differences in some characteristics between participants and non-participants at the different points of data collection. These included technological affinity, the average number of steps during the first month of use, self-reported hours of physical activity per week, and perceived usability of the tested device. No differences between the samples at the different points in time were observed. Nevertheless, there might be differences in relation to further variables that were not tested. Furthermore, the study was based on a convenience sample. Participants in the study might have been generally more favourable towards new technologies than an average older adult. Finally, participants' experiences in this study were limited to one specific device. Other devices might display different information or make use of other motivational strategies, which could have led to different results.

Finally, ambulatory assessments, as an innovative method for surveys in older populations, have only been evaluated on a conceptual basis. Empirical studies will be necessary to test the practical applicability of these methods. Research on ambulatory assessments has shown a certain degree of reactivity due to the method (Fahrenberg, 2010). The assessment itself can influence answers, because individuals are permanently or

at least regularly reminded of certain issues. This can influence attitudes and behaviour and needs to be considered when this method is applied to aging research (Fahrenberg, 2010). Also, possible age effects (see chapter 1.1.1) should be contemplated.

3.3.2 Theoretical background and measurement instruments.

No uniform theoretical framework on technology adoption was used as the basis of the publications in this dissertation, since existing models were not suitable for the present research focus. The life course perspective informed the research in this dissertation as a general framework, and an exploratory mixed methods approach was chosen, in which self-developed items and open-ended questions were applied. These had been developed with reference to the existing literature, but were not deduced from theory. Theories on adoption from different scientific disciplines were applied as background information and to interpret results. There are several reasons why the existing theories on technology adoption were not suitable for the research focus of this dissertation.

Most studies on technology adoption are based on TAM, due to several advantages of the model, like a pragmatic view on technology acceptance, the easy-to-use inventory, and the parsimony of the model (Bagozzi, 2007). As described in the beginning, TAM poses that intention to use is the central determinant of behaviour. This pragmatic assumption is not only the reason for the parsimony of the model, but at the same time one of its most relevant weaknesses. TAM poses that cognitive evaluations are the only relevant determinant of intentions and behaviour. However, research in the field of behaviour change has discussed the so-called *intention-behaviour gap* (Sniehotta, Scholz, & Schwarzer, 2005), meaning that a certain behaviour is not performed, although individuals form an intention to do so. A meta-analysis of the relationship between intentions and behaviour showed that only about 30% of the variance in behaviour is explained by intentions (Sheeran, 2002). This gap might be overcome by action planning, self-regulatory strategies, and perceived self-efficacy (Sniehotta et al., 2005). It is possible that these mechanisms also apply to the decision process for use of a specific technology. The own research on older adults' use of an activity

tracker showed that individuals quite often used devices in a passive manner (Schlomann et al., 2016; Schlomann, 2017). Other research from the field of human-computer interaction has also provided evidence that users frequently pause using an activity tracker, while some restart using at a later point in time (Meyer, Wasmann, Heuten, El Ali, & Boll, 2017). Sometimes, the devices are only used for specific occasions. These natural usage patterns need to be considered (Meyer et al., 2017). TAM overlooks these mechanisms and does not recognise that adoption is a process, that intentions need planning, that there are obstacles that need to be overcome, and that actions need to be readjusted. A systematic literature review on the power of TAM to predict actual usage behaviour showed that only a few papers considered objective measurements of usage (Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). The review furthermore identified different relationships between TAM constructs and objective and subjective measurements of technology use. Therefore, the authors propose that studies should consider actual use, not just subjective use (Turner et al., 2010). Bagozzi (2007) proposes a new paradigm to study adoption processes. He defines a decision chain for technology acceptance, starting with goal desire, followed by goal intention and action desire, and finally leading to action intention. Integrating these modifications into future models predicting technology adoption might improve the quality of analyses and the explanatory power of the models.

Rogers' IDT also needs to be discussed. IDT poses that innovations are accessible, used for a specific purpose, and provide an objective benefit (Krotz, 2007). In this way, IDT is technology-centred. However, it has been shown that the functionality and advantages of technological innovations are not determined per se, but defined by the individual user (Krotz, 2007). Particularly, older users might use modern technologies differently than originally planned by the developers. This could also be shown for the use of an activity tracker in the own study (see Schlomann, 2017). Older users partly evaluated the non-smart functions of the devices as the most important, or used the activity trackers only in specific situations. Furthermore, the purpose of use of technological innovations might change over

time. Krotz (2007) concludes that IDT is too little differentiated, because it assumes the diffusion of a uniform innovation over time and does not consider changes in technologies or different user needs.

Given these points of discussion, theory development seems to be necessary, combining the areas of technology adoption and gerontological theory. This will be discussed in more detail in the next section.

3.4 Integration of Technology and Gerontological Theory

Researching aspects of technology and aging in gerontology started in the 1980s in different parts of the world (see Schulz et al., 2015 for an overview). The field of gerontechnology conducts research at the intersection between modern technology and gerontology. This includes gerontological research in different domains, such as human-factors research or ecological gerontology (Claßen et al., 2014). Nevertheless, the integration of technology into gerontological theory has not yet been well established. As reported by Schulz et al. (2015) the research field is fragmented and the importance of technology for the life course is not sufficiently studied. The authors claim that technologies for older adults should consider life-span developments and address issues that are relevant for older individuals and for society. To increase the meaning of technology in gerontological research, it is important to link existing gerontological theories to technology (Schulz et al., 2015). Carstensen's (2006) Socioemotional Selectivity Theory (SST), Selective Optimization with Compensation (SOC) Theory (Baltes & Baltes, 1990), and aspects of person-environment interaction provide possible starting points.

SST poses that individuals' motives in life change due to different time-horizons. With a decreasing time-horizon (when people age) the theory assumes that individuals become more selective in choosing their goals and shift their motives from knowledge-related goals to emotionally meaningful goals (Carstensen, 2006). These assumptions can be applied to technology adoption in several ways. On the one hand, technologies can facilitate the selection of desired contexts and people (Schulz et al., 2015). On the other hand,

technologies need to be safe and successful, since failure experiences lead to emotional distress and possible rejection (Schulz et al., 2015). In this line of argument, Sims, Reed, and Carr (2017) could show for the oldest-old, individuals age 80 years and older, that information and communication technologies (ICT) are more often used for social goals than for information goals. ICT use was also related to higher well-being (Sims et al., 2017).

The SOC-Theory on selection, optimisation and compensation proposed by Baltes and Baltes (1990), assumes that these three processes are relevant for development over the lifespan. The theory deals with gains and losses associated with aging processes. Selection refers to the choice and prioritisation of an individual's goals in life. Optimisation means an improvement of resources and actions that help an individual reach the selected goals and maximise gains in these areas. Compensation describes the adaptive capacity of how an individual uses specific resources to cope with the burdens of everyday life. The processes of selection and compensation contribute to optimisation. By applying these three principles, an individual can allocate resources in a better way and maintain relative stability and well-being over the lifespan (Baltes & Baltes, 1990).

Applied to the context of technology, Freund and Baltes (2002) refer to the use of a hearing device to compensate for hearing loss in old age. Another study showed that people age 80 years and older are highly selective in the range of media used, and mainly limit this use to their own home (Doh, 2011). Technology might compensate for cognitive changes (such as technology aided recall) or optimise cognitive abilities (technology based cognitive training). Fozard and Wahl (2012) describe how gerontechnology can compensate for age related deficits such as multimorbidity, reduced everyday competence, or mobility problems. In this sense, technology is a means to support the triad of selection, optimisation, and compensation.

Kamin and Lang (2013) refer to the principles of selection, optimisation, and compensation to study technology use in older adults and to develop the *Subjective Technology Adaptivity Inventory*. This is an inventory used to measure individual differences

in the motivation to use technology. The authors argue that selection, in the context of technology adoption, involves decisions on the purposes for which a specific technology is used. Optimisation deals with the question of how commitments or abilities to use technology can be improved. Compensation is related to how individuals develop a sense of safety when handling technology. It is their central assumption that individuals will improve the use of technology when the context of use is challenging to some extent, but still manageable. If the demands of using are too high or too low, new technologies are more likely to be rejected (Kamin & Lang, 2013).

A third relevant theoretical perspective involves the aspects of person-environment interactions. Wahl, Iwarsson, and Oswald (2012) developped a framework to describe older adults' interactions with their environment, including two core processes of person-environment relations in old age. The process of *belonging* is experience-based and includes subjective evaluations of the environment. Belonging involves emotional aspects, like positive relationships to other people and the environment. The process of *agency* is behaviour-based and is related to intentional behaviours to change one's own life. It includes aspects of compensating and adapting. Interactions between the individual with his/her environment (person-environment resources) are central to both processes and can lead to developmental outcomes such as identity, autonomy, and well-being. The authors pose that the interaction between belonging and agency develops over the life course. Belonging gains more importance in older age, while agency loses importance. This change can, for example, explain the relative stability in activities and the importance of a well-known home and neighbourhood in old age (Wahl et al., 2012).

A central question in this context is, how modern technologies are part of the environment and how they can be integrated into this concept. Following the reasoning of Wahl et al. (2012), interactions with technologies are included in a broad understanding of environments. Processes of belonging might imply that a certain meaning is ascribed to technologies. Subjective attitudes, evaluations of technologies, and images associated with

technologies are relevant in this context. Agency-processes in the context of technology would then be the active and intentional decision to adopt, the actual use of (new) technologies, and the handling of technologies in everyday life (Claßen et al., 2014). The described focus on traditional media in old age (Doh, 2011) can also be related to these processes. Traditional media are more often used because these are well-known and are associated with positive experiences, while emerging digital technologies need to be actively adopted and are consequently less likely to be used.

To conclude, aspects of technology are starting to be discussed within gerontological theory. There are several points of reference for technology and aging research. This discussion should be further developed in the future to examine the role of new technologies over the lifespan, for older adults' everyday lives, and for society.

3.5 Recommendations for Future Research

Specific recommendations for future research in the field of technology and gerontological research will be discussed in the next chapter. These include aspects of digital literacy, participatory user-centred research, and the consideration of current technology trends in research.

3.5.1 Researching aspects of digital literacy.

Knowledge-related barriers have been shown to affect how older adults use and adopt modern technologies (LeRouge et al., 2014). Furthermore, greater experiences with technologies led to higher perceived benefits of use (Fischer et al., 2014). Conceptually, these observations are related to the idea of *digital literacy*. Different definitions of digital literacy have been proposed (Lankshear & Knobel, 2008), while a modern understanding of digital literacy encompasses more than technical abilities to use digital devices or applications (Eshet-Alkalai, 2004). Buckingham (2008) refers to a concept of digital literacy that includes "to be able to evaluate and use information critically […] and [to understand]

how [..] technological developments are related to broader social, political and economic forces" (p. 78).

According to Bawden (2008), most definitions include four components: underpinnings, background knowledge, central competencies, and attitudes and perspectives. Underpinnings refer to traditional skills that contribute to literacy and ability to function in society on a general level. Background knowledge involves knowledge about the new forms of information in a digitised world. Central competencies include the understanding of different digital and non-digital formats, communication about digital information, evaluation of this information, and the gathering of knowledge. These can be regarded as a wide set of basic skills and competencies. Finally, attitudes and perspectives help the individual to refer to specific situations. For a digitally literate person, it is not enough to gain skills and knowledge. Relevant attitudes and perspectives might include independent learning, moral literacy, and issues of privacy. This component is the most essential for digital literacy but difficult to teach (Bawden, 2008).

Eshet-Alkalai and Chajut (2009) conducted a study on the development of digital literacy skills over a period of five years, which showed different patterns for students and adults 30 to 40 years old. All participants could generally improve their digital literacy skills over time, while adults improved more than students in the context of experience and technical control. Students decreased significantly in creativity and critical thinking. Based on an additional comparison to a control group, the authors concluded that it is experience and familiarity with technologies, and not the individual's age, that causes changes in digital literacy skills over time (Eshet-Alkalai & Chajut, 2009). In consideration of these differences, research on digital literacy skills should be extended to people in old age. By examining how digital literacy evolves over the life span, more reliable conclusions can be made about the effects of previous experiences and other potential influencing factors. This would allow research on whether age effects and/or cohort effects are evident when differences in digital skills are observed.

3.5.2 Participatory user-centred research.

Technology development today is driven mainly by technological progress, while sociological, as well as psychosocial, perspectives are often neglected (Pelizäus-Hoffmeister, 2013). More attention is paid to technical feasibility than to the needs of users. Furthermore, technology development mainly addresses younger age groups, while older adults' perspectives, needs, and preferences are not considered. A scoping review on the use of digital devices for self-management showed that only a few studies are explicitly targeted at older adults, revealing a lack of gerontological research in the field (Kim & Lee, 2017).

More user-centred approaches in technology development would imply that older people participate in the development of new devices to achieve high acceptability. Verdegem and De Marez (2011) explain failing technology innovations by the lack of attention to user acceptance. User-centred approaches might also prevent individual lags (technology develops faster than the needs and capabilities of individuals), as well as structural lags (technology lags behind the needs and interest of users) (Fozard & Wahl, 2012). Technology-based interventions are most effective when there is a match between technologies and the target group. One specific reason for abandoned use in the long term might be due to repetitive use of the same technologies and functions that are tiresome (Bhavnani et al., 2016). A declining interest in use was also shown for older adults' long-term use of an activity tracker in the own study (Schlomann, 2017). A review of free coaching apps concluded that almost none of these apps were evidence-based or suitable for beginners. There is a risk that users engage in exercise programmes without being physically prepared and without a sufficient awareness of safety concerns (Modave et al., 2015). The limitations to the adaptivity of new technologies apply especially to older users. Feelings of being overstrained, by using an activity tracker that was not adapted to their personal level of fitness, were also shown in the own study (Schlomann et al., 2016).

Different design strategies to improve older adults' usability of technological interfaces have been proposed (see Ruzic & Sanfod, 2017), including universal design, design for aging, universal usability, and guidelines for handheld mobile device interface design. The different strategies address usability issues in different ways. While universal design, universal usability, and the guidelines for handheld mobile device interface design all aim to design devices for everyone, design for aging focuses on the special demands and limitations of older users. However, according to Ruzic and Sanfod (2017) these four strategies are not comprehensive enough, because they were either not developed for mobile interfaces, or do not sufficiently acknowledge diversity and limitations in older adults. The authors propose their own guidelines, which place more emphasis on a universal design strategy, adapted to the specific user, in terms of design of the overall interface and in terms of specific features within the interface (Ruzic & Sanfod, 2017). Testing and further development of these guidelines is a promising field for future research on older adults' technology adoption.

Research in the field of user experience focuses on the affective experiences of users and the psychological effects of use. According to the ISO 9241-210 standard, user experience is defined as a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service. […]. User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use" (International Organization for Standardization, 2010). While including a broad definition of experiences, it is a major drawback of these user experience approaches that they are not always scientifically sound and require further development. Nevertheless, the general approach of user experience studies seems promising for the study of older adults' preferences in the context of technology use.

3.5.3 Current technology trends: gamification and augmented reality.

In addition to technology development it is equally important to study the use and potentials of existing and emerging technologies. A huge number of digital devices and applications for various purposes are available today, and a growing number of smartphone applications make use of some components of gamification (Lister, West, Cannon, Sax, & Brodegard, 2014).

Gamification involves the use of gaming elements in non-game contexts (Deterding, 2012; Deterding, Dixon, Khaled, & Nacke, 2011). Many applications for self-tracking have incorporated gamification components, such as built-in reward systems (badges, medals or points) depending on how the user performs in certain tasks or relating to a predefined goal (Cugelman, 2013; Fritz, Huang, Murphy, & Zimmermann, 2014). The question then arises as to whether these game elements also appeal to older people. Most research on gamification has been conducted in young people, mostly with students, and only some studies exist in older age groups (Sun, Qiu, & Zuo, 2017). At the same time, research has also pointed to demographic differences in perceived benefits from gamification. Ease of use of gamification elements decreases with age, and novelty effects of gamification were stronger in younger people (Koivisto & Hamari, 2014). The own study on the long-term use of an activity tracker in older adults (Schlomann, 2017) also showed that not all users judged gamification elements, such as badges and success messages, positively and these may even impede use.

Another current technology trend is the incorporation of augmented reality elements into technology use. Currently, the most successful game in this context is Niantic's game Pokémon GO, which was released in 2016. Pokémon GO combines real-life physical activity with a geocaching concept and augmented reality features. Animated images of the game are embedded into a real-world context, captured by the smartphone camera. Initial research on Pokémon GO has examined the effects of playing the game on physical activity levels (Althoff, White, & Horwitz, 2016; LeBlanc & Chaput, 2017), and has analysed aspects of

motivation to start and continue playing (Marquet, Alberico, Adlakha, & Hipp, 2017; Rasche, Schlomann, & Mertens, 2017). No research has been conducted with a focus on different age groups. A relevant question would be related to the specific features that should be integrated into game concepts for older adults. Zahn & Senger (2012) summarise recommendations for the design of serious games for older people on a more general level. Among other things, the authors recommend adapting known game principles and using easy rules and instructions. Future research might focus on older adults' preferences and motivation to use these new gaming concepts and technologies. Important questions are whether these can offer an added value for older people, if and how they are used, and what are the most important reasons for use or non-use. In this way, the potentials of existing technologies, like smartphones, for aging research can be addressed in more detail in future research.

3.6 General Conclusion

Currently, little is known about how older people interact with new digital technology in their everyday lives, and which psychosocial aspects are relevant for use. Understanding experiences and attitudes is an important research field that needs further investigation. Personal, relational, social, and ethical intended and unintended consequences of use (positive, as well as negative) will need more careful attention in future research. This dissertation has contributed to a better understanding of older adults' preferences and use of modern technologies in a digitised world. Usage patterns, facilitators and barriers for long-term use, and the potential for gerontological research have been discussed. Future directions for research on technology adoption and the integration of gerontological theory in the research field have been outlined. This can provide a basis for a better understanding of relevant processes and for future research.

References

Althoff, T., White, R. W., & Horvitz, E. (2016). Influence of Pokémon Go on Physical Activity: Study and Implications. *Journal of medical Internet research, 18*(12), e315. doi:10.2196/jmir.6759

Appelboom, G., Camacho, E., Abraham, M. E., Bruce, S. S., Dumont, E. L., Zacharia, B. E., . . . Connolly, E. S. (2014). Smart wearable body sensors for patient self-assessment and monitoring. *Archives of public health, 72*(28). doi:10.1186/2049-3258-72-28

Asua, J., Orruño, E., Reviriego, E., & Gagnon, M. P. (2012). Healthcare professional acceptance of telemonitoring for chronic care patients in primary care. *BMC medical informatics and decision making, 12,* 139. doi:10.1186/1472-6947-12-139

Bagozzi, R. P. (2007). The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift. *Journal of the Association for Information Systems, 8*(4), 244–254.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful Aging. Perspectives from the Behavioral Sciences* (pp. 1–34). Cambridge: Cambridge University Press.

Barnard, Y., Bradley, M. D., Hodgson, F., & Lloyd, A. D. (2013). Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior, 29*(4), 1715–1724. doi:10.1016/j.chb.2013.02.006

Bawden, D. (2008). Origins and Concepts of Digital Literacy. In C. Lankshear & M. Knobel (Eds.), *New literacies and digital epistemologies. Digital literacies. Concepts, policies and practices* (pp. 17–32). New York: Peter Lang.

Bhavnani, S. P., Narula, J., & Sengupta, P. P. (2016). Mobile technology and the digitization of healthcare. *European heart journal, 37*(18), 1428–1438. doi:10.1093/eurheartj/ehv770

Brose, A., & Ebner-Priemer, U. W. (2015). Ambulatory Assessment in the Research on Aging: Contemporary and Future Applications. *Gerontology, 61*(4), 372–380. doi:10.1159/000371707

Bruner, G. C., & Kumar, A. (2005). Explaining consumer acceptance of handheld Internet devices. *Journal of Business Research, 58*(5), 553–558. doi:10.1016/j.jbusres.2003.08.002

Buckingham, D. (2008). Defining Digital Literacy - What Do Young People Need to Know About Digital Media? In C. Lankshear & M. Knobel (Eds.), *New literacies and digital epistemologies. Digital literacies. Concepts, policies and practices* (73-90). New York: Peter Lang.

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science, 312*(5782), 1913–1915. doi:10.1126/science.1127488

Chen, K., & Chan, A. (2011). A review of technology acceptance by older adults. *Gerontechnology, 10*(1), 1-12. doi:10.4017/gt.2011.10.01.006.00

Chen, K., & Chan, A. H. S. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: a senior technology acceptance model (STAM). *Ergonomics, 57*(5), 635–652. doi:10.1080/00140139.2014.895855

Cho, J. (2016). The impact of post-adoption beliefs on the continued use of health apps. *International journal of medical informatics, 87,* 75–83. doi:10.1016/j.ijmedinf.2015.12.016

Claßen, K., Oswald, F., Doh, M., Kleinemas, U., & Wahl, H.-W. (2014). *Umwelten des Alterns: Wohnen, Mobilität, Technik und Medien* (1. Aufl.). *Grundriss Gerontologie: Vol. 10*. Stuttgart: Kohlhammer.

Coneus, K., & Schleife, K. (2010). *Online But Still Divided – Inequality in Private Internet Use in Germany*. Discussion Paper No. 10-042. Retrieved from ftp://ftp.zew.de/pub/zew-docs/dp/dp10042.pdf

Corrocher, N. (2011). The adoption of Web 2.0 services: An empirical investigation. *Technological Forecasting and Social Change, 78*(4), 547–558. doi:10.1016/j.techfore.2010.10.006

Cugelman, B. (2013). Gamification: what it is and why it matters to digital health behavior change developers. *JMIR serious games, 1*(1), e3. doi:10.2196/games.3139

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., & Sharit, J. (2006). Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and aging, 21*(2), 333–352. doi:10.1037/0882-7974.21.2.333

Davies, K., Collerton, J. C., Jagger, C., Bond, J., Barker, S. A. H., Edwards, J., . . . Robinson, L. (2010). Engaging the oldest old in research: lessons from the Newcastle 85+ study. *BMC geriatrics, 10*, 64. doi:10.1186/1471-2318-10-64

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13*(3), 319–340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982–1003.

Deterding, S. (2012). Gamification: designing for motivation. *Interactions, 19,* 14–17.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. E. (2011). Gamification: Toward a Definition. In D. Tan (Ed.), *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems CHI EA 2011*. New York, NY: ACM.

Diekmann, A. (2007). *Empirische Sozialforschung: Grundlagen, Methoden, Anwendungen* (19th ed.). Reinbek bei Hamburg: Rowohlt-Taschenbuch-Verl.

Direito, A., Jiang, Y., Whittaker, R., & Maddison, R. (2015). Apps for IMproving FITness and Increasing Physical Activity Among Young People: The AIMFIT Pragmatic Randomized Controlled Trial. *Journal of medical Internet research, 17*(8), e210. doi:10.2196/jmir.4568

Dobkin, B. H. (2013). Wearable motion sensors to continuously measure real-world physical activities. *Current opinion in neurology, 26*(6), 602–608. doi:10.1097/WCO.0000000000000026

Dobkin, B. H., & Dorsch, A. (2011). The promise of mHealth: daily activity monitoring and outcome assessments by wearable sensors. *Neurorehabilitation and neural repair, 25*(9), 788–798. doi:10.1177/1545968311425908

Docampo Rama, M., Ridder, H. D., & Bouma, H. (2001). Technology generation and age in using layered user interfaces. *Gerontechnology, 1*(1), 25-40. doi:10.4017/gt.2001.01.01.003.00

Doh, M. (2011). *Heterogenität der Mediennutzung im Alter: Theoretische Konzepte und empirische Befunde*. *Gesellschaft - Altern - Medien: Bd. 2*. München: Kopaed.

Dünnebeil, S., Sunyaev, A., Blohm, I., Leimeister, J. M., & Krcmar, H. (2012). Determinants of physicians' technology acceptance for e-health in ambulatory care. *International journal of medical informatics, 81*(11), 746–760. doi:10.1016/j.ijmedinf.2012.02.002

Engstler, H., & Hameister, N. (2016). *Deuter Alterssurvey (DEAS): Kurzbeschreibung des Datensatzes SUF DEAS 2014, Version 1.0*. Berlin: Deutsches Zentrum für Altersfragen (DZA).

Ernsting, C., Dombrowski, S. U., Oedekoven, M., O Sullivan, J. L., Kanzler, M., Kuhlmey, A., & Gellert, P. (2017). Using Smartphones and Health Apps to Change and Manage Health Behaviors: A Population-Based Survey. *Journal of medical Internet research, 19*(4), e101. doi:10.2196/jmir.6838

Eshet-Alkalai, Y. (2004). Digital Literacy: A Conceptual Framework for Survival Skills in the Digital Era. *Journal of Educational Multimedia and Hypermedia, 13*(1), 93–106.

Eshet-Alkalai, Y., & Chajut, E. (2009). Changes over time in digital literacy. *Cyberpsychology & behavior: the impact of the Internet, multimedia and virtual reality on behavior and society, 12*(6), 713–715. doi:10.1089/cpb.2008.0264

Fahrenberg, J. (2010). Ambulantes Assessment. In H. Holling (Ed.), *Handbuch der Psychologie: Vol. 13. Handbuch Statistik, Methoden und Evaluation* (pp. 201–212). Göttingen [u.a.]: Hogrefe.

Fahrenberg, J., Myrtek, M., Pawlik, K., & Perrez, M. (2007). Ambulatory Assessment - Monitoring Behavior in Daily Life Settings. *European Journal of Psychological Assessment, 23*(4), 206–213. doi:10.1027/1015-5759.23.4.206

Fischer, S. H., David, D., Crotty, B. H., Dierks, M., & Safran, C. (2014). Acceptance and use of health information technology by community-dwelling elders. *International journal of medical informatics, 83*(9), 624–635. doi:10.1016/j.ijmedinf.2014.06.005

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. *Addison-Wesley series in social psychology*. Reading, Mass.: Addison-Wesley Pub. Co.

Fox, S. & Duggan, M. (2013). *Tracking for Health*. Retrieved from http://www.pewinternet.org/files/old-media//Files/Reports/2013/PIP_TrackingforHealth%20with%20appendix.pdf

Fozard, J. L., & Wahl, H.-W. (2012). Age and cohort effects in gerontechnology: A reconsideration. *Gerontechnology, 11*(1), 10-21. doi:10.4017/gt.2012.11.01.003.00

Frees, B., & Koch, W. (2015). Internetnutzung: Frequenz und Vielfalt nehmen in allen Altersgruppen zu: Ergebnisse der ARD/ZDF-Onlinestudie 2015. *Media Perspektiven, 9,* 366–377.

Freund, A. M., & Baltes, P. B. (2002). Life-management strategies of selection, optimization and compensation: Measurement by self-report and construct validity. *Journal of Personality and Social Psychology, 82*(4), 642–662. doi:10.1037//0022-3514.82.4.642

Fritz, T., Huang, E. M., Murphy, G. C., & Zimmermann, T. (2014). Persuasive technology in the real world. In M. Jones, P. Palanque, A. Schmidt, & T. Grossman (Eds.), *CHI '14 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 487–496).

Groves, R. M. (2004). *Survey methodology*. *Wiley series in survey methodology*. Hobroken, NJ: John Wiley.

Gurtner, S., Reinhardt, R., & Soyez, K. (2014). Designing mobile business applications for different age groups. *Technological Forecasting and Social Change, 88,* 177–188. doi:10.1016/j.techfore.2014.06.020

Hayles, K. (2012). *How we think: Digital media and contemporary technogenesis*. Chicago, London: The University of Chicago Press.

Heart, T., & Kalderon, E. (2013). Older adults: are they ready to adopt health-related ICT? *International journal of medical informatics, 82*(11), e209-31. doi:10.1016/j.ijmedinf.2011.03.002

Herrmann, L. K., & Kim, J. (2017). The fitness of apps: a theory-based examination of mobile fitness app usage over 5 months. *mHealth, 3,* 2. doi:10.21037/mhealth.2017.01.03

Hingle, M., & Patrick, H. (2016). There Are Thousands of Apps for That: Navigating Mobile Technology for Nutrition Education and Behavior. *Journal of nutrition education and behavior, 48*(3), 213-8.e1. doi:10.1016/j.jneb.2015.12.009

Holzinger, A., Searle, G., & Nischelwitzer, A. (2007). On Some Aspects of Improving Mobile Applications for the Elderly. *LECTURE NOTES IN COMPUTER SCIENCE*, (4554), 923–932.

Huinink, J., & Schröder, T. (2014). *Sozialstruktur Deutschlands* (2nd ed.). *UTB basics: 3146 : Soziologie*. Konstanz [u.a.]: UVK Verlagsgesellschaft.

Initiative D21. (2016). *D21-Digital-Index 2016: Jährliches Lagebild zur Digitalen Gesellschaft*. Retrieved from http://initiatived21.de/app/uploads/2017/01/studie-d21-digital-index-2016.pdf

International Organization for Standardization. (2010). *ISO 9241-210: 2010: Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems*. Retrieved from https://www.iso.org/standard/52075.html

Intille, S. S. (2007). Technological innovations enabling automatic, context-sensitive ecological momentary assessment. In A. A. Stone, S. Shiffman, A. A. Atienza, & L. Nebeling (Eds.), *The science of real-time data capture. Self-reports in health research* (pp. 308–337). Oxford, New York: Oxford University Press.

Joyce, K. A., & Loe, M. (2010). *Technogenarians: Studying health and illness through an ageing, science, and technology lens*. *Sociology of health and illness monograph series*. Malden, MA: Wiley-Blackwell.

Kamin, S. T., & Lang, F. R. (2013). The Subjective Technology Adaptivity Inventory (STAI): A motivational measure of technology usage in old age. *Gerontechnology, 12*(1), 16-25. doi:10.4017/gt.2013.12.1.008.00

Kang, H. G., Mahoney, D. F., Hoenig, H., Hirth, V. A., Bonato, P., Hajjar, I., & Lipsitz, L. A. (2010). In situ monitoring of health in older adults: technologies and issues. *Journal of the American Geriatrics Society, 58*(8), 1579–1586. doi:10.1111/j.1532-5415.2010.02959.x

Karaiskos, D. C., Drossos, D. A., Tsiaousis, A. S., Giaglis, G. M., & Fouskas, K. G. (2012). Affective and social determinants of mobile data services adoption. *Behaviour & Information Technology, 31*(3), 209–219. doi:10.1080/0144929X.2011.563792

Kim, B. Y., & Lee, J. (2017). Smart Devices for Older Adults Managing Chronic Disease: A Scoping Review. *JMIR mHealth and uHealth, 5*(5), e69. doi:10.2196/mhealth.7141

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management, 43*(6), 740–755. doi:10.1016/j.im.2006.05.003

Knäuper, B., Schwarz, N., & Park, D. (2002). Selbstberichte im Alter. In A. Motel-Klingebiel & U. Kelle (Eds.), *Reihe Alter(n) und Gesellschaft: Vol. 7. Perspektiven der empirischen Alter(n)ssoziologie* (pp. 75–98). Opladen: Leske + Budrich.

Koch, W., & Frees, B. (2016). Dynamische Entwicklung bei mobiler Internetnutzung sowie Audios und Videos: Ergebnisse der ARD/ZDF-Onlinestudie 2016. *Media Perspektiven, 9,* 418–437.

Koch, W., & Frees, B. (2017). ARD/ZDF-Onlinestudie 2017: Neun von zehn Deutschen online. *Media Perspektiven, 9,* 434–446.

Koivisto, J., & Hamari, J. (2014). Demographic differences in perceived benefits from gamification. *Computers in Human Behavior, 35,* 179–188. doi:10.1016/j.chb.2014.03.007

Konradt, U., & Fary, Y. (2006). Determinanten der Motivation und der Bereitschaft zur Teilnahme an Fragebogenstudien. *Zeitschrift für Psychologie, 214*(2), 87–96. doi:10.1026/0044-3409.214.2.87

Krotz, F. (2001). *Die Mediatisierung kommunikativen Handelns: Der Wandel von Alltag und sozialen Beziehungen, Kultur und Gesellschaft durch die Medien*. Wiesbaden: Westdt. Verl.

Krotz, F. (2007). *Mediatisierung: Fallstudien zum Wandel von Kommunikation* (1. Aufl.). *Medien - Kultur - Kommunikation*. Wiesbaden: VS, Verlag für Sozialwissenschaften.

Lankshear, C., & Knobel, M. (Eds.). (2008). *New literacies and digital epistemologies*. *Digital literacies: Concepts, policies and practices*. New York: Peter Lang.

Lazar, A., Koehler, C., Tanenbaum, J., & Nguyen, D. H. (2015). Why we use and abandon smart devices. In K. Mase, M. Langheinrich, D. Gatica-Perez, H. Gellersen, T. Choudhury, & K. Yatani (Eds.), *the 2015 ACM International Joint Conference* (pp. 635–646).

LeBlanc, A. G., & Chaput, J.-P. (2017). Pokémon Go: A game changer for the physical inactivity crisis? *Preventive medicine, 101,* 235–237. doi:10.1016/j.ypmed.2016.11.012

Ledger, D. & McCaffrey, D. (2014). *Inside Wearables: How the Science of Human Behavior Change Offers the Secret to Long-Term Engagement*. Retrieved from http://endeavourpartners.net/assets/Endeavour-Partners-Wearables-and-the-Science-of-Human-Behavior-Change-Part-1-January-20141.pdf

LeRouge, C., van Slyke, C., Seale, D., & Wright, K. (2014). Baby boomers' adoption of consumer health technologies: survey on readiness and barriers. *Journal of medical Internet research, 16*(9), e200. doi:10.2196/jmir.3049

Lister, C., West, J. H., Cannon, B., Sax, T., & Brodegard, D. (2014). Just a fad? Gamification in health and fitness apps. *JMIR serious games, 2*(2), e9. doi:10.2196/games.3413

Marquet, O., Alberico, C., Adlakha, D., & Hipp, J. A. (2017). Examining Motivations to Play Pokémon GO and Their Influence on Perceived Outcomes and Physical Activity. *JMIR serious games, 5*(4), e21. doi:10.2196/games.8048

Marshall, V. W., & Bengtson, V. L. (2011). Theoretical Perspectives on the Sociology of Aging. In R. A. Settersen & J. L. Angel (Eds.), *Handbooks of sociology and social research. Handbook of sociology of aging* (pp. 17–34). New York, NY: Springer.

McHenry, J. C., Insel, K. C., Einstein, G. O., Vidrine, A. N., Koerner, K. M., & Morrow, D. G. (2015). Recruitment of Older Adults: Success May Be in the Details. *The Gerontologist, 55*(5), 845–853. doi:10.1093/geront/gns079

Melenhorst, A.-S., Rogers, W. A., & Bouwhuis, D. G. (2006). Older adults' motivated choice for technological innovation: evidence for benefit-driven selectivity. *Psychology and aging, 21*(1), 190–195. doi:10.1037/0882-7974.21.1.190

Meyer, J., Wasmann, M., Heuten, W., El Ali, A., & Boll, S. C. (2017). Identification and Classification of Usage Patterns in Long-Term Activity Tracking. In G. Mark, S. Fussell, C. Lampe, M. Schraefel, J. P. Hourcade, C. Appert, & D. Wigdor (Eds.), *The 2017 CHI Conference* (pp. 667–678).

Misoch, S., Doh, M., & Wahl, H.-W. (2014). Neue Medien - neue Lebensläufe? Vergleichende Betrachtung der Rolle neuer Medien für Kindheit/Jugend und für das höhere Lebensalter. In H.-W. Wahl & A. Kruse (Eds.), *Lebensläufe im Wandel. Entwicklung über die Lebensspanne aus Sicht verschiedener Disziplinen* (pp. 272–286). Stuttgart: Kohlhammer.

Modave, F., Bian, J., Leavitt, T., Bromwell, J., Harris Iii, C., & Vincent, H. (2015). Low Quality of Free Coaching Apps With Respect to the American College of Sports Medicine Guidelines: A Review of Current Mobile Apps. *JMIR mHealth and uHealth, 3*(3), e77. doi:10.2196/mhealth.4669

Morgan, H. (2016). 'Pushed' self-tracking using digital technologies for chronic health condition management: A critical interpretive synthesis. *DIGITAL HEALTH, 2*(2). doi:10.1177/2055207616678498

Musselwhite, C., Freeman, S., & Marston, H. R. (2017). An Introduction to the Potential for Mobile eHealth Revolution to Impact on Hard to Reach, Marginalised and Excluded Groups. In H. R. Marston, S. Freeman, & C. Musselwhite (Eds.), *Mobile E-health* (pp. 3–12). New York: Springer International Publishing.

Palfrey, J. G., & Gasser, U. (2008). *Born Digital: Understanding the First Generation of Digital Natives*. New York: Basic Books.

Papastefanou, G. (2009). Ambulatorisches Assessment: Eine Methode (auch) für die Empirische Sozialforschung. In M. Weichbold, J. Bacher, & C. Wolf (Eds.), *Umfrageforschung. Herausforderungen und Grenzen* (Vol. 9, pp. 443–468). Wiesbaden: VS, Verlag für Sozialwissenschaften.

Pelizäus-Hoffmeister, H. (2013). *Zur Bedeutung von Technik im Alltag Älterer: Theorie und Empirie aus soziologischer Perspektive*. *Alter(n) und Gesellschaft: Band 24*. Wiesbaden: VS, Verlag für Sozialwissenschaften.

Peek, S. T. M., Wouters, E., van Hoof, J., Luijkx, K. G., Boeije, H. R., & Vrijhoef, H. (2014). Factors influencing acceptance of technology for aging in place: a systematic review. *International journal of medical informatics, 83*(4), 235–248. doi:10.1016/j.ijmedinf.2014.01.004

Pew Research Center. (2014). *Older Adults and Technology Use: Adoption is increasing, but many seniors remain isolated from digital life*. Retrieved from http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/

Pew Research Center. (2015). *Three Technology Revolutions*. Retrieved from http://www.pewinternet.org/three-technology-revolutions/

Piper, A. M., Brewer, R., & Cornejo, R. (2017). Technology learning and use among older adults with late-life vision impairments. *Universal Access in the Information Society, 16*(3), 699–711. doi:10.1007/s10209-016-0500-1

Plaza, I., Martín, L., Martin, S., & Medrano, C. (2011). Mobile applications in an aging society: Status and trends. *Journal of Systems and Software, 84*(11), 1977–1988. doi:10.1016/j.jss.2011.05.035

Poirier, J., Bennett, W. L., Jerome, G. J., Shah, N. G., Lazo, M., Yeh, H.-C., . . . Cobb, N. K. (2016). Effectiveness of an Activity Tracker- and Internet-Based Adaptive Walking Program for Adults: A Randomized Controlled Trial. *Journal of Medical Internet Research, 18*(2), e34. doi:10.2196/jmir.5295

Prensky, M. (2009). H. Sapiens Digital: From Digital Immigrants and Digital Natives to Digital Wisdom. *Innovate: Journal of Online Education, 5*(3). Retrieved from http://nsuworks.nova.edu/innovate/vol5/iss3/1

Preusse, K. C., Mitzner, T. L., Fausset, C. B., & Rogers, W. A. (2014). Older Adults' Changes in Intent to Adopt Wellness Management Technologies. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 58*(1), 200–204. doi:10.1177/1541931214581042

Quadagno, J. (2011). *Aging and the life course: An introduction to social gerontology* (5th ed.). New York, NY: McGraw-Hill.

Rasche, P., Schlomann, A., & Mertens, A. (2017). Who Is Still Playing Pokémon Go? A Web-Based Survey. *JMIR serious games, 5*(2), e7. doi:10.2196/games.7197

Renaud, K., & van Biljon, J. (2008). Predicting technology acceptance and adoption by the elderly: A qualitative study. In R. Botha & C. Cilliers (Eds.), *the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists* (pp. 210–219).

Revels, J., Tojib, D., & Tsarenko, Y. (2010). Understanding consumer intention to use mobile services. *Australasian Marketing Journal (AMJ), 18*(2), 74–80. doi:10.1016/j.ausmj.2010.02.002

Rice, R. E., & Pearce, K. E. (2015). Divide and diffuse: Comparing digital divide and diffusion of innovations perspectives on mobile phone adoption. *Mobile Media & Communication, 3*(3), 401–424. doi:10.1177/2050157915590469

Ridda, I., MacIntyre, C. R., Lindley, R. I., & Tan, T. C. (2010). Difficulties in recruiting older people in clinical trials: an examination of barriers and solutions. *Vaccine, 28*(4), 901–906. doi:10.1016/j.vaccine.2009.10.081

Riley, W. T., Rivera, D. E., Atienza, A. A., Nilsen, W., Allison, S. M., & Mermelstein, R. (2011). Health behavior models in the age of mobile interventions: are our theories up to the task? *Translational behavioral medicine, 1*(1), 53–71. doi:10.1007/s13142-011-0021-7

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

Rupp, M. A., Michaelis, J.R., McConnell, D.S., & Smither, J. A. (2016). Examining the usability of several wearable fitness devices. *Gerontechnology*, (15(suppl)), 160s. doi:10.4017/gt.2016.15.s.755.00

Ruzic, L., & Sanfod, J. A. (2017). Universal Design Mobile Interface Guidelines (UDMIG) for an Aging Population. In H. R. Marston, S. Freeman, & C. Musselwhite (Eds.), *Mobile E-health* (pp. 17–37). New York: Springer International Publishing.

Saborowski, M., & Kollak, I. (2015). "How do you care for technology?" – Care professionals' experiences with assistive technology in care of the elderly. *Technological Forecasting and Social Change, 93,* 133–140. doi:10.1016/j.techfore.2014.05.006

Sackmann, R., & Weymann, A. (1994). *Die Technisierung des Alltags: Generationen und technische Innovationen*. Frankfurt [u.a.]: Campus-Verlag.

Sackmann, R., & Winkler, O. (2013). Technology generations revisited: The internet generation. *Gerontechnology, 11*(4), 493-503. doi:10.4017/gt.2013.11.4.002.00

Safran Naimark, J., Madar, Z., & Shahar, D. R. (2015). The impact of a Web-based app (eBalance) in promoting healthy lifestyles: randomized controlled trial. *Journal of medical Internet research, 17*(3), e56. doi:10.2196/jmir.3682

Saßenroth, D. (2012). Der Einfluss von Persönlichkeitseigenschaften auf die Kooperationsbereitschaft in Umfragen: Befunde der Allgemeinen Bevölkerungsumfrage der Sozialwissenschaften 2004, 2006 und 2008. *Methoden, Daten, Analysen (mda), 6*(1), 21–44.

Schlomann, A. (2017). A case study on older adults' long-term use of an activity tracker. *Gerontechnology, 16*(2), 115-124, doi:10.4017/gt.2017.16.2.007.00.

Schlomann, A. & Rietz, C. (in press): *Erhebung von Daten in der älteren Bevölkerung*. In: K. Hank, F. Schulz-Nieswandt, M. Wagner, S. & Zank (Hrsg.): Alternsforschung. Handbuch für Wissenschaft und Studium. Kapitel 26. Baden-Baden: Nomos-Verlag.

Schlomann, A., Seifert, A., & Rietz, C. (under review). Moderating effect of mobile activity tracking on the relationship between physical activity level and satisfaction with physical fitness in older adults.

Schlomann, A., von Storch, K., Rasche, P., & Rietz, C. (2016). Means of Motivation or of Stress? The Use of Fitness Trackers for Self-Monitoring by Older Adults. *HeilberufeScience*, *7*(3), 111-116, doi: 10.1007/s16024-016-0275-6.

Schulz, R., Wahl, H.-W., Matthews, J. T., De Vito Dabbs, A., Beach, S. R., & Czaja, S. J. (2015). Advancing the Aging and Technology Agenda in Gerontology. *The Gerontologist, 55*(5), 724–734.

Schwarz, N., & Knäuper, B. (2004). Kognitionspsychologie und Umfrageforschung: Altersabhängige Kontexteffekte*. Kölner Zeitschrift für Soziologie und Sozialpsychologie, Sonderhefte, 44,* 203–216.

Schwarze, B. (2012). Alter, Demografie und Technikentwicklung – Herausforderungen für die Hochschulausbildung. In B. Kampmann, B. Keller, M. Knippelmeyer, & F. Wagner (Eds.), *Die Alten und das Netz* (pp. 340–350). Wiesbaden: Gabler Verlag.

Seifert, A., & Schelling, H. R. (2015). Mobile use of the Internet using smartphones or tablets by Swiss people over 65 years. *Gerontechnology, 14*(1), 57–62. doi:10.4017/gt.2015.14.1.006.00

Seifert, A., & Schelling, H. R. (2016). Seniors Online: Attitudes Toward the Internet and Coping With Everyday Life. *Journal of applied gerontology,* 99–109. doi:10.1177/0733464816669805

Seifert, A., Schlomann, A., Rietz, C., & Schelling, H. R. (2017). The use of mobile devices for physical activity tracking in older adults' everyday life. *Digital Health, 3*, 1-12, doi: 10.1177/2055207617740088.

Seto, E., Leonard, K. J., Masino, C., Cafazzo, J. A., Barnsley, J., & Ross, H. J. (2010). Attitudes of heart failure patients and health care providers towards mobile phone-based remote monitoring. *Journal of Medical Internet Research, 12*(4), e55. doi:10.2196/jmir.1627

Sheeran, P. (2002). Intention-Behavior Relations: A Conceptual and Empirical Review. *European Review of Social Psychology, 12*(1), 1–36. doi:10.1080/14792772143000003

Shull, P. B., Jirattigalachote, W., Hunt, M. A., Cutkosky, M. R., & Delp, S. L. (2014). Quantified self and human movement: a review on the clinical impact of wearable sensing and feedback for gait analysis and intervention. *Gait & posture, 40*(1), 11–19. doi:10.1016/j.gaitpost.2014.03.189

Sims, T., Reed, A. E., & Carr, D. C. (2017). Information and Communication Technology Use Is Related to Higher Well-Being Among the Oldest-Old. *The journals of gerontology. Series B, Psychological sciences and social sciences, 72*(5), 761–770. doi:10.1093/geronb/gbw130

Sniehotta, F. F., Scholz, U., & Schwarzer, R. (2005). Bridging the intention–behaviour gap: Planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. *Psychology & Health, 20*(2), 143–160. doi:10.1080/08870440512331317670

Statistisches Bundesamt. (2016). *Private Haushalte in der Informationsgesellschaft: Nutzung von Informations- und Kommunikationstechnologien*. Fachserie 15, Reihe 4. Retrieved from https://www.destatis.de/DE/Publikationen/Thematisch/EinkommenKonsumLebensbedingungen/PrivateHaushalte/PrivateHaushalteIKT.html

Sun, K., Qiu, L., & Zuo, M. (2017). Gamification on Senior Citizen's Information Technology Learning: The Mediator Role of Intrinsic Motivation. In J. Zhou & G. Salvendy (Eds.), *Lecture Notes in Computer Science: 10297-10298. Human aspects of IT for the aged population* (pp. 461–476). Springer International Publishing.

Swan, M. (2012). Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0. *Journal of Sensor and Actuator Networks, 1*(3), 217–253. doi:10.3390/jsan1030217

Swan, M. (2013). The Quantified Self: Fundamental Disruption in Big Data Science and Biological Discovery. *Big data, 1*(2), 85–99. doi:10.1089/big.2012.0002

Turner, M., Kitchenham, B., Brereton, P., Charters, S., & Budgen, D. (2010). Does the technology acceptance model predict actual use? A systematic literature review. *Information and Software Technology, 52*(5), 463–479. doi:10.1016/j.infsof.2009.11.005

U.S. Food & Drug Administration. (2017). *Digital Health*. Retrieved from https://www.fda.gov/MedicalDevices/DigitalHealth/default.htm

van Bronswijk, J., Bouma, H., & Fozard, J. L. (2002). Technology for quality of life: An enriched taxonomy. *Gerontechnology, 2*(2). doi:10.4017/gt.2002.02.02.001.00

van de Goor, A.-G., & Becker, H. A. (2000). *Technology generations in the Netherlands: A sociological analysis*. Maastricht: Shaker Pub.

van Deursen, A., & van Dijk, J. (2011). Internet skills and the digital divide. *New Media & Society, 13*(6), 893–911. doi:10.1177/1461444810386774

van Deursen, A. J., & Helsper, E. J. (2015). A nuanced understanding of Internet use and non-use among the elderly. *European Journal of Communication, 30*(2), 171–187. doi:10.1177/0267323115578059

Vandelanotte, C., Muller, A. M., Short, C. E., Hingle, M., Nathan, N., Williams, S. L., . . . Maher, C. A. (2016). Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. *Journal of nutrition education and behavior, 48*(3), 219-228.e1. doi:10.1016/j.jneb.2015.12.006

Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a Research Agenda on Interventions. *Decision Sciences, 39*(2), 273–315. doi:10.1111/j.1540-5915.2008.00192.x

Venkatesh, V., & Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science, 46*(2), 186–204. doi:10.1287/mnsc.46.2.186.11926

Venkatesh, V., Davis, F. D., & Morris, M. G. (2007). Dead Or Alive? The Development, Trajectory And Future Of Technology Adoption Research. *Journal of the Association for Information Systems, 8*(4), 267–286.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478.

Verdegem, P., & De Marez, L. (2011). Rethinking determinants of ICT acceptance: Towards an integrated and comprehensive overview. *Technovation, 31*(8), 411–423. doi:10.1016/j.technovation.2011.02.004

Wahl, H.-W., & Heyl, V. (2015). *Gerontologie - Einführung und Geschichte* (2nd ed.). *Grundriss Gerontologie: Vol. 1*. Stuttgart: Kohlhammer.

Wahl, H.-W., Iwarsson, S., & Oswald, F. (2012). Aging well and the environment: toward an integrative model and research agenda for the future. *The Gerontologist, 52*(3), 306–316. doi:10.1093/geront/gnr154

Walsh, J. C., Corbett, T., Hogan, M., Duggan, J., & McNamara, A. (2016). An mHealth Intervention Using a Smartphone App to Increase Walking Behavior in Young Adults: A Pilot Study. *JMIR mHealth and uHealth, 4*(3), e109. doi:10.2196/mhealth.5227

Wang, L., Rau, P.-L. P., & Salvendy, G. (2011). Older Adults' Acceptance of Information Technology. *Educational Gerontology, 37*(12), 1081–1099. doi:10.1080/03601277.2010.500588

Ward, R. (2013). The application of technology acceptance and diffusion of innovation models in healthcare informatics. *Health Policy and Technology, 2*(4), 222–228. doi:10.1016/j.hlpt.2013.07.002

World Health Organization. (2008). *Pacific Physical Activity Guidelines for Adults: Framework for Accelerating the Communication of Physical Activity Guidelines*. Retrieved from

http://www.who.int/dietphysicalactivity/publications/pacific_activity_9789290613947/en/

World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland: World Health Organization. Retrieved from http://www.who.int/dietphysicalactivity/publications/9789241599979/en/

Wu, P. F. (2012). A Mixed Methods Approach to Technology Acceptance Research. *Journal of the Association for Information Systems, 13*(3), 172–187.

Yang, Y. (2011). Aging, Cohorts, and Methods. In R. H. Binstock & L. K. George (Eds.), *The handbooks of aging. Handbook of aging and the social sciences* (pp. 17–32).

Zahn, F. A., & Senger, J. (2012). Dreimal täglich spielen – Wie Serious Games die Gesundheit älterer Menschen fördern können. In B. Kampmann, B. Keller, M. Knippelmeyer, & F. Wagner (Eds.), *Die Alten und das Netz* (pp. 143–156). Wiesbaden: Gabler Verlag.

Zhou, J., Rau, P.-L. P., & Salvendy, G. (2014). Older adults' use of smart phones: An investigation of the factors influencing the acceptance of new functions. *Behaviour & Information Technology, 33*(6), 552–560. doi:10.1080/0144929X.2013.780637